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ORCHID DIVERSITY (Orchidaceae) IN TWO URBAN SITES IN THE STATE OF VERACRUZ, MEXICO

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ABSTRACT

Knowledge of urban orchids and their phorophytes is essential for conservation and education initiatives in these areas. The objective of this study was to assess the diversity of epiphytic orchids and identify their phorophytes at Postgraduate College Campus Córdoba (CPCC) and Paso Coyol Ecological Park (PEPC) in order to better understand the differences in their composition. The hypothesis was that the diversity of naturally established orchids would be higher in the less urbanized area, while the phorophytes would be mostly introduced trees. Orchids growing on phorophytes of the garden area (12 000 m²) of both sites were quantified from November 2019 to December 2021. The origin (endemic, native, or exotic) of the orchids and their phorophytes were determined. Simpson and Shannon-Weaver diversity indices were applied, and Whittaker curves were developed. A total of 13 419 orchid individuals were recorded, divided into 31 species, with 26 species reported in the CPCC and 17 in the PEPC. The Simpson and Shannon-Weaver indices showed that the diversity of epiphytic orchids was higher in the CPCC (1-D = 0.78) than in the PEPC (1-D = 0.41). In contrast, species dominance was lower in the CPCC (H = 2.6) than in the PEPC (H = 1.16). Whittaker curves showed that *Catasetum integerrimum* was the most abundant species in the CPPC and *Platystele stenostachya* in the PEPC. The CPCC had a greater level of diversity. Fifteen species of phorophytes were recorded in the CPCC and 10 in the PEPC, with a predominance of exotic species, while introduced species accounted for 70 % of the phorophytes found.

Keywords: urban flora, native orchids, urban gardens, green spaces, host tree.

INTRODUCTION

The growth of cities and changes in land use have decreased the size of natural ecosystems, causing the loss of habitats and species in occupied spaces (de Oliveira *et al*., 2011). Cities have become study systems for urban ecology, integrating theories and methods from the natural and social sciences with the intention of studying the patterns and processes of urban ecosystems (Cursach *et al*., 2012). This allows for improved understanding of global climate change and how biological and cultural components interact in a particular setting (Redman *et al*., 2004).

In cities, green areas are made up of parks, gardens, and tree-lined streets and avenues, where humans interact with biological diversity. These spaces have the appropriate conditions for the survival of several species (Lara *et al*., 2017). Green spaces beautify cities, serve as indicators of the environmental quality of the urban ecosystem, improve the quality of life of their inhabitants, and fulfill their productive, social, and environmental functions (Córdova-Stroobandt, 2013). The planning of green spaces is generally based on aesthetic and economic perspectives, using mostly fast-growing, low-cost, shade-producing ornamental flora (González-Ball *et al*., 2017; Lara *et al*., 2017).

A mix of native and exotic species from various evolutionary and geographic origins make up urban flora. For example, the flora of European cities presents a higher composition of native species, whereas in the Americas exotic species dominate (Castro et al., 2018). Exotic flora normally causes negative effects on native flora since some species can compete with and parasitize native plants, affecting their development and reproduction, modifying the abiotic conditions of the site, and generating unnecessary shade to other plants and allelopathy (Carvallo, 2009).

Within the epiphyte group, the Orchidaceae family is one of the most diverse, with the highest number of endemic species and being the second most threatened in Mexico (Castillo-Pérez *et al*., 2018; Villaseñor, 2016). In addition, orchids are recognized by commensalism associations with phorophytes (Izuddin *et al*., 2019). The growth and survival of orchids depend on the availability and characteristics of their phorophytes in their natural habitats and in disturbed environments (Izuddin *et al*., 2019). In urban green spaces, trees, shrubs, and cycads are used as phorophytes for the natural and assisted establishment of several species of orchids native to Mexico (Baltazar-Bernal *et al*., 2020). However, despite the importance of epiphytic orchids, there are few reports concerning their diversity in public urban areas (Izuddin *et al*., 2019; Lussu, 2022; Salazar-Rojas and Mata-Rosas, 2003).

Epiphytes in nearby urban sites may differ (Gomes and Campos, 2019), because urbanization generates a hostile microclimate that has a negative impact on flora diversity (Acosta-Hernández, 2017), related phorophytes (Gomes and Campos, 2019), and pollinators (Newman *et al*., 2013). Parks and other public places are designed by humans, and some of them are located in large cities and host diverse plant groups. Therefore, these spaces can be considered key sites to carry out the observation, determination, and conservation of orchid diversity.

Based on the above, the objective of this study was to evaluate the diversity of orchids that inhabit the gardens of the Postgraduate College Campus Córdoba (CPCC) and Paso Coyol Ecological Park (PEPC) to know their origin (endemic, native, and introduced) and category of extinction risk, as well as their phorophytes.

MATERIALS AND METHODS

Study sites

Two urban sites were evaluated from November 2019 to December 2021. The first site is located in the garden area of the Postgraduate College Campus Córdoba (CPCC), located in the municipality of Amatlán de los Reyes, Veracruz, Mexico (18° 51′ 21″ N and 96° 51′ 35″ W), at an altitude of 647 m (Figure 1). The climate in this site is warm-humid, with abundant rainfall in summer (INEGI, 2008), a mean annual temperature of 20 °C (INEGI, 2007), and a mean total annual precipitation of 1900 mm (INEGI, 2006). The CPCC gardens are open areas with less than 50 % tree cover surrounding the research center buildings. These gardens occupy an area of 18 000 m^2. The land surrounding the CPCC is mostly used for sugar cane cultivation, followed by industrial use. There are also two streams, roads, and areas for residential use (Figure 2A).

The second site evaluated was the Paso Coyol Ecological Park (PEPC), which has an area of 45 000 m^2 and is located in Córdoba, Veracruz, Mexico (18° 53′ 26″ N and 96° 56′ 35″ W), at an altitude of 915 m (Figure 1). The climate is semi-warm and humid with abundant rainfall in summer (INEGI, 2008), a mean annual temperature of 21 °C (INEGI, 2007), and a mean annual total of 2000 mm (INEGI, 2006). The PEPC has 80 % (36 000 m^2) of green areas and the rest of the space is occupied by buildings

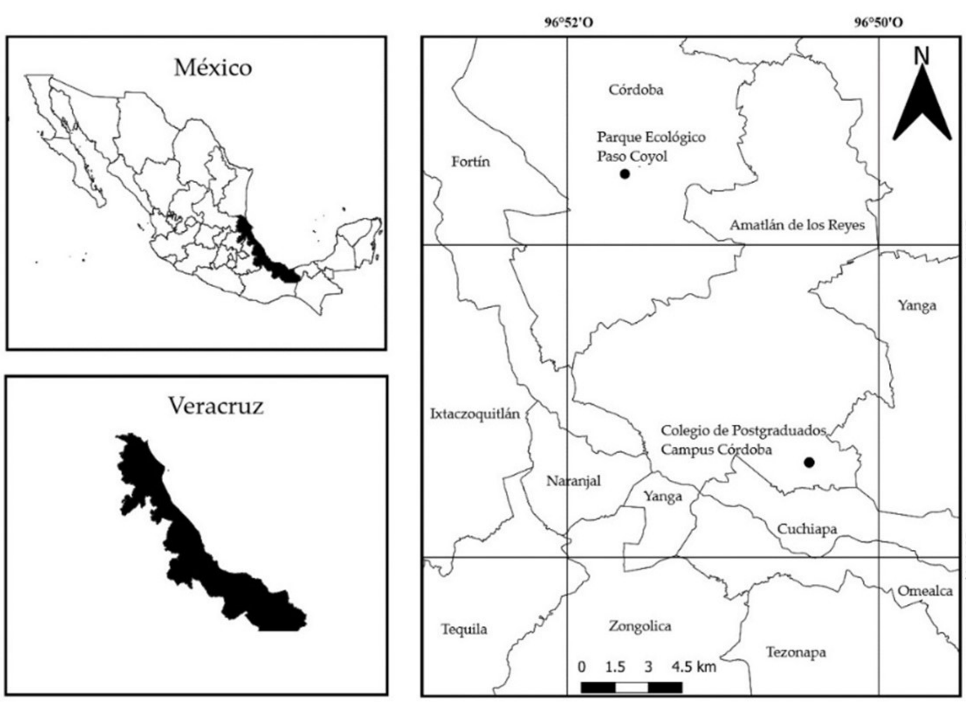

Figure 1. Geographical location of Postgraduate College Campus Córdoba, in Amatlán de los Reyes, Veracruz, Mexico, and Paso Coyol Ecological Park, in Córdoba, Veracruz, Mexico.

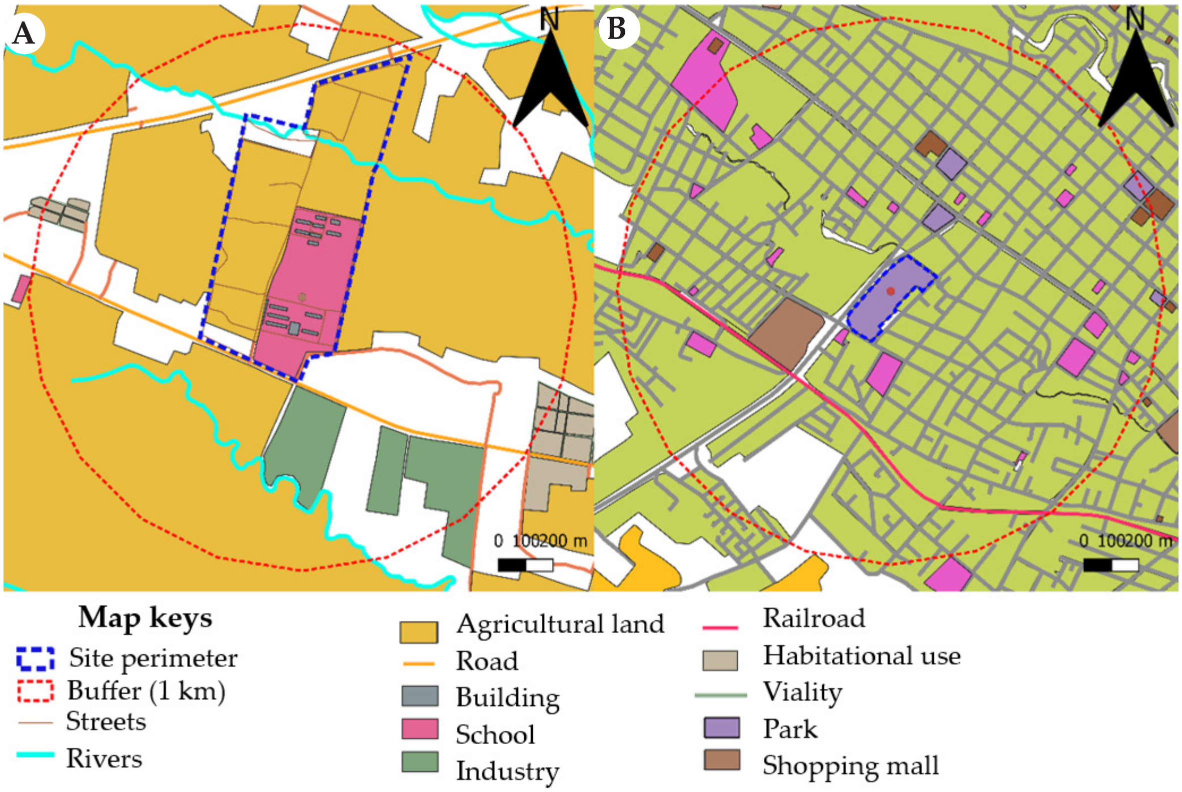

Figure 2. Zoning and land use around the study areas. A: Postgraduate College Campus Córdoba, in Amatlán de los Reyes, Veracruz, Mexico; B: Paso Coyol Ecological Park, in Córdoba, Veracruz, Mexico.

(auditorium, warehouse, public restrooms, exhibition area, administrative area, ticket office, and parking lot). The surrounding area of the PEPC is mainly occupied by residential areas with few green areas around it (Figure 2B).

Sampling of orchids and phorophytes

The orchid and phorophyte census were carried out in the gardens of the CPCC and the green areas of the PEPC (Figure 1). To register the number of orchids of each species, one plant (an individual with one or a group of pseudobulbs) was considered, except *Vanilla planifolia* and *Epidendrim radicans*, which are monopodic in growth. Epiphytic orchid individuals were quantified in each of the phorophytes (trees, shrubs, palms, and a *Zamia*). In addition, for each phorophyte, the species to which it belongs was recorded. For the determination of the orchid species, different bibliographic sources were consulted (García-Cruz *et al*., 2003; Hágsater *et al*., 2005; Soto-Arenas *et al*., 2005). Also, the identification was corroborated with specialists in systematics of the Orchidaceae family. To determine its conservation status, NOM-059 (DOF, 2010) was consulted.

Data analysis

To determine orchid diversity, only species that conserve natural populations were used, which are those that existed in the site prior to human intervention or colonized the trees without the need for human intervention. The diversity index (Simpson, 1945) was used, using the equation:

$$1-\sum_{i=1}^{N} p_i^2$$

where p_i represents the proportion or relative abundance of each species, from 1 to the umpteenth (i = 1, 2, 3, ..., N) species in the population. This index measures the probability that two individuals from a sample taken at random belong to different species; its values range from 0 to 1. In addition, the Shannon-Weaver index was used (Shannon and Weaver, 1949), which measures the average degree of uncertainty in predicting to which species an individual will belong in a random sample by means of the equation:

$$H' = -\sum_{i=1}^{N} p_i \, log_2 p_i$$

where p_i measures the average degree of uncertainty in predicting to which species a randomly chosen individual from a sample will belong.

RESULTS AND DISCUSSION

Epiphytic orchids

A total of 13 419 individuals were recorded, distributed across 24 genera and 31 species, of which 26 were found in the CPCC and 17 in the PEPC (Table 1). Nine orchid species (*Encyclia parviflora*, *Gongora galeata*, *Lycaste aromatica*, *Maxillaria densa*, *Maxillaria elatior*, *Myrmecophila grandiflora*, *Restrepiella ophiocephala*, *Specklinia digitale,* and *Trichocentrum lindenii*) are endemic species; 21 are native to Mexico, and only *Dendrobium nobile* is introduced. *Guarianthe skinneri*, *Specklinia digitale*, and *Stanhopea oculata* are classified as threatened (A), while *Vanilla planifolia* is considered under special protection (Pr) (DOF, 2010).

According to the Simpson's diversity index, the diversity of epiphytic orchids was higher in the CPCC (1 - D = 0.75) than in the PEPC (1 - D = 0.4). The Simpson's dominance index (D) was higher in the PEPC (D = 0.59), indicating a higher dominance by one species (*Platystele stenostachya* with 9673 individuals), compared to the CPCC, which indicates a lower dominance (D = 0.22). According to the Shannon-Weaver

Table 1. Epiphytic orchids species found in the gardens of the Postgraduate College Campus Córdoba (CPCC) and Paso Coyol Ecological Park (PEPC), in Veracruz, Mexico.

Number	Species	Establishment	CPCC	PEPC
			Individuals	
1	*Brassia verrucosa* Lindl.	¤	3	---
2	*Catasetum integerrimum* Hook.	Þ	157	5
3	*Coelia macrostachya* Lindl.	¤	1	---
4	*Dendrobium nobile* Lindl.	¤	---	2
5	*Encyclia parviflora* (Regel) Withner†	Þ	3	---
6	*Epidendrum cardiophorum* Schltr.	Þ	1	---
7	*Epidendrum ciliare* Jacq.	Þ	1	---
8	*Epidendrum radicans* Pav. ex Lindl.	Þ, ¤	10	1
9	*Gongora galeata* Lindl.†	¤	---	1
10	*Guarianthe skinneri (Bateman)* Dressler & W.E. Higgins §	¤	---	7
11	*Laelia anceps* Lindl.	¤, Þ	6	14
12	*Lycaste aromatica* (Graham.) Lindl.†	¤	2	---
13	*Maxillaria densa* Lindl.†	Þ	4	21
14	*Maxillaria lineolata* (Fenzl Molinari)	¤	---	1
15	*Maxillaria elatior* Rchb. f.†	Þ	2	---
16	*Maxillaria variabilis* Bateman ex Lindl.	¤	2	---
17	*Myrmecophila grandiflora* (Lindl.) Carnevali, Tapia-Muñoz & I. Ramírez†	Þ, ¤	10	---
18	*Notylia barkeri* Lindl.	Þ	28	---
19	*Oncidium sphacelatum* Lindl.	¤	105	44
20	*Platystele stenostachya* (Rchb. f.) Garay	Þ	1	9673
21	*Prosthechea ochracea* (Lindl.) W.E. Higgins	¤	9	---
22	*Prosthechea radiata* (Lindl.) W.E. Higgins	¤	20	8
23	*Restrepiella ophiocephala* (Lindl.) Garay & Dunst†	Þ	---	286
24	*Rhyncholaelia glauca* (Lindl.) Schltr.	¤	1	7
25	*Specklinia digitale* (Luer) Pridgeon & M.W. Chase†	Þ	18	984
26	*Specklinia tribuloides* (Sw.) Pridgeon & M.W. Chase	Þ	20	1854
27	*Stanhopea oculata* (G.Lodd.) Lindl. §	¤	1	---
28	*Trichocentrum lindenii* (Brongn.) M.W. Chase & N.H. Williams†	Þ	60	---
29	*Trichocentrum luridum* (Lindl.) M.W. Chase & N.H. Williams	Þ	82	10
30	*Trichosalpinx ciliaris* (Lindl.) Luer.	¤	1	---
31	*Vanilla planifolia* Jacks. ¶	¤	1	2

†Endemic species; ¶species under special protection (Pr); §threatened species, according to NOM-059-SEMARNAT-2010 (DOF, 2010). Þ Naturally established plant; ¤human-established plant.

index, species diversity was higher in the CPCC (H' = 2.24) than in the PEPC (H' = 1.14) (Table 2).

Regarding the relative abundance of orchids, the abundance range or Whittaker curves showed that *Catasetum integerrimum* was the most abundant species in the CPPC and *Platystele stenostachya* in the PEPC (Figure 3).

Table 2. Diversity indices of naturally established orchids in the gardens of the Postgraduate College Campus Córdoba (CPCC) and Paso Coyol Ecological Park (PEPC), in Veracruz, Mexico.

Variables	CPCC	PEPC
Number of species	12	6
Number of individuals	385	12832
Simpson´s diversity index	0.75	0.40
Shannon-Weaver´s diversity index	2.24	1.14

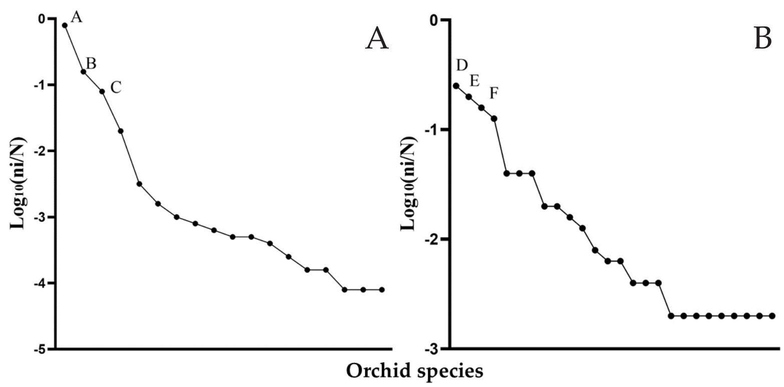

Figure 3. Whittaker range-abundance curves of orchids for the evaluated sites. A: Paso Coyol Ecological Park (PEPC); B: Colegio de Postgraduados Campus Córdoba (CPCC). Letters represent the most abundant species (A*: Platystele stenostachya*, B: *Specklinia tribuloides*, C: *Specklinia digitale*, D: *Catasetum integerrimum*, E: *Oncidium sphacelatum*, F: *Trichocentrum luridum*).

Regarding the origin of the orchids in the CPCC, 12 species were established naturally (46 %), while 14 (54 %) were established manually. Among the former, *Specklinia digitale* stands out, and among the latter, *Stanhopea oculata*, both under the threatened category (A); *S. oculata* is a native species of the mountain mesophyll forest, with ornamental value (Table 1). In the PEPC, six species (35 %) were found to be naturally established, and 11 species (65 %) were manually established. Among the former, *S. digitale* stands out, and among the latter, *Guarianthe skinneri* and *Dendrobium nobile*. *S. digitale* is a tiny orchid with large populations and is considered threatened (A). Like *G. skinneri*, it is an introduced species found from the humid forests of Chiapas in Mexico to Panama. *D. nobile* is a species of Asian origin with wide ornamental use in the region (Table 1). The study showed that there are 30 species of orchids native to Mexico, representing approximately 7 % of the orchid species in the state of Veracruz and 2.4 % of the orchid species of Mexico (Soto-Arenas *et al*., 2007). One exotic species (*Dendrobium nobile*) was also found (Table 1). This could indicate that the CPCC and the PEPC have favorable conditions for hosting a large part of the species of the region and other parts of the country, so these areas should be taken advantage of and used as reservoirs of native diversity or sites for the protection of urban orchids. This could be the beginning for utilizing these patches of vegetation in urban environments (Lussu, 2022).

At CPCC and PEPC, 26 and 17 orchid species were found, respectively. These values are lower than the 190 species found in the Soconusco Regional Botanical Garden at the Southern Border College in Tapachula, Chiapas, where they are used for conservation, research, propagation, and dissemination (Damon, 2018); and also lower than the 329 species held by the Clavijero Botanical Garden of the Institute of Ecology in Xalapa, Veracruz, where they are propagated with the purpose of contributing to their conservation (Salazar-Rojas and Mata-Rosas, 2003). However, both the CPCC and the PEPC harbor more species than those reported in the city of Cagliari, Italy (Lussu, 2022).

In the PEPC, *Guarianthe skinneri* was found, which is an orchid native to the southeast of the state of Chiapas, with distribution as far as Panama. This species faces serious problems of intensive and illegal extraction, which has caused a drastic decrease in its populations (Coutiño-Cortés *et al*., 2018). Thus, it is considered a threatened species according to NOM-059 (DOF, 2010). International trade is regulated by the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES), under Appendix II (CITES, 2013).

Manually established orchids represented 54 and 65 % of the species found in the CPCC and the PEPC, respectively, possibly influenced by the aesthetic attributes of the flowers of species such as *Brassia verrucosa*, *Dendrobium nobile*, *Guarianthe skinneri*, *Lycaste aromatica*, *Oncidium sphacelatum*, *Stanhopea oculate,* and *Vanilla planifolia*, known for their high ornamental value (Castillo-Pérez *et al*., 2018) and for providing an important visual attraction to the landscape.

The Shannon-Weaver and Simpson indices indicated a higher diversity of orchid species in the CPCC than in the PEPC. This difference between sites is due to higher urbanization in the PEPC (Alvim *et al*., 2020), which may originate an adverse microclimate (Oliván and Volponi, 2012), decreased orchid diversity (Acosta-Hernández, 2017), phorophytes (Alvim *et al*., 2020), and pollinators, as demonstrated in other studies (Newman *et al*., 2013). In Colombia, Acosta-Hernández (2017) explains that due to low urbanization, Paseo del Bosque had the highest species richness in flora and a high proportion of native species; he also indicated low urbanization compared to Alberti Park (Oliván and Volponi, 2012).

The presence of orchids in these urban sites requires the monitoring of specimens, their management, and sustainable use so that they are not seriously affected, nor their survival or the loss of genetic material is compromised, preserving the high value of orchids. Urban sites facilitate the recording of the reproductive phenology of the species in order to know the flowering, pollination, and fruiting periods. In addition, it is important to analyze the potential of these spaces as refuges or institutional and public reserves that protect orchids as a valuable natural resource. Urban sites also facilitate management focused mainly on conservation, as it is important to protect and multiply the species designated in NOM-059-2010 (DOF, 2010), such as *Guarianthe skinneri*, *Specklinia digitale*, *Stanhopea oculate*, and *Vanilla planifolia*.

Phorophytes

A total of 23 species were recorded, distributed in 19 families: 15 in the CPCC (Table 3), 10 in the PEPC (Table 4), and two in both sites. Only *Dioon edule* was recognized as an endemic species and in the category of endangered (P) according to NOM-059-SEMARNAT-2010 (DOF, 2010). In the CPCC, 53 % of the phorophyte species are exotic. *Azadirachta indica* harbored the highest number of orchid species (10), while *Persea schiedeana* and *Pouteria sapota* were the native phorophytes that harbored more orchid species (six) (Table 3).

In the PEPC, 80 % of exotic species of phorophytes were recorded. *Mangifera indica* hosted the largest number of orchid species (six), with large populations of *Platystele stenostachya, Restrepiella ophiocephala, Specklinia digitale*, and *Specklinia tribuloides*. On the other hand, *Acrocomia aculeata* was the only native phorophyte species that hosts *Epidendrum radicans* in this park (Table 4).

The diversity of phorophytes reported in this study is important for the establishment and colonization of epiphytic orchids inhabiting the study sites, as indicated by Izuddin *et al.* (2019). In the CPCC, 53 % of the phorophyte population are exotic species, highlighting *Azadirachta indica*, which is widely used for assisted orchid establishment due to its high availability and easy accessibility in the CPCC. It is notorious that

Table 3. Phorophyte species present in the gardens of the Postgraduate College Campus Córdoba (CPCC) in Veracruz, Mexico.

Family	Species	Origin	Orchids†
Anacardiaceae	*Anacardium occiddentale* L.	Exotic	2,20
Anonaceae	*Annona muricata* L.	Exotic	2,20
Arecaceae	*Phoenix roebelenii* O'Brien.	Exotic	2
Asparagaceae	*Yucca elephantipes* Regel.	Native	2,18,22,23
Boraginaceae	*Cordia alliodora* (Ruiz & Pav.) Oken.	Native	12,13
Cupressaceae	*Thuja occidentalis* L.	Exotic	19,29,30
Lauraceae	*Persea schiedeana* Nees.	Native	2,7,12,14,21
Meliaceae	*Cedrela odorata* L.	Native	12,13,25
Combretaceae	*Combretum* sp.	Exotic	20
Moraceae	*Ficus macrophylla* Desf. ex Pers.	Exotic	2,5,30
Myrtaceae	*Psidium guajava* L.	Native	20
Meliaceae	*Azadirachta indica* A. Juss.	Exotic	1,2,3,6,18,20,22,23,28,31
Rutaceae	*Citrus x limon* (L.) Osbeck	Exotic	5
Sapotaceae	*Pouteria sapota* (Jacq.) H.E.Moore & Stearn	Native	2,14,16,26,27,29
Zamiacea	*Dioon edule* Lindl.*	Native	30

†Orchid species (Table 1).

Table 4. Phorophyte species in the green areas of the Paso Coyol Ecological Park (PEPC) in Veracruz, Mexico.

Family	Species	Origin	Orchids†
Anacardiaceae	*Mangifera indica* L.	Exotic	2,14,21,24,26,27
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	Native	8
Bignoniaceae	*Spathodea campanulata* P. Beauv.	Exotic	10,12,20,23,31
Fabaceae	*Delonix regia* (Boyer ex Hook.) Raf.	Exotic	2,9,12,20,25
Malvaceae	*Hibiscus* sp. L.	Exotic	20
Moraceae	*Ficus benjamina* L.	Exotic	14,20
	Ficus macrophylla Desf. ex Pers.	Exotic	14,19,20
Myrtaceae	*Psidium guajava* L.	Native	20,32
Rosaceae	*Prunus dulcis* (Mill.) D.A. Webb.	Exotic	11,12,24
Rutaceae	*Citrus x limon* Osbeck	Exotic	19,20,31

†Orchid species (Table 1).

47 % of native orchid species are naturally hosted on *Persea schiedeana* and *Pouteria sapota*, confirming that they are optimal for orchid colonization and anchorage due to their cracked bark (Izuddin and Webb, 2015). It is clear that both phorophytes can be used to establish orchids obtained from *in vitro* culture to evaluate their adaptation. In addition, being dual-purpose species, as they are fruit trees, it is important to carry out their planting. Thus, urban flora fragments can be considered outdoor laboratories for botany teaching, especially on university campuses (Dávila *et al*., 2021).

In the PEPC, 90 % of the phorophytes are exotic species, such as *Mangifera indica*, which stands out for hosting large colonies of orchids such as *Platystele stenostachya*, which exceed 9000 individuals naturally established in this host. On the other hand, *Delonix regia* and *Spathodea campanulata* are dangerous species for urban areas due to their thick, shallow, spreading roots and their aggressive growth, which damages hydraulic networks in houses and other constructions (Vargas-Garzón and Molina-Prieto, 2010). According to Lowe *et al*. (2000), *Spathodea campanulata* is on the list of the 100 most damaging invasive species in the world because of its impact on biological diversity and the ease with which it can establish, thrive, and dominate new habitats. For this reason, it is advisable to undertake studies to determine the dominance of this species in the PEPC and to evaluate the impact it has had on other species. Regarding native species of phorophytes, only one specimen of the *Acrocomia aculeata* palm was found, which hosts the *Epidendrum radicans* orchid in its trunk, an orchid of mainly rupicolous habits, but which was established in an assisted manner.

In the two sites studied, the population of exotic phorophytes exceeds native phorophytes, significantly confirming human intervention in these urban spaces, based mainly on ornamental criteria (González-Ball *et al*., 2017; Lara *et al*., 2017) rather than on the biological importance of native species in the landscape (Ruas *et al*., 2022).

CONCLUSIONS

The Colegio de Postgraduados Campus Córdoba (CPCC) had a higher diversity of orchids than the Paso Coyol Ecological Park (PEPC); however, the diversity found in both sites indicates the potential of urban green areas as refuges for native and endemic orchids. Natural populations of *Platystele stenostachya* are the most numerous at PEPC, while at CPCC *Catasetum integerrimum* is the most abundant species. Phorophyte species found in CPCC and PEPC represented 53 and 90 % of introduced species, respectively. This may be associated with the fact that in the CPCC there is less urbanization. The study of orchid diversity in urban areas helps us to understand how these plants react to environmental disturbances caused by human activity.

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