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AN EXPLORATORY STUDY OF ORCHIDACEAE SPECIES FRUITS IN THE CENTRAL ZONE OF VERACRUZ STATE, MEXICO

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ABSTRACT

The knowledge on Orchidaceae family fruits becomes useful in new studies, by helping to identify species that are not in flowering period and providing material for *in vitro* germination of orchid seeds. The hypothesis was that the number of orchid specimens with naturally pollinated fruits, from the central zone of the state of Veracruz, Mexico, would be more than the number of specimens that do not developed fruit naturally. The objectives of this work were: to record the flowering and fruiting periods, to characterize the orchid fruits pollinated naturally or manually. The fruit collection sites were located within the municipalities of Amatlán de los Reyes, Fortín and Tlaltetela. The work was performed between January 2019 and April 2022 (39 months). Ripe orchid fruits were collected. Morphometry was measured by recording weight (g), length (cm) and diameter of the central region (cm), complemented with a photographic record. The greatest fruit diversity of these orchids was observed and collected during the month of March. Forty-two species and their fruits were recorded, which were grouped into 8 subtribes and 32 genera. The genera with the highest number of species were: *Epidendrum*, *Prosthechea* and *Oncidium*, each with three species. Three species bloomed for 11 months: *Platystele stenostachya, Specklinia digitale* and *S. tribuloides*. The minor and major fruiting periods correspond to *Specklinia digitale* and *Trichocentrum stramineum*, respectively. Given the fact that in all three sites studied the greatest number of species and fruits is associated with natural pollination (27 species, 113 fruits), which exceeds the number of manually pollinated species (15 species, 51 fruits), it is possible to suggest that the largest contingent inhabits environments still compatible with the natural process of their reproduction in these sites.

Keywords: Orchid capsules, orchid flowering, fruit morphometry, natural pollination of orchids, hand pollination of orchids.

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INTRODUCTION

The Orchidaceae family is one of the richest and most diverse plant groups worldwide, second only to the Asteraceae family (Chase *et al*., 2015), with an estimated 24,500 species (Dressler, 2005). The fruit formed by species within this family is a dehiscent capsule that presents longitudinal openings when ripe, it expels 1,000 to 4,000,000 seeds (Hágsater *et al*., 2015). The Mexican orchidoflora has been extensively studied, recording 1,315 species (Solano-Gómez *et al*., 2019), a number that may increase (Hágsater *et al*., 2015). Mexico has one of the highest orchid endemism percentages (56.2 %) (Espejo-Serna, 2012), and it is higher than 41.7 % in Colombia and 42.6 % in Ecuador (Castillo-Pérez *et al*., 2018). In Mexico, the flora of the state of Veracruz is one of the best explored and documented (Krömer *et al*., 2020), with 432 orchid species reported (Castañeda-Zárate *et al*., 2012; Krömer *et al*., 2021) and three endemic species (Gómez-Pompa *et al*., 2010). However, human activities have a high impact on the diversity of orchids and other epiphytic plants. For example, epiphyte populations in ecosystems where there is human intervention are reported to be reduced by more than half compared to conserved environments (Krömer *et al*., 2021). As a complement, in other studies that evaluate orchid richness in coffee agroecosystems (Espejo-Serna *et al*., 2005; Solís-Montero *et al*., 2005; García-Franco and Toledo-Aceves, 2017), urban environment (Baltazar-Bernal *et al*., 2020) or in home gardens (Hernández-Alcázar *et al*., 2017), a decrease in natural pollination (Espejo-Serna *et al*., 2005) and capsule development (Rasmussen and Johansen, 2006) is reported.

Damon and Roblero (2007) addressed the flowering period, natural pollination and fruiting period of some orchids in Chiapas. Mayer *et al*. (2011) studied the fruit development of *Oncidium flexuosum*. Sims, and Dirks-Mulder *et al*. (2019) focused on the anatomy and molecular characterization of hand-pollinated *Erycina pusilla* and *Epipactis helleborine*. However, studies on fruits in relation to their seed qualities for propagation purposes are scarce (Arditti and Ghani, 2000), and studies on ecosystems health are even scarcer. The study by Cetzal-Ix *et al.* (2014) on the diversity of orchid fruits in fragments of mesophyll forest and high evergreen forest in the municipality of Cuetzalan del Progreso, Puebla, Mexico, is considered to be the pioneer in evaluating the health of an ecosystem, by estimating its equilibrium using flowering, fruits and their morphometry as variables, in addition to providing guidance on some measures for its conservation.

This scarcity of scientific data makes it necessary to expand the knowledge on fruits of more Mexican orchid species, which would allow the identification of species when they are not in the flowering stage. By knowing the flowering and fruiting periods, the optimum time to harvest the fruits could be identified, for their specific use in conservation and utilization programs. Therefore, the hypothesis of this study was that the number of orchid specimens with naturally pollinated fruit in the central zone of the state of Veracruz, Mexico, would be more than the number of specimens that would not form fruit naturally, but rather assisted. The objectives of this work were: to record the flowering stage, natural pollination and fruiting stage in the central zone of the state of Veracruz and to characterize the fruits of orchids pollinated in a natural and assisted way.

MATERIALS AND METHODS

The methodology of this contribution is in accordance with the scope of an exploratory study, to generate practical information to know the orchid fruits in the region, for conservation purposes.

The methodology of this study consisted of the following activities: 1) selection of three nearby and accessible sites to carry out the field data collection. For each site, 2) an inventory was made of the species of orchids with fruit obtained naturally or manually, which were identified at the species level at the flowering stage, according to García-Cruz *et al.* (2003). Then, for each of the species found, it was recorded: 3) flowering period. The species that flowered and that had a record of two previous flowering periods without fruiting were considered as candidates for assisted pollination, so cross-pollination was carried out manually, 4) pollination type was recorded: natural or assisted, for the species that developed fruits, 5) fruiting period was recorded and photographs were taken, 6) mature fruits were collected and, 7) a morphometry survey was performed, considering three variables: a) weight and its main dimensions; b) length and c) maximum width of each of the fruits; finally 8) a photographic record of the collected fruits was created.

Site of study

Field observations were carried out in two anthropized sites and in a mesophyll forest in the center of the state of Veracruz, Mexico (Figure 1). These sites were chosen under the criteria of accessibility to fruit collection and the purpose of obtaining the

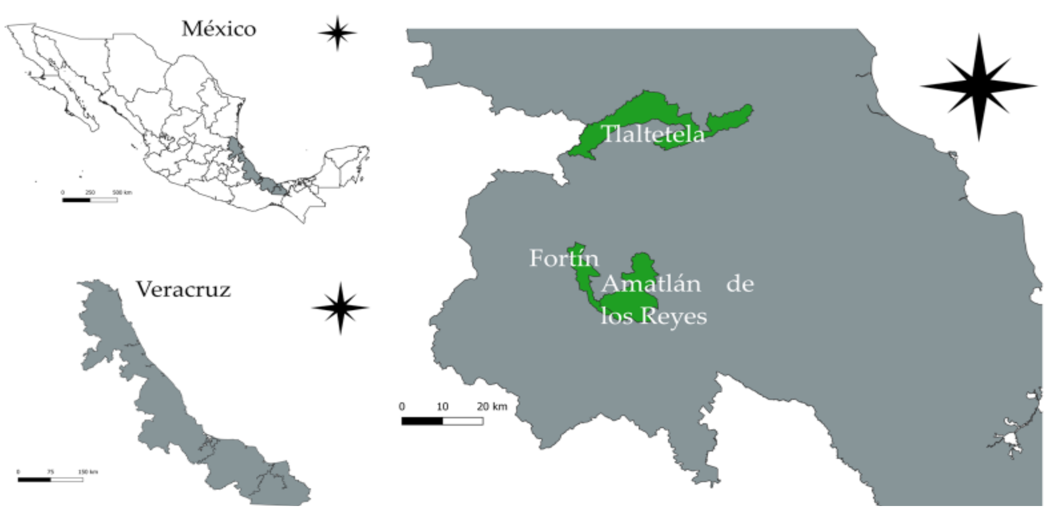

Figure 1: Location of the municipalities of Amatlán de los Reyes, Fortín and Tlaltetela, Veracruz, Mexico. The map was generated with QGIS®.

greatest number of fruits. Site one consists of gardens and an orchid garden with an approximate area of 2 ha, within a total urbanized rural area of 57 ha of gardens, laboratories, offices, roads and other facilities, in addition to experimental crop lands, of the Colegio de Postgraduados Campus Córdoba, in the municipality of Amatlán de los Reyes, at coordinates 18° 51′ 21′′ N and 96° 51′ 35′′ W, at an altitude of 647 m above sea level. The climate of site one is warm humid with abundant summer rainfall (INEGI, 2008), an average annual temperature of 20°C (INEGI, 2007) and an average total annual precipitation of 1,900 mm (INEGI, 2006). The original vegetation of site one is tropical lowland rainforest and mesophyll forest, completely disturbed. In site one, 25 orchid species were identified, grouped in 19 genera (Baltazar-Bernal *et al.*, 2020) and, of these, ten species were born in the site on trunks and branches of *Pouteria sapota*, *Dioon edule* and *Thuja occidentalis* and the rest of the species were introduced and placed in *Mangifera indica*, *Citrus x limon*, *Persea schiedeana* and *Cedrela odorata* forophytes, more than 25 years ago. The most important species *Specklinia digitale* (Luer.) Solano & Soto Arenas. Chase (A), *Stanhopea oculata* (G. Lodd.) Lindl. (A) and *Vanilla planifolia Andrews* (Pr), classified in some risk category, according to Mexican Official Standard 059 (SEMARNAT, 2010/2019).

Site two is a private collection of an estimated area of 0.25 ha, in a suburban area, in Fortín de las Flores, at the coordinates 18° 53′ 56.5′′ N and 96° 59′ 53.6′′ W, at an altitude of 1,400 m. The climate of site two is semi-warm and humid, with abundant rainfall in summer (INEGI, 2008), an average annual temperature between 18°C (INEGI, 2007) and an average total annual precipitation of 2,000 mm (INEGI, 2006). The original vegetation of site two is tropical evergreen forest with *Bursera simaruba*, today converted into a suburban area, with remnants of native tree species and, mostly, introduced species of the genera *Citrus* and *Thuja*, mainly. Site two is home to 70 wild species, grouped into 30 genera.

Site three is a fragment of mountain mesophyll forest of about 400 ha, adjacent to coffee plantations, in Tlaltetela, at coordinates 19° 18′ 55.6′′ N and 96° 53′ 59.9′′ W, at an altitude of 960 m. The climate of site three is semi-warm sub-humid, with abundant summer rainfall (INEGI, 2008), a mean annual temperature of 18°C (INEGI, 2007) and a total annual precipitation of 1,800 mm (INEGI, 2006). The vegetation of site three is secondary arboreal vegetation of mountain mesophyll forest, with characteristic species such as *Platanus mexicana, Nephelea mexicana, Clethra mexicana, Liquidambar styraciflua, Inga vera, Ulmus* sp. and *Quercus* sp. (cf. Ellis and Martínez-Bello, 2010). At site three there were 50 species of orchids, from 28 different genera.

Data logging

In the three study sites, the flowering period, pollination and fruiting period of the species and their duration were determined between January 2019 and April 2022 (39 months). The duration of flowering was established with the opening of the first flower until the last flower wilted. The duration of the fruiting period, in naturally pollinated orchids, was considered from the wilting of the first pollinated flower until the fruit was harvested and, for artificially pollinated species, manual pollination was carried out during the flowering period, with the criterion of having recorded two previous flowering periods without fruiting. Finally, the fruits were harvested when ripe, green-yellow in color and the remains of the flower could be removed easily and before dehiscence, which was developed in all cases. After collection, morphometric analysis was performed in the laboratory. The weight of each fruit was measured with a balance (ADAM Core® CQT 202, California, USA), and the length and width of its middle region with a digital vernier (Stainless hardened, Shanghai, China). Additionally, other features such as the presence of protuberances or spiniform warts were recorded. Finally, each fruit was photographed and an illustrated record of the identified species was created.

RESULTS AND DISCUSSION

Flowering

In the three study sites, 42 species of orchids were found flowering. The record of the flowering period of the different orchid species, indicates that most of them (24) flowered from January to April, 12 species started flowering in May and ended in August, and six species flowered from September to December (Table 1). Most species (39) have an annual flowering cycle with a flowering period between one and three months; in contrast, very few species flowered for up to 11 months, such as *Platystele*

Table 1. Pollination patterns studied, flowering and fruiting periods of orchid species in three sites: green areas of the Colegio de Postgraduados Campus Córdoba (1), private collection area of Fortín de las Flores (2); and mesophyll forest of Tlaltetela (3), Veracruz, Mexico.

Species	Site	Pollination†	Flowering	Fruiting (Month)	Fruit harvest
Acianthera circumplexa (Lindl.) Pridgeon and M.W. Chase	2	Natural	February-March	March (1)	March
Campylocentrum micranthum (Lindl.) Rolfe	2	Natural	July-December	January-February (3)	February
Catasetum integerrimum Hook.	1, 2, 3	Natural	May-September	June-April (11)	April
Comparettia falcata Poepp. Y Endl.	3	Natural	July	August-January (6)	January
Dichaea neglecta Schltr.	3	Natural	July	August-January (6)	January
Encyclia hanburyi (Lindl.) Schltr.	2	Assisted	February-March	March-June (4)	June
Encyclia parviflora (Regel) Withner	1, 3	Assisted	April-June	May-October (6)	October
Epidendrum melistagum Hágsater.	3	Natural	July-September	August-March (8)	March
Epidendrum parkinsonianum	2, 3	Assisted	March-May	May-April (12)	April
Epidendrum radicans Pav. ex Lindl.	1, 2, 3	Assisted	January-April	February-April (3)	April
Guarianthe aurantiaca (Bateman ex Lindl.) Dressler and W.E. Higgins.	2, 3	Assisted	August	August- May (10)	May
Gongora galeata (Lindl.) Rchb.f.	2, 3	Natural	November-January	January-March (3)	March
Ionopsis utricularioides (Sw.) Lindl.	2	Natural	January	January-March (3)	March

Table 1. Continue

Species	Site	Pollination†	Flowering	Fruiting (Month)	Fruit harvest
Laelia albida Bateman ex Lindl.	2	Assisted	October-November	November-March (5)	March
Laelia anceps Lindl.	1, 2, 3	Assisted	October-December	December-April (5)	April
Leochilus oncidioides Knowles and Westc.	2	Natural	November-May	January-June (6)	June
Lycaste aromatica (Graham) Lindl.	1, 2, 3	Natural	April-May	May-January (10)	January-February
Masdevallia floribunda Lindl.	2	Natural	October-January	January-February (2)	January-February
Maxillaria densa Lindl.	1, 3	Natural	January-February	February-April (3)	March-April
Maxillaria elatior (Rchb. f.) Rchb. f.	2, 3	Assisted	October-November	October-September (12)	September
*Myrmecophila grandiflora (*Lindl.) Carnevali, Tapia-Muñoz y I. Ramírez.	1, 3	Assisted	April-May	May (1)	May
Nidema bothii (Lindl.) Schltr.	2	Assisted	February-March	March-July (5)	July
Notylia barkeri Lindl.	1	Natural	March-April	March-May (3)	May-June
Oestlundia luteorosea (A. Rich. and Galeotti) W.E. Higgins	2	Natural	April-May	April-June (3)	June-July
Oncidium graminifolium (Lindl.) Lindl.	2	Natural	June	June-July (13)	July
Oncidium maculatum (Lindl.) Lindl.	2, 3	Assisted	January-April	April-January (10)	January
Oncidium sphacelatum Lindl.	1, 2, 3	Natural	April-May	May-April (11)	March
Ornithocephalus inflexus Lindl.	3	Natural	June	June-July (2)	July-August
Platystele stenostachya (Rchb. f.) Garay.	1, 3	Natural	January-October	February-November (1)	February-November
Prosthechea cochleata (L.) W.E. Higgins	2, 3	Assisted	June-September	July-February (8)	February-May
Prosthechea karwinskii (Mart.) Soto Arenas y Salazar	2	Assisted	April	April- July (4)	July
Prosthechea ochracea (Lindl.) W.E. Higgins	1, 3	Natural	May-June	July-September (3)	September
Restrepiella ophiocephala (Lindl.) Garay and Dunst.	2	Natural	January-March	March-April (2)	April
Rhyncholaelia glauca (Lindl.) Schltr.	1, 3	Assisted	January-February	February-May (4)	May-June
Rhynchostele maculata (Lex.) Soto Arenas and Salazar.	2	Assisted	January-February	February-June (5)	June
Sobralia macratha Lindl.	2, 3	Natural	May	May-January (8)	January
Specklinia digitale (Luer) Pridgeon and M.W. Chase	1, 3	Natural	January-November	January-November (< 1)	January-November
Specklinia tribuloides (Sw.) Pridgeon and M.W. Chase	1	Natural	February-October	February-October (2.5)	February-October
Stanhopea oculata [Lodd.] Lindley 1832	3	Natural	July-September	October-March (6)	March

Table 1. Continue

Species	Site	Pollination†	Flowering	Fruiting (Month)	Fruit harvest
Stelis purpurascens A. Rich. and Galeotti.	3	Natural	January-February	February-April (2)	March-April
Trichocentrum stramineum (Bateman ex Lindl.) M.W. Chase y N.H. Williams.	1, 3	Natural	January-February	February-May (14)	May
Trichosalpinx ciliaris (Lindl.) Luer.	1	Natural	February-June	February-June (5)	June-October

†Assisted pollination was carried out after two consecutive periods without fruiting.

stenostachya, Specklinia digitale and *S. tribuloides*. Cetzal-Ix *et al*. (2014) report flowering of *P. stenostachya* in October in the tropical rainforest, as possibly high temperatures limit the flowering period. However, *Campylocentrum micranthum, Epidendrum melistagum, Gongora galeata, Lycaste aromatica, Masdevallia floribunda, Nidema bothii, Notylia barkeri, Platystele stenostachya, Prosthechea cochleata, P. ochracea, Sobralia macratha and Stanhopea oculata*, which are also reported by Cuetzal-Ix *et al.* (2014), had similar flowering periods, being orchid species that develop in mesophyll forest and tropical forest.
Of all the species studied, Specklinia digitale (Figure 2O), which is classified in the Threatened (A) category (SEMARNAT, 2010/2019) as well as, Laelia albida (Figure 3I), an orchid of great beauty with great ornamental potential, stand out.

Pollination types

Regarding pollination, it was found that, of the 42 different species that formed fruit, 27 (64 %) were naturally pollinated and 15 (36 %) were hand-pollinated (Table 1). This ratio is an indication that environmental conditions are compatible with the presence of natural pollinators. Bees of the tribe Euglossini (Williams *et al.*, 1981; Damon and Roblero, 2007) and the genus *Euglossa* have been documented to pollinate the orchids *Catasetum integerrimum, Notylia barkeri, Oestlundia luteorosea* and *Lycaste aromatica*, the latter of which have been recorded as pollinators of up to more than 600 orchid species (Santos-Murgas and Añino-Ramos, 2016). However, natural pollination in the anthropogenic environment analyzed suggests that, for these organisms, food sources are available in situ and/or relatively close by, thus allowing natural pollination of 27 of the species studied.

Fruiting

Although fruiting as a result of natural pollination is a positive indicator that the individual orchid has sufficient conditions for natural reproduction, it is not a guarantee that the individual orchid will be able to recover its populations. Orchid fruits are therefore valuable resources for mass propagation programs using *in vitro* culture techniques or with symbiotic assistance. Given that the ripening period for collection is relatively short, it is very important to determine its fruiting period, as

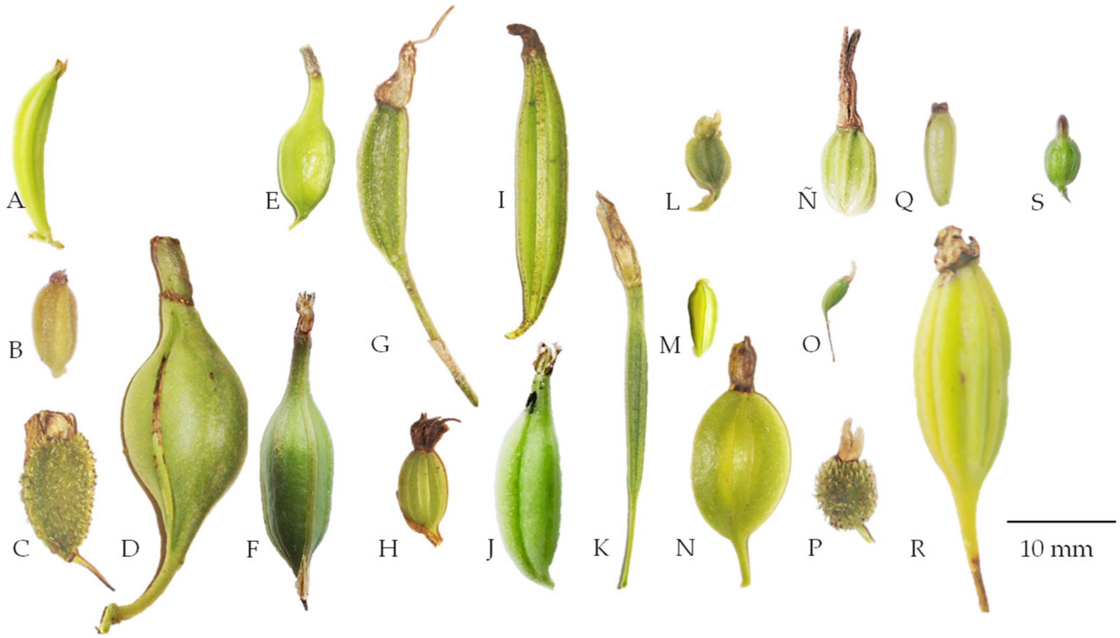

Figure 2. Fruits obtained from orchids at three sites† in central Veracruz state, Mexico, product of natural (Pn) or assisted (Pa) pollination. A: *Acianthera circumplexa* (Pn). B: *Campylocentrum micranthum* (Pn). C: *Dichaea neglecta* (Pn). D: *Epidendrum melistagum* (Pn). E: *Ionopsis utricularioides* (Pn). F: *Leochilus oncidioides* (Pn). G: *Masdevallia floribunda* (Pn). H: *Maxillaria densa* (Pn). I: *Nidema bothii* (Pn). J: *Notylia barkeri* (Pn). K: *Oestlundia luteorosea* (Pn). L: *Ornithocephalus inflexus* (Pn). M: *Platystele stenostachya* (Pn). N: *Prosthechea ochracea* (Pn). Ñ: *Restrepiella ophiocephala* (Pn). O: *Specklinia digitale* (Pn). P: *Specklinia tribuloides* (Pn). Q: *Stelis purpurascens* (Pn). R: *Trichocentrum stramineum* (Pn). S: *Trichosalpinx ciliaris* (Pn). †Sites: (1) Jardines en Amatlán de Reyes; (2) Suburban area in Fortín de las Flores; and (3) Secondary arboreal vegetation of mesophyll forest in Tlaltetela.

it could facilitate the creation of germplasm banks of orchids that require priority conservation actions (Cuetzal-Ix *et al.*, 2014).

The fruits collected were from 42 orchid species, grouped into nine subtribes and 32 genera. Of the 42 fruits in total, 27 fruits (from an equal number of species, classified in 25 genera) were the product of natural pollination and 15 fruits (15 species, 11 genera) originated from assisted pollination (Table 1; Figures 2 and 3). Therefore, it is feasible to suggest that the most numerous group inhabits environments that are still compatible with the natural pollination process for their reproduction. The subtribes with the highest number of species from the fruits collected were: Laeliinae (15), followed by Oncidiinae (10) and Pleurothallidinae (8). The genera with the highest number of species were: *Epidendrum, Prosthechea* and *Oncidium* with three each and the rest with only two or one species (Table 2, Figures 2 and 3). Observations from this study showed that fruiting is concentrated in the greatest dry period, from January to June, and that most orchid fruiting periods occur in March. Two species require less

Figure 3. Orchid fruits at three sites† in central Veracruz state, Mexico, product of natural (Pn) or assisted (Pa) pollination. A: *Catasetum integerrimum* (Pn). B: *Comparettia falcata* (Pn). C: *Encyclia hanburyi* (Pa). D: *Encyclia parviflora* (Pa). E: *Epidendrum melistagum* (Pn). F: *Epidendrum parkinsonianum* (Pa). G: *Gongora galeata* (Pn). H: *Guarianthe aurantiaca* (Pa). I: *Laelia albida* (Pa). J: *Laelia anceps* (Pa). K: *Lycaste Aromatica* (Pn). L: *Maxillaria elatior* (Pa). M: *Myrmecophila grandiflora* (Pa). N: *Oncidium graminifolium* (Pn). Ñ: *Oncidium maculatum* (Pa). O: *Oncidium sphacelatum* (Pn). P: *Prosthechea cochleata* (Pa). Q: *Prosthechea karwinskii* (Pa). R: *Rhyncholaelia glauca* (Pa). S: *Rhynchostele maculata* (Pa). T: *Sobralia macrantha* (Pn). U: *Stanhopea oculata* (Pn). †Sites: (1) Jardines en Amatlán de Reyes; (2) Suburban area in Fortín de las Flores; and (3) Secondary arboreal vegetation of mesophyll forest in Tlaltetela.

Table 2. Orchid species, number and morphometry of fruits obtained in three sites: garden areas of the Colegio de Postgraduados Campus Córdoba (1); private collection area of Fortín de las Flores (2); and mesophyll forest of Tlaltetela (3), Veracruz, Mexico.

Subtribe†	Species	Number of fruits	Weight (g) / Length (cm) x Width (cm)	Shape
Angraecinae	*Campylocentrum micranthum (*Lindl.) Rolfe.	10	0.10 / 0.85 x 0.4	Oblong
Catasetiinae	*Catasetum integerrimum* Hook.	6	70.20 / 12 x 5.2	Ribbed oblong
	Encyclia hanburyi (Lindl.) Schltr.	3	1.78 / 5.5 x 1.5	Ribbed eliptical
	Encyclia parviflora (Regel) Withner.	3	1.91 / 6.2 x 1.1	Ribbed Obovate
	Epidendrum melistagum Hágsater.	1	3.37 / 4.5 x 1.2	Ribbed elliptical
	Epidendrum parkinsonianum Hook.	2	4.05 / 12.5 x 2.3	Ribbed oblong
	Epidendrum radicans Pav. ex Lindl.	6	1.24 / 4.6 x 1.8	Eliptical
	Guarianthe aurantiaca (Bateman ex Lindl.) Dressler and W.E. Higgins.	3	1.70 / 3.2 x 1.3	Eliptical
	Laelia albida Bateman ex Lindl.	4	0.55 / 2.1 x 1	Ribbed globose
	Laelia anceps Lindl.	10	4.38 / 5.4 x 1.8	Ribbed oblong
Laeliinae	*Myrmecophila grandiflora* (Lindl.) Carnevali, Tapia-Muñoz and I. Ramírez	4	9.49 / 8.2 x 2.3	Obovate
	Nidema bothii (Lindl.) Schltr.	1	0.48 / 3.2 x 0.4	Ribbed oblong
	*Oestlundia luteorosea (*A. Rich. and Galeotti) W.E. Higgins	1	0.24 / 2.1 x 0.2	Ribbed elongated
	Prosthechea cochleata (L.) W.E. Higgins	2	2.78 / 4.1 x 1.8	Ribbed obovada
	Prosthechea karwinskii (Mart.) Soto Arenas y Salazar	1	3.56 / 10.4 x 1.2	Elongated
	Prosthechea ochracea (Lindl.) W.E. Higgins	4	0.28 / 1.7 x 1	Globose
	Rhyncholaelia glauca (Lindl.) Schltr.	4	12.25 / 12.3x2.3	Eliptical

Table 2. Continue

Subtribe†	Species	Number of fruits	Weight (g) / Length (cm) x Width (cm)	Shape
Maxillariinae	*Lycaste aromatica* (Graham) Lindl.	4	12.08 / 5.5 x 2.2	Ribbed globose
	Maxillaria densa Lindl.	40	0.10 / 0.85 0.4	Globose
	Maxillaria elatior (Rchb. f.) Rchb. f.	2	1.68 / 3.8 x 1.1	Ribbed oblong
Oncidiinae	*Comparettia falcata* Poepp. and Endl.	2	1.87 / 5.75 x 1.2	Ribbed ovate
	Ionopsis utricularioides (Sw.) Lindl.	1	0.22 / 1.8 x 0.5	Ovate
	*Leochilus oncidioide*s Knowles and Westc.	3	0.95 / 2.2 x 0.7	Oblong
	Notylia Barkeri Lindl.	2	0.48 / 1.6 x 0.5	Ribbed ovate
	Oncidium graminifolium (Lindl.) Lindl.	3	0.71 / 4 x 0.7	Ribbed oblong
	Oncidium maculatum (Lindl.) Lindl.	3	3.20 / 6.5 x 1.8	Curved oblong
	Oncidium sphacelatum Lindl.	15	5.82 / 5.2 x 1.6	Oblong
	Ornithocephalus inflexus Lindl.	1	0.003 / 1 x 0.3	Ribbed globose
	Rhynchostele maculata (Lex.) Soto Arenas and Salazar.	2	6.68 / 6.9 x 1.6	Ovate
	Trichocentrum stramineum (Bateman ex Lindl.) M.W. Chase y N.H. Williams	3	0.12 / 2.3 x 0.9	Ribbed ovate
Sobraliinae	*Sobralia macratha* Lindl.	2	10.62 / 8.0 x 2.0	Ribbed oblong
Stanhopeinae	*Gongora galeata* (Lindl.) Rchb.f.	2	4.25 / 7.0 x 1.0	Curved oblong
Pleurothallidinae	*Stanhopea oculata* [Lodd.] Lindley 1832	1	15.00 / 11 x 2.0	Ribbed oblong
	Acianthera circumplexa (Lindl.) Pridgeon and M.W. Chase	1	0.34 / 1.6 x 0.3	Curved oblong
	Masdevallia floribunda Lindl.	1	0.24 / 1.5 x 0.5	Oblong
	Platystele stenostachya (Rchb. f.) Garay.	2	0.005 / 0.5 x 0.2	Obovate
	Specklinia digitale (Luer) Pridgeon and M.W. Chase	2	0.017 / 0.3 x 0.1	Oblong
	Specklinia tribuloides (Sw.) Pridgeon and M.W. Chase††	1	0.11 / 1 x 0.5	Spiny globose
	Stelis purpurascens A. Rich. and Galeotti.	1	0.14 / 0.9 x 0.3	Oblong
	Restrepiella ophiocephala (Lindl.) Garay and Dunst.	2	0.11 / 1 x 0.5	Ribbed oblong
	Trichosalpinx ciliaris (Lindl.) Luer.	2	0.009 / 0.6 x 0.3	Globose
Zygopetalinae	*Dichaea neglecta* Schltr. ††	1	0.10 / 1.2 x 0.8	Spiny globose

† Angulo and Balam (2021).
†† Fruit with presence of protuberances or spiniform warts.

than 28 days to mature, which contributes to the periods reported by Rasmussen and Johansen (2006) of 45 days to 20 months for cultivated orchid species.

Fruit morphometry

Fruit morphometry is the quantitative characterization, in this case, the measurement of the weight, dimensions and shape of the fruits that were harvested for this study (Table 2). In general, orchid fruits are light; however, there are contrasts. For example, with respect to weight, the heaviest fruit recorded was of the species *Catasetum integerrimum* (70.2 g, Figure 3A), followed by the fruit of *Stanhopea oculata* (15.0 g, Figure 3U). In contrast, the lightest fruit was that of *Platystele stenostachya* species (5 mg, Figure 2M), followed by the fruit of *Trichosalpinx ciliaris* (9 mg, Figure 2S).

Regarding fruit size, there are also contrasts. For example, the largest fruit size recorded was of *Epidendrum parkinsonianum* species (12.5 cm, Figure 3F), followed by *Rhyncholaelia glauca* fruit (12.35 cm, Figure 3R), *Catasetum integerrimum* capsule 12 x 5.2 cm (Figure 3A) and *Stanhopea oculata* fruit 11 x 2 cm (Figure 3), which coincides with the size reported by Cetzal-Ix *et al.* (2014). There are also very tiny orchid fruits, such as those of the species *Specklinia digitale*, measuring only 0.3 x 0.1 cm (Figure 2O) or those of *Platystele stenostachya* measuring 0.5 x 0.2 cm (Figure 2M), which coincide with those reported by Cetzal-Ix *et al.* (2014). In contrast, the widest fruits were of the species *Catasetum integerrimum* (4.2 cm, Figure 3A) and *Lycaste aromatica* (3.2 cm, Figure 3K) and the narrowest fruits were of the species *Specklinia digitale* (0.1 cm, Figure 2O) and *Platystele stenostachya* (0.2 cm, Figure 2M) (Table 2). Fruit shapes can vary (Figures 2 and 3) and only two of them showed spiniform protuberances or warts (Figures 2C and 2P).

The observations of this study confirm the conclusions of Cetzal-Ix *et al.* (2014), on the need for further research regarding orchid fruits. Although the results of this work support the idea that fruit morphometrics and their images could help in the identification of the orchids shown, as suggested by Reyes-López *et al.* (2014) and Rojas-García and Maldonado-Peralta (2021), when they are not in flowering season, it is necessary to expand the study of systematic botany of orchid species that includes the detailed description of the fruits.

CONCLUSIONS

In this exploratory study it was possible to identify fruits of 42 different orchid species (32 genera) in the central zone of the state of Veracruz, Mexico. The greatest diversity and number of species and fruits is associated with natural pollination (27 species, 113 fruits), which exceeds those pollinated by hand (15 species, 51 fruits). It is possible to suggest that, although they are in disturbed environments, their pollinators are still present. It was also possible to observe that there are more fruits in the dry season, around the beginning of spring. The orchids *Platystele stenostachya*, *Specklinia digitale* and *S. tribuloides* showed availability of fruits almost all year round, which can be used for symbiotic or asymbiotic reproduction. The morphometrics recorded and the photographic record of the material studied evidenced a variety, ranging from tiny (*Specklinia digitale*, 17 mg, 0.3 x 0.1 cm) to large (*Catasetum integerrimum*, 70.2 g, 12 x 5.2 cm) weights and sizes. The information generated in this study of orchid fruits is important as an identification tool when flowers are not present. Furthermore, it can be used in future studies on *in vitro* germination of wild orchids.

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REFERENCES

Angulo DF, Balam NR. 2021. Clasificación de las Orquídeas: una breve reseña filogenética. *In* Las Orquídeas de Veracruz. Viccon Esquivel J, Castañeda Zárate M, Castro Cortés R, Cetzal-Ix W. (eds.); Universidad Veracruzana: Xalapa, Veracruz, México, pp: 77–88.

Arditti J, Ghani AKA. 2000. Tansley Review No. 110. Numerical and physical properties of orchid seeds and their biological implications. New Phytologist 145 (3): 367–421. https://doi.org/10.1046/j.1469-8137.2000.00587.x

Baltazar-Bernal O, De la Cruz-Martínez VM, Zavala-Ruiz J. 2020. Las orquídeas del Campus Córdoba, su estudio y preservación. Texcoco, México: Colegio de Postgraduados.

Castañeda-Zárate M, Viccon-Esquivel J, Ramos-Castro SE, Solano-Gómez R. 2012. New records of Orchidaceae for Veracruz, Mexico. Revista Mexicana de Biodiversidad 83 (1): 281–284.

Castillo-Pérez LJ, Martínez-Soto D, Maldonado-Miranda JJ, Alonso-Castro, AJ, Carranza-Álvarez C. 2018. The endemic orchids of Mexico: A review. Biologia 74 (1): 1–13. https://doi.org/10.2478/s11756-018-0147-x

Chase MW, Cameron KM, Freudenstein JV, Pridgeon AM, Salazar G, Van den Berg C, Schuiteman A. 2015. An updated classification of Orchidaceae. Botanical Journal of the Linnean Society 177 (2): 151–174. https://doi.org/10.1111/boj.12234

Cetzal-Ix W, Alvarez-Mora R, Basu SK, Cosme-Pérez J, Noguera-Savelli E. 2014. Orchid fruit diversity at Puebla Mexico: A new insight into the biodiversity of a fragmented ecosystem with need for conservation and potential for horticultural exploitations in future. *In:* Sustainable Horticultural Systems: Issues, technology and innovation Vol 2. Nandwani D. (ed.); Springer: Switzerland. pp. 207–220. https://doi.org/10.1007/978-3-319-06904-3

Damon A, Roblero PS. 2007. A survey of pollination in remnant orchid populations in Soconusco Chiapas, Mexico. Tropical Ecology 48 (1): 1–14.

Dirks-Mulder A, Ahmed I, uit het Broek M, Krol L, Menger N, Snier J, van Winzum A, de Wolf A, van't Wout M, Zeegers JJ, Butôt R, Heijungs R, van Heuven BJ, Kruizinga J, Langelaan R, Smets EF, Star W, Bemer M, Gravendeel B. 2019. Morphological and Molecular Characterization of Orchid Fruit Development. Frontiers in Plant Science 10: 137. https://doi: 10.3389/fpls.2019.00137

Dressler RL. 2005. How many orchid species? Selbyana 26 (1-2): 155–158.

Ellis EA, Martínez-Bello M. 2010. Vegetación y uso de suelo. *In* Atlas del Patrimonio Natural, Histórico y Cultural de Veracruz: I Patrimonio natural. Benítez G, Welsh-Rodríguez C. (eds.); Universidad Veracruzana: Xalapa, Veracruz, México, pp: 203–226.

Espejo-Serna A, López-Ferrari AR, Jiménez Machorro R, Sánchez Saldaña L. 2005. Las orquídeas de los cafetales en México: una opción para el uso sostenible de ecosistemas tropicales. Revista de Biología Tropical 53 (1-2): 73–84.

Espejo-Serna A. 2012. El endemismo en las Liliopsida mexicanas. Acta Botánica Mexicana 100: 195–257. https://doi.org/10.21829/abm100.2012.36

García-Cruz J, Sánchez LM, Jiménez R, Solano R. 2003. Flora del Bajío y de regiones adyacentes. Orchidaceae, tribu Epidendreae. Herbario AMO, Fascículo, 119.

García-Franco JG, Toledo-Aceves MT. 2017. Diversidad de orquídeas (Orchidaceae) en agroecosistemas cafetaleros. Agroproductividad 10 (6): 19–24.

Gómez-Pompa A, Krömer T, Castro-Cortés R. 2010. Atlas de la Flora de Veracruz: Un patrimonio natural en peligro. Primera edición. Gobierno del Estado de Veracruz y Universidad veracruzana. Xalapa, México.

Hágsater E, Soto-Arenas MÁ, Salazar GA, Jiménez-Machorro R, López-Rosas MA, Dressler RL. 2015. Las orquídeas de México. Ciudad de México: Instituto Chinoín.

Hernández-Alcázar JA, Farrera-Sarmiento O, Beutelspacher CR. 2017. Orquídeas en huertos familiares de Pantelhó, Chiapas, México. Lacandonia 11 (1): 11–18.

INEGI (Instituto Nacional de Estadística Geografía e Informática). 2006. Conjunto de datos vectoriales escala 1:1 000 000, Precipitación media anual, Estados Unidos Mexicanos [shapefile]. 1:1,000,000. Aguascalientes, México. Recuperado el 7 de mayo, 2022 de: https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825267544

INEGI (Instituto Nacional de Estadística Geografía e Informática). 2007. Conjunto de datos vectoriales escala 1:1 000 000. Temperatura media anual, Estados Unidos Mexicanos [shapefile]. 1:1,000,000. Aguascalientes, México. Recuperado el 7 de mayo, 2022 de: https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825267551

INEGI (Instituto Nacional de Estadística Geografía e Informática). 2008. Conjunto de datos vectoriales escala 1:1 000 000, Unidades climáticas, Estados Unidos Mexicanos [shapefile]. 1:1,000,000. Aguascalientes, México. Recuperado el 7 de mayo, 2022 de: https://www.inegi.org.mx/app/biblioteca/ficha.html?upc=702825267568

Krömer T, Espejo-Serna A, López-Ferrari AR, Acebey AR, García-Cruz J, Mathieu G. 2020. Las angiospermas epífitas del estado de Veracruz, México: diversidad y distribución. Revista Mexicana de Biodiversidad 91: 1–110. https://doi.org/10.22201/ib.20078706e.2020.91.3415

Krömer T, Viccon-Esquivel J, Gómez-Díaz JA. 2021. Efectos antrópicos sobre la diversidad de epífitas vasculares y orquídeas en el centro de Veracruz. *In* Las Orquídeas de Veracruz. Viccon Esquivel J, Castañeda Zárate M, Castro Cortés R, Cetzal Ix W. (eds.); Universidad Veracruzana. Xalapa, Veracruz, México, pp: 235–252.

Mayer JLS, Carmello-Guerreiro SM, Appezzato-da-Glória B. 2011. Anatomical development of the pericarp and seed of *Oncidium flexuosum* Sims (Orchidaceae). Flora-Morphology, Distribution, Functional Ecology of Plants 206 (6): 601–609. https://doi:10.1016/j.flora.2011.0

Rasmussen FN, Johansen B. 2006. Carpology of orchids. Selbyana 27 (1): 44–53.

Reyes-López D, Flores-Jiménez Á, Huerta-Lara M, Kelso-Bucio HA, Avendaño-Arrazate CH, Lobato-Ortiz R, Aragón-García A, López-Olguín JF. 2014. Variación morfométrica de fruto y semilla en cuatro especies del género *Vanilla*. Ecosistemas y Recursos Agropecuarios 1 (3): 205–218.

Rojas-García AR, Maldonado-Peralta MÁ. 2021. Cualidades morfológicas de frutos de tres especies de bromelia (Bromeliaceae). Revista Fitotecnia Mexicana 44 (4): 521–521.

Santos-Murgas A, Añino-Ramos YJ. 2016. Contribución al conocimiento de la diversidad de abejas de las orquídeas (Apidae: Euglossini) de la Península de Azuero, Panamá. Tecnociencia 18: 45–58.

SEMARNAT (Secretaría del Medio Ambiente y Recursos Naturales). 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental - Especies nativas de México de flora y fauna silvestres - Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio - Lista de especies en riesgo. México: Diario Oficial de la Federación, 30 de diciembre de 2010.

Solano-Gómez R, Salazar GA, Huerta H, Hágsater E, Jiménez R. 2019. Diversity of Mexican Orchids: Synopsis of richness and distribution patterns. *In* Proceedings of the 22th World Orchid Conference. Pridgeon AM. (ed.); Asociación Ecuatoriana de Orquideología. Guayaquil, Ecuador. pp. 255–270.

Solís-Montero L, Flores-Palacios A, Cruz-Angón A. 2005. Shade-coffee plantations as refuges for tropical wild orchids in central Veracruz, Mexico. Conservation Biology 19 (3): 908–916. https://doi.org/10.1111/j.1523-1739.2005.00482.x

Williams NH, Atwood JT, Dodson CH. 1981. Floral fragrance analysis in Anguloa, Lycaste and Mendoncella (Orchidaceae). Selbyana 5 (3-4): 291–295.