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The melliferous flora of Veracruz, Mexico

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ABSTRACT

Objective: To contribute to the knowledge of the situation of the melliferous flora in Veracruz for pollinators and to communicate it for the benefit of beekeepers and stingless beekeepers, as well as to develop comprehensive strategies with these activities.

Design/Methodology/Approach: The information was obtained through a bibliographic review in reference databases such as Scopus, Web of Science Group, Academic Google, Elsevier and Springer Link, using the following keywords: flora, bees, pollinators, honey, pollen.

Results: 63 families were recorded, with 176 genera and 216 species of melliferous flora, finding that the largest number of species are found in the Fabaceae family (20%) and Asteraceae (16.55%). There were also 44 crops with 22 families.

Study Limitations/Implications: There were no limitations in conducting this study.

Findings/Conclusions: The greatest diversity of melliferous flora species is related to wild plants, and strategies need to be implemented for their protection and multiplication. For these actions, various actors must be involved at different levels of government, educational and private institutions, civil society, farmers, beekeepers, and stingless beekeeping. Conservation actions include the use of melliferous plants in gardens and their protection in crops, sites surrounding crops and on edges. It is necessary to preserve natural landscapes and restore damaged ones, as well as to lead favorable practices in pollinator-dependent crops.

Keywords: flora, bees, pollinators, honey, pollen.

INTRODUCTION

Bees maintain a close relationship with melliferous flora, since they depend on them for their food, when consuming nectar and pollen obtained from the flowers. Likewise, they also collect resinous material that they use for the construction of their nest and for the elaboration of propolis, which serve as protection against pathogens and predators (Bonet and Vergara, 2016).



Melliferous flora or honey flora is made up of plants that produce resins or whose flowers produce nectar and/or pollen; it is classified into polliniferous, nectariferous or pollen-nectariferous (Montoya-Bonilla *et al.*, 2017). In exchange for food or resins that the bees receive from wild and cultivated plants, they pollinize their flowers thus favoring the formation of fruits that serve as food for human beings and other animals, contributing with this to food security and ecological equilibrium of ecosystems (Alquisira-Ramírez, 2019).

The availability of flower resources for the development and reproduction of bee colonies is required during the whole year. This is achieved through short flowering periods that most agricultural crops have, as well as native plants of the Asteraceae and Fabaceae families, which are important to feed the populations of bees and other pollinators because they are the most visited (González-Suárez *et al.*, 2020).

The conservation and multiplication of melliferous flora is of huge interest for beekeepers and meliponiculture producers, because they ensure the production and quality of honey from their bee colonies (Araujo-Mondragón and Redonda-Martínez, 2019). In order to achieve this, the following strategies have been applied: use of melliferous plants in agroecologic gardens, or else interspersed in the crops or on the edges of the paths (Kremen and M'Gonigle, 2015; Landaverde-González *et al.*, 2017).

The implementation of conservation strategies for both melliferous flora and pollinators is vital, since the absence or decline of the populations of any of them can impact their survival, in addition to reducing the production of fruits and seeds, which will have an environmental, social and economic impact globally (Hipólito *et al.*, 2016; Wilson *et al.*, 2017).

Therefore, the objective of this study was to understand the situation of the melliferous flora of the state of Veracruz, Mexico, through a bibliographic review with the aim of broadening knowledge about the available flower resources for pollinators, in addition to contributing with this information to beekeepers and meliponiculture producers to develop integral strategies in these activities.

MATERIALS AND METHODS

The information of melliferous flora of the state

of Veracruz, Mexico, was obtained through the bibliographic review of the reference databases Scopus, Web of Science Group, Academic Google, Elsevier and Springer Link, using the following keywords: flora, bees, pollinators, honey, pollen. The information was systematized assigning categories of use, phenology, taxonomy and biology, in the following way: family, scientific name, resource that bees are supplied with—nectar or pollen—, flowering period, status—whether native, exotic or naturalized—, and life form; in the case of crops pollinated by bees, the common name was added.

RESULTS AND DISCUSSION

Flora in Mexico

In Mexico there is a record of 23,314 species of vascular plants, among which 2,854 genera, 297 families and 73 orders were included; in this flora there are 149 gymnosperms and 22,126 angiosperms (Ulloa *et al.*, 2017; Villaseñor, 2016). The state of Veracruz occupies the third place in floristic richness of the country (Martínez-Adriano *et al.*, 2016), divided into 271 families, 1,956 genera and 8,497 species (Villaseñor, 2016).

Despite the great floristic richness of Veracruz, it is primarily threatened by deforestation, as shown in a study carried out by Von *et al.* (2021), in three regions of the state of Veracruz from 2003 to 2013, in the region of the Tuxtlas, with a loss of natural plant coverage of 4.6% (3,516 ha), the old Antigua with 2% (1,634 ha) and Sierra de Otontepec with 1.4% (618 ha). This deforestation also causes fragmentation of habitats, loss of soil fertility, loss of biodiversity, and reduction of environmental services (Ramírez-Bravo and Hernández-Santín, 2016).

Additionally, erosion and genetic loss were caused by the loss of biodiversity, since angiosperms present reduced germination and progeny of lower quality (Aguilar *et al.*, 2019), because of the loss of biological corridors for their pollinators (Gómez-Pompa *et al.*, 2010), which has the consequence of smaller, scarce and isolated populations at the local scale, landscape and regional, with which their probability of extinction increases (Auffret *et al.*, 2017).

Bee-Plant Ecological Interactions

Bees have evolved with plants and present a complex network of inter-specific interactions where sight, smell, moisture detection, contact and weak electrostatic field between a flower and a bee are involved; through these

interactions flowers use bees as vehicles for the transport of pollen for fertilization (Thakur and Nanda, 2020), and the bees benefit from nectar and pollen as sources of food that plants provide, thus establishing an ecological relationship between them known as mutualism. Therefore, bees are attracted by the nectar which is an aqueous substance, rich in sugars, which contributes carbohydrates as main source of energy for the bees. During nectar collection, bees transport pollen from the anthers to the stigma of the plants, thus benefiting a large number of species of angiosperms (Castellanos-Potenciano et al., 2012).

Bees, in addition to nectar, use the pollen that they find in the anthers (apical part) of the stamens, both in angiosperms and in gymnosperms; during their visits, foraging bees attract these grains of pollen through the generation of a weak electrostatic field generated between the flower (with negative charge) and the bee's body (positive charge) (Clarke et al., 2017).

The way in which the bees harvest pollen from the flowers is by scraping or licking the anther and then sticking it on the carbuncle (cavity that is found in the tibia of the third pair of legs), using nectar to stick the pollen and thus transport it, accumulating it in form of granules; then, they take it to their nest and, generally, they deposit it around the breeding area where the larvae are developing, since it is the protein source for larvae and adults, containing between 10 and 40% of protein (Leonhardt et al., 2007; Vossler, 2015).

Pollen is an indicator that allows understanding the botanical and geographic characteristics of beekeeping products such as honey (Stephen, 2014; Thakur and Nanda, 2020). In addition, bees collect resins from some plants for the production of propolis, which they use as building material and defensive substance (Bankova et al., 2018).

The interactions that happen between plant and pollinator play an important role in the structure of communities, in addition to determining the diversity, wealth and persistence of species in a specific locality (Martínez-Adriano et al., 2018). Entomopalynology studies pollen found in the body or in the intestine of insects and provides information about the migration routes and their feeding, in addition to defining the pollination mechanisms and the foraging resources. Another important research area is Melissopalynology,

which studies the botanical and geographic origin of honey, through the analysis of pollen in honey (Stephen, 2014). In palynological studies, there are records that bees, particularly *Apis mellifera*, visit approximately 2,000 plant species (Cadena et al., 2019).

Melliferous Plant Species in Veracruz, Mexico

Based on the information gathered through scientific search engines, an inventory of 63 families were obtained, with 176 genera and 216 species of melliferous flora in the state of Veracruz, Mexico. The families that present the highest number of genera are Fabaceae with 20%, and Asteraceae with 16.55%, the same as the highest number of species (Fabaceae 22.58% and Asteraceae 15.59%) (Table 1, Annex 1), as mentioned by González-Suárez et al. (2020).

Most of the species of melliferous flora reported for the state of Veracruz are native (85.65%), exotic species contribute 10.19% and naturalized 4.17%. Concerning their life form, 37.04% are trees, 33.80% are herbaceous, 24.07% shrubs, 2.31% arborescent, 2.31% vines, and 0.46% liana. Most of the species of melliferous flora are nectar-producing (37.96%), followed by pollen-producing (32.87%) and, in lower numbers, there are pollen-nectariferous (29.17%) (Figure 1).

The Asteraceae family is one of the most diverse plant families in Mexico, with around 392 genera and approximately 3,005 species; several of its species are of interest to beekeepers (Cadena et al., 2019), so they are considered as a nectar-polliniferous family. The

Table 1. The most representative melliferous flora families of Veracruz, Mexico.

Family	Genus	%	Species	%
Asteraceae	24	16.55	29	15.59
Combretaceae	4	2.76	4	2.15
Commelinaceae	4	2.76	4	2.15
Convolvulaceae	3	2.07	6	3.23
Euphorbiaceae	6	4.14	7	3.76
Fabaceae	29	20	42	22.58
Lamiaceae	6	4.14	9	4.84
Malvaceae	8	5.52	10	5.38
Myrtaceae	4	2.76	5	2.69
Poaceae	4	2.76	5	2.69
Rubiaceae	4	2.76	4	2.15
Sapindaceae	7	4.83	8	4.30
Verbenaceae	4	2.76	4	2.15

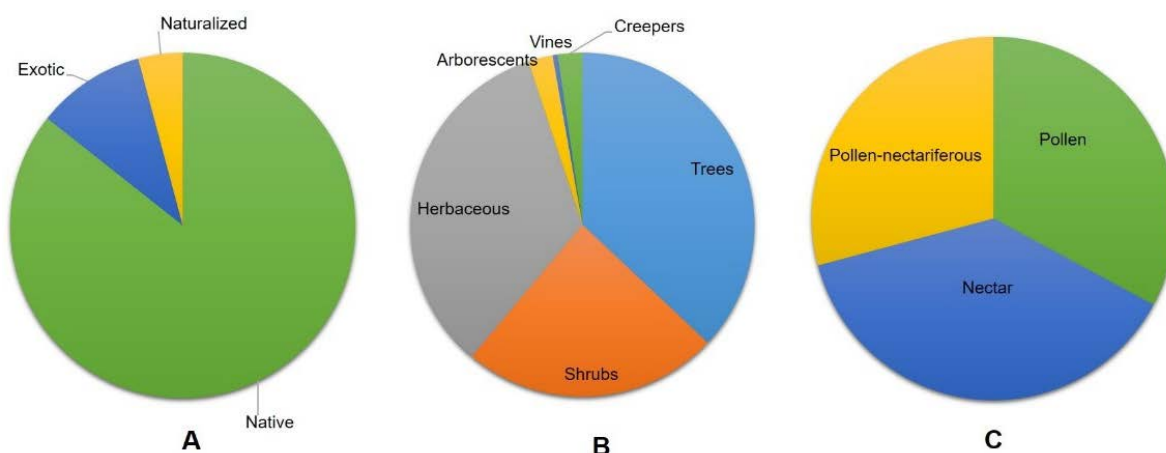


Figure 1. Main characteristics of melliferous flora: A) Status, B) Life form and C) Resource offered to pollinators.

Fabaceae family is also one of the most important in Mexico, since it presents 139 genera and 1,850 species (Ramírez-Arriaga *et al.*, 2016).

On the other hand, there is a record of 44 plant species that are cultivated and visited by bees to obtain their food; these crops belong to 23 botanical families, of which 43.18% are nectariferous and the same percentage are also pollen-nectariferous, and only 9.09% are polliniferous (Annex 2, Figure 2).

The crops that depend on pollination are soybean, coffee, tomato and orange; the importance of pollinators in agricultural crops is that they improve the yield and quality of the seeds and fruits, so this service presents a social and economic impact (Giannini *et al.*, 2020); however, some of the crops only provide food to pollinators during a few weeks, that is, during a short period, and then they must survive a long scarcity, and although some may migrate,

social pollinators require accessible floral resources throughout the year for survival of the colony. For that, wild melliferous flora can provide food and nesting sites, so changes must be made in agricultural practices to foster biodiversity and restore, at least to a certain degree, the complexity of the ecosystem, as well as its functionality and sustainability (Kevan and Silva, 2020).

On the other hand, regional and local crops could depend on more

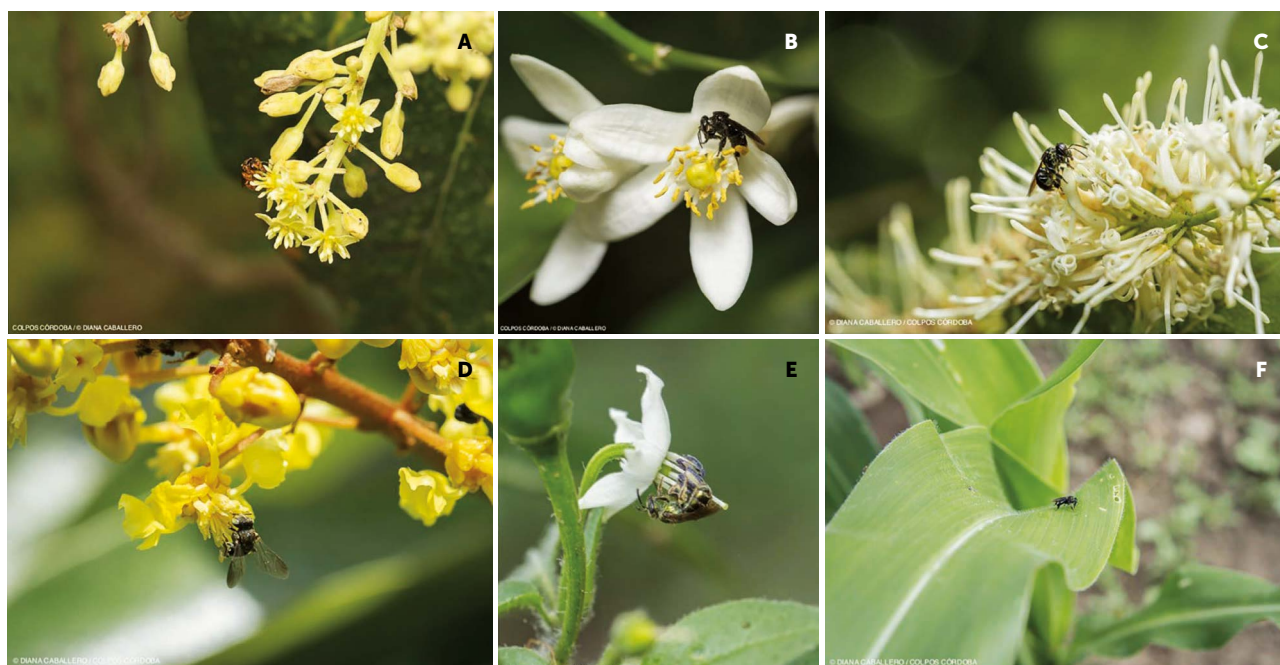


Figure 2. Crops pollinated by bees: A) *Persea americana* Mill., B) *Citrus limon* (L.) Osbeck, C) *Macadamia integrifolia* Maiden & Betche D) *Byrsonima crassifolia* (L.) Kunth, E) *Capsicum annuum* L. y F) *Zea mays* L. Photographs: Diana Caballero Alvarado.

specialized pollinators, although more research in this regard is required, particularly in small-scale agriculture, since this benefits the local and regional economy, in addition to this knowledge being important in local communities (Giannini et al., 2020).

Beekeeping and meliponiculture are important activities thanks to the pollination service that they provide, in addition to the products that bees provide to human beings, such as honey, pollen, wax and propolis, which arise directly or indirectly from the melliferous flora from which working bees feed (Kevan and Silva, 2020).

CONCLUSIONS

In Veracruz there is a great richness of melliferous flora represented by 215 wild plant species, the vast majority of species belong to Fabaceae (20%) and Asteraceae (16.55%). There were also 44 crops detected that provide pollen and nectar to the bees.

The bibliographic references analyzed in this study report that melliferous flora is represented essentially by wild plants, which tend to be eliminated because they are considered weeds. Due to the importance of this type of plants in the life of bees, it is necessary to implement strategies for their protection and reproduction. These actions involve various actors at different levels of government, educational and private institutions, as well as in civil society, although especially farmers, beekeepers and meliponiculture producers. Among the actions for conservation of melliferous flora, the use of melliferous plants in garden design stands out, both in urban and in rural zones in places next to the crops or edges, whether of crops, paths, forests, etc. It is necessary to conserve natural landscapes and restore those damaged by agriculture and livestock activities, as well as using favorable practices for bees in agriculture, primarily for the crops on which these pollinators depend.

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Appendix 1. Melliferous flora in Veracruz state, Mexico

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Acanthaceae	<i>Avicennia germinans</i> (L.) L.	X	X	April-July	Native	Tree	Castellanos-Potenciano et al. (2012); Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Bravaisia integrerrima</i> (Spreng.) Standl.		X	January-April	Native	Tree	Villegas et al. (2000)
Altingiaceae	<i>Liquidambar</i> sp.	X		January-March	Native	Tree	Niembro-Rocas et al. (2015); Ramírez-Arriaga et al. (2018)
Amaranthaceae	<i>Chamissoa altissima</i> (Jacq.) Kunth		X	February-April	Native	Shrub	Villegas et al. (2000)
	<i>Dysphania ambrosioides</i> (L.) Mosyakin & Clements	X		April-December	Native	Herbaceous	Contreras-Oliva et al. (2018)
	<i>Iresine diffusa</i> Humb. & Bonpl. ex Willd.	X			Native	Herb	Bonet y Vergara (2016)
Anacardiaceae	<i>Spondias mombin</i> L.	X		April-May	Native	Tree	Castellanos-Potenciano et al. (2012); Contreras-Oliva et al. (2018); Niembro-Rocas et al. (2010)
Apocynaceae	<i>Asclepias curassavica</i> L.		X	May-August	Native	Herbaceous	Villegas et al. (2000)
	<i>Plumeria rubra</i> L.	X	X	March-September	Native	Tree	Villegas et al. (2000)
	<i>Tabernaemontana citrifolia</i> L.		X	February-April	Native	Shrub	Villegas et al. (2000)
Araliaceae	<i>Dendropanax arboreus</i> (L.) Decne. & Planch.	X	X	December-August	Native	Tree	Contreras-Oliva et al. (2018); Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Oreopanax</i> sp.	X		September-December	Native	Tree	Ramírez-Arriaga et al. (2018)
Arecaceae	<i>Acrocomia aculeata</i> (Jacq.) Lodd. ex Mart.		X	March-September	Native	Arborescent	Villegas et al. (2000)
	<i>Attalea butyracea</i> (Mutis ex L. f.) Wess. Boer		X	January-May	Native	Arborescent	Villegas et al. (2000)
Asparagaceae	<i>Sabal mexicana</i> Mart.	X	X	December-April	Native	Arborescent	Villegas et al. (2000)
	<i>Echeandia albiflora</i> (Schtdl. & Cham.) M. Martens & Galeotti	X		March-June	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari y Espejo (1995)
	<i>Nolina parviflora</i> (Kunth) Hemsl.		X	January-March	Native	Arborescent	Villegas et al. (2000)
Asteraceae	<i>Yucca gigantea</i> Lem.		X	January-April	Native	Arborescent	Villegas et al. (2000)
	<i>Achillea millefolium</i> L.	X		May-November	Native	Herbaceous	Villegas et al. (2000)
	<i>Ageratum houstonianum</i> Mill.	X		All year	Native	Herbaceous	Villegas et al. (2000)
	<i>Ambrosia peruviana</i> Willd.	X	X	May-July	Native	Herbaceous	Villegas et al. (2000)
	<i>Baccharis conferta</i> Kunth		X	January-March	Native	Shrub	Villegas et al. (2000)
	<i>Baccharis trinervis</i> (Cham.) Pers.	X	X	January-March	Native	Shrub	Villegas et al. (2000)
	<i>Baltimora recta</i> L.	X	X	July-September	Native	Herbaceous	Villegas et al. (2000)
	<i>Barkleyanthus salicifolius</i> (Kunth) H. Rob & Brettell	X	X	January-March	Native	Shrub	Villegas et al. (2000)
	<i>Bidens pilosa</i> L.	X	X	September-January	Native	Herbaceous	Contreras-Oliva et al. (2018); Parra-Tabla et al. (2019); Villegas et al. (2000)
	<i>Bidens reptans</i> (L.) G. Don		X	All year	Native	Herbaceous	Villegas et al. (2000)

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Asteraceae	<i>Bidens triplinervia</i> Kunth	X	X	December-March	Native	Herbaceous	Villegas et al. (2000)
	<i>Chromolaena odorata</i> (L.) R.M. King & H. Rob.		X		Native	Shrub	Villegas et al. (2000)
	<i>Elephantopus mollis</i> Kunth	X		September-December	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Helianthus</i> sp.	X			Native	Herbaceous	Contreras-Oliva et al. (2018)
	<i>Helopsis bupththalmoides</i> (Jacq.) Dunal	X			Native	Herbaceous	Bonet y Vergara (2016)
	<i>Melampodium divaricatum</i> (Rich.) DC.	X	X	August-December	Native	Herbaceous	Villegas et al. (2000)
	<i>Montanoa grandiflora</i> Alamán ex DC.	X	X	January-March	Native	Shrub	Villegas et al. (2000)
	<i>Parthenium fruticosum</i> Less.	X			Native	Shrub	Contreras-Oliva et al. (2018)
	<i>Pluchea odorata</i> (L.) Cass		X	September-December	Native	Shrub	Villegas et al. (2000)
	<i>Sanvitalia procumbens</i> Lam.	X		August- January	Native	Herbaceous	Villegas et al. (2000)
	<i>Simsia amplexicaulis</i> (Cav.) Pers.	X	X	September-December	Native	Herbaceous	Hernández-Villa et al. (2020) Villegas et al. (2000)
	<i>Simsia eurylepis</i> S. F. Blake	X	X	October-December	Native	Herbaceous	Villegas et al. (2000)
	<i>Smallanthus maculatus</i> (Cav.) H. Rob.	X		August-October	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Tithonia tubiformis</i> (Jacq.) Cass.	X	X	December-March	Native	Herbaceous	Hernández-Villa et al. (2020) Villegas et al. (2000)
	<i>Tridax procumbens</i> L.	X	X		Native	Herbaceous	Villegas et al. (2000)
	<i>Verbesina</i> sp.	X		December-March	Native	Shrub	Contreras-Oliva et al. (2018)
	<i>Vernonia</i> sp.	X			Native	Herbaceous	Contreras-Oliva et al. (2018)
	<i>Vernonanthura patens</i> (Kunth) H. Rob.		X	January-April	Native	Shrub	Villegas et al. (2000)
Balsaminaceae	<i>Viguiera dentata</i> (Cav.) Spreng.	X	X	August-December	Native	Herbaceous	Gonzalez(2014) Villegas et al. (2000)
	<i>Viguiera grammatoglossa</i> D. C.		X	August-February	Native	Shrub	Villegas et al. (2000)
	<i>Impatiens walleriana</i> Hook. f.	X		January-June	Naturalized	Herbaceous	Bonet y Vergara(2016)
Berberidaceae	<i>Berberis trifolia</i> Schult. & Schult. f.		X	January-March	Native	Shrub	Villegas et al. (2000)
Bignoniaceae	<i>Handroanthus chrysanthus</i> (Jacq.) S. O. Grose	X	X	January-March	Native	Tree	Villegas et al. (2000)
	<i>Tabebuia rosea</i> (Bertol.) DC.	X	X	February-April	Native	Tree	Niembro-Rocas et al. (2010; Villegas et al. (2000)
	<i>Tecoma stans</i> (L.) Juss. ex Kunth		X	All year	Native	Shrub	Canto et al. (2017) Villegas et al. (2000)
Bixaceae	<i>Cochlospermum vitifolium</i> (Willd.) Spreng.		X	December-May	Native	Tree	Niembro-Rocas et al., (2010; Villegas et al. (2000)
Boraginaceae	<i>Cordia alliodora</i> (Ruiz & Pav.) Oken	X	X	August-April	Native	Tree	Contreras-Oliva et al. (2018); Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Cordia dentata</i> Poir.		X	All year	Native	Tree	Villegas et al. (2000)
	<i>Cordia megalantha</i> S.F. Blake	X		February-May	Native	Tree	Villegas et al. (2000)

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Brassicaceae	<i>Brassica rapa</i> L.	X	X	May-December	Naturalized	Herbaceous	Villegas et al. (2000)
	<i>Brassica nigra</i> (L.) W.D.J. Koch	X		December-February	Naturalized	Herbaceous	Villegas et al. (2000)
	<i>Raphanus raphanistrum</i> L.	X	X	September-May	Exotic	Herbaceous	Villegas et al. (2000)
Burseraceae	<i>Bursera simaruba</i> (L.) Sarg.	X	X	February-August	Native	Tree	Contreras-Oliva et al. (2018); Herrera-López et al. (2019); Villegas et al. (2000)
Cactaceae	<i>Cylindropuntia imbricata</i> (Haw.) F.M. Knuth	X	X	January-April	Native	Shrub	Villegas et al. (2000)
	<i>Opuntia huajuapensis</i> Bravo	X	X	February-May	Native	Shrub	Villegas et al. (2000)
	<i>Opuntia stricta</i> (Haw.) Haw.	X	X	February-April	Native	Shrub	Villegas et al. (2000)
Campanulaceae	<i>Lobelia xalapensis</i> Kunth	X		January-April	Native	Herbaceous	Bonet y Vergara (2016)
Cannabaceae	<i>Trema micrantha</i> (L.) Blume		X	February-April	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
Chloranthaceae	<i>Hedyosmum mexicanum</i> C. Cordem.	X		February-April	Native	Shrub	Ramírez-Arriaga et al. (2018)
Combretaceae	<i>Combretum farinosum</i> Kunth		X	December-March	Native	Vine	Villegas et al. (2000)
	<i>Conocarpus erectus</i> L.	X	X	April-June	Native	Tree	Parra-Tabla et al. (2019); Villegas et al. (2000)
	<i>Laguncularia racemosa</i> (L.) C.F. Gaertn.		X	February-May	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Terminalia catappa</i> L.		X	February-March	Naturalized	Tree	Villegas et al. (2000)
Commelinaceae	<i>Commelina diffusa</i> Burm. f.	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari et al. (2014)
	<i>Gibasis pellucida</i> (M. Martens & Galeotti) D.R. Hunt	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari et al. (2014)
	<i>Tinantia erecta</i> (Jacq.) Schlttdl.	X		August-November	Native	Herbaceous	Bonet y Vergara, 2016; Hernández-Villa et al., 2020
	<i>Tripogandra serrulata</i> (Vahl) Handlos	X		All year	Native	Herbaceous	Bonet y Vergara (2016); López-Ferrari et al. (2014)
Convolvulaceae	<i>Convolvulus nodiflorus</i> Desv.	X	X	May-December	Native	Herbaceous	Villegas et al. (2000)
	<i>Ipomoea arborescens</i> (Humb. & Bonpl. ex Willd.) G. Don		X	December-March	Native	Tree	Villegas et al. (2000)
	<i>Ipomoea carnea</i> subsp. <i>fistulosa</i> (Mart. ex Choisy) D.F. Austin		X	November-May	Native	Shrub	Villegas et al. (2000)
	<i>Ipomoea indica</i> (Burm.) Merr.	X		All year	Native	Vine	Bonet y Vergara (2016)
Crassulaceae	<i>Ipomoea triloba</i> L.		X	October-February	Native	Herbaceous	Canto et al. (2017); Villegas et al. (2000)
	<i>Merremia dissecta</i> (Jacq.) Hallier f.	X	X	All year	Native	Vine	Canto et al. (2017); Villegas et al. (2000)
	<i>Sedum praealtum</i> A. DC.		X	January-February	Native	Herbaceous	Villegas et al. (2000)

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Cucurbitaceae	<i>Luffa aegyptiaca</i> Mill.		X	All year	Exotic	Vine	Villegas et al. (2000)
	<i>Momordica charantia</i> L.	X	X	All year	Exotic	Vine	Villegas et al. (2000)
	<i>Sicyos microphyllus</i> Kunth		X	September-December	Native	Herbaceous	Villegas et al. (2000)
Cyperaceae	<i>Rhynchospora radicans</i> (Schtdl. & Cham.) H. Pfeiff.	X			Native	Herbaceous	Bonet y Vergara (2016)
Ehretiaceae	<i>Ehretia anacua</i> (Terán & Berland.) I.M. Johnst.		X	April-December	Native	Tree	Villegas et al. (2000)
	<i>Ehretia tinifolia</i> M. Martens & Galeotti		X	February-July	Native	Tree	Villegas et al. (2000)
Euphorbiaceae	<i>Alchornea latifolia</i> Sw.	X		December-April	Native	Tree	Niembro-Rocas et al. (2010); Ramírez-Arriaga et al. (2018)
	<i>Cnidioscolus multilobus</i> (Pax) I.M. Johnst.	X	X	December-March	Native	Shrub	Villegas et al. (2000)
	<i>Croton draco</i> Schtdl. & Cham.		X	October-February	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Croton reflexifolius</i> Kunth		X		Native	Shrub	Villegas et al. (2000)
	<i>Euphorbia heterophylla</i> L.	X		February-April	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Euphorbia schlechtendalii</i> Boiss.		X	March-June	Native	Tree	Villegas et al. (2000)
	<i>Ricinus communis</i> L.	X	X	All year	Exotic	Shrub	Villegas et al. (2000)
	<i>Acacia</i> sp.	X			Native	Shrub	Ramírez-Arriaga et al. (2018)
	<i>Vachellia cornigera</i> (L.) Seigler & Ebinger	X	X	February-April	Native	Shrub	Villegas et al. (2000)
	<i>Vachellia farnesiana</i> (L.) Wight & Arn.	X	X	December-May	Native	Shrub	Villegas et al. (2000)
Fabaceae	<i>Vachellia pennatula</i> (Schtdl. & Cham.) Seigler & Ebinger	X	X	April-June	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Bauhinia divaricata</i> L.	X	X	All year	Native	Shrub	Villegas et al. (2000)
	<i>Caesalpinia cacalaco</i> Bonpl.	X	X	November-February	Native	Tree	Villegas et al. (2000)
	<i>Cajanus cajan</i> (L.) Huth	X		September-February	Exotic	Shrub	Villegas et al. (2000)
	<i>Cassia fistula</i> L.	X		February-April	Exotic	Tree	Villegas et al. (2000)
	<i>Cassia grandis</i> L. f.	X		February-May	Native	Tree	Villegas et al. (2000)
	<i>Chamaecrista</i> sp.	X			Exotic	Shrub	Contreras-Oliva et al. (2018)
	<i>Cojoba arborea</i> (L.) Britton & Rose		X	January-March	Native	Tree	Villegas et al. (2000)
	<i>Dalbergia brownnei</i> (Jacq.) Schinz		X	February-April	Native	Shrub	Villegas et al. (2000)
	<i>Dalea botterii</i> (Rydb.) Barneby		X	September-December	Native	Herbaceous	Villegas et al. (2000)
	<i>Delonix regia</i> (Bojer ex Hook.) Raf.		X	April-July	Naturalized	Tree	Villegas et al. (2000)
	<i>Desmodium adscendens</i> (Sw.) DC.	X			Native	Herbaceous	Contreras-Oliva et al. (2018)

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Fabaceae	<i>Desmodium canescens</i> (L.) DC.	X		April-July	Exotic	Herbaceous	Bonet y Vergara (2016)
	<i>Desmodium tortuosum</i> (Sw.) DC.	X			Native	Herbaceous	Contreras-Oliva et al. (2018)
	<i>Enterolobium cyclocarpum</i> (Jacq.) Griseb.	X	X	March-May	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Eysenhardtia polystachya</i> (Ortega) Sarg.	X	X	September-October	Native	Tree	Villegas et al. (2000)
	<i>Gliricidia sepium</i> (Jacq.) Kunth ex Walp.	X	X	December-April	Native	Tree	Niembro-Rocas et al. 2010; Villegas et al. (2000)
	<i>Haematoxylum brasiletto</i> H. Karst.	X	X	February-March	Native	Tree	Villegas et al. (2000)
	<i>Haematoxylum campechianum</i> L.	X	X	September-April	Native	Tree	González, (2014) Villegas et al. (2000)
	<i>Inga inicuili</i> Schtdl. & Cham. ex G. Don	X	X	February-April	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Inga vera</i> Willd.	X	X	April-May	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Leucaena diversifolia</i> (Schtdl.) Benth.	X			Native	Tree	Villegas et al. (2000)
	<i>Leucaena lanceolata</i> S. Watson	X		August-December	Native	Shrub	Villegas et al. (2000)
	<i>Leucaena</i> sp.	X			Native	Tree	Ramírez-Arriaga et al. (2018)
	<i>Lonchocarpus guatemalensis</i> Benth.		X	February-May	Native	Tree	Villegas et al. (2000)
	<i>Lonchocarpus</i> sp.	X			Native	Tree	Ramírez-Arriaga et al. 2018)
	<i>Lysiloma acapulcense</i> (Kunth) Benth.	X	X	March-May	Native	Tree	Villegas et al. (2000)
	<i>Mimosa albida</i> Humb. & Bonpl. ex Willd.	X		August-November	Native	Shrub	Villegas et al. (2000)
	<i>Mimosa pigra</i> L.		X	March-July	Native	Shrub	Villegas et al. (2000)
	<i>Mimosa pudica</i> L.	X		September-November	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Mimosa scabrella</i> Benth.	X		December-January	Exotic	Shrub	Villegas et al. (2000)
	<i>Piscidia piscipula</i> (L.) Sarg.	X	X	May-July	Native	Tree	Niembro-Rocas et al. (2010); Canto et al. (2017); Villegas et al. (2000)
	<i>Pithecellobium dulce</i> (Roxb.) Benth.	X	X	November-May	Native	Shrub	Niembro-Rocas et al. (2010); Contreras-Oliva et al. (2018); Villegas et al. (2000)
	<i>Pithecellobium insigne</i> Micheli ex Donn. Sm.	X	X	January-March	Native	Tree	Villegas et al. (2000)
	<i>Prosopis juliflora</i> (Sw.) DC.	X	X	January-April	Native	Tree	Villegas et al. (2000)
	<i>Trifolium repens</i> L.	X	X	All year	Naturalized	Herbaceous	Villegas et al. (2000)
	<i>Vachellia pringlei</i> (Rose) Seigler & Ebinger	X	X	February-may	Native	Tree	Villegas et al. (2000)
	<i>Verbesina turbacensis</i> Kunth	X	X	November-January	Native	Shrub	Villegas et al. (2000)
	<i>Vicia sativa</i> L.		X	January-March	Native	Herbaceous	Villegas et al. (2000)

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Fagaceae	<i>Quercus</i> sp.	X		June	Native	Tree	Ramírez-Arriaga et al. (2018)
	<i>Hypoxis decumbens</i> L.	X			Native	Herbaceous	Bonet y Vergara (2016)
Juglandaceae	<i>Juglans pyriformis</i> Liebm.	X		February-March	Native	Tree	Villegas et al. (2000)
Lamiaceae	<i>Hyptis mutabilis</i> (Rich.) Briq.		X	August-December	Exotic	Herbaceous	Villegas et al. (2000)
	<i>Hyptis suaveolens</i> (L.) Poit.		X	August-October	Native	Herbaceous	Villegas et al. (2000)
	<i>Marrubium vulgare</i> L.		X		Naturalized	Herbaceous	Villegas et al. (2000)
	<i>Marsipianthes chamaedrys</i> (Vahl) Kuntze	X		February-May	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Mentha x piperita</i> L.		X		Exotic	Herbaceous	Villegas et al. (2000)
	<i>Ocimum</i> sp.	X		June-October	Native	Herbaceous	Ramírez-Arriaga et al. (2018)
	<i>Salvia albiflora</i> M. Martens & Galeotti	X			Native	Herbaceous	Bonet y Vergara (2016)
	<i>Salvia purpurea</i> Cav.		X	September-January	Native	Herbaceous	Villegas et al. (2000)
	<i>Salvia rubiginosa</i> Benth.		X	September-January	Native	Shrub	Villegas et al. (2000)
	<i>Nectandra ambigens</i> (S.F. Blake) C.K. Allen		X	February-May	Native	Tree	Villegas et al. (2000)
Lauraceae							
Lythraceae	<i>Ginoria nudiflora</i> (Hemsl.) Koehne	X	X	November-May	Native	Tree	Villegas et al. (2000)
	<i>Ceiba aesculifolia</i> (Kunth) Britten & Baker f.		X	November-May	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Dombeya wallichii</i> (Lindl.) Baill.		X	November-February	Exotic	Tree	Villegas et al. (2000)
Malvaceae	<i>Hampea nutricia</i> Fryxell		X	September-November	Native	Shrub	Villegas et al. (2000)
	<i>Heliolepis pallidus</i> Rose	X		October-February	Native	Tree	Contreras-Oliva et al. (2018); Villegas et al. (2000)
	<i>Heliolepis appendiculatus</i> Turcz.	X		December-March	Native	Tree	Ramírez-Arriaga et al. (2018)
	<i>Malvaviscus arboreus</i> Cav.	X	X	All year	Native	Shrub	Canto et al. (2017); Parra-Tabla et al. (2019); Villegas et al. (2000)
	<i>Pachira aquatica</i> Aubl.		X	All year	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Pseudobombax ellipticum</i> (Kunth) Dugand	X	X	January-June	Native	Tree	Villegas et al. (2000)
	<i>Sida acuta</i> Burm. f.	X			Exotic	Shrub	Bonet y Vergara (2016)
Meliaceae	<i>Sida rhombifolia</i> L.	X		All year	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Trichilia havanensis</i> Jacq.		X	December-April	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Trichilia hirta</i> L.		X		Native	Tree	Villegas et al. (2000)
Melastomataceae	<i>Miconia</i> sp.	X			Native	Herbaceous	Ramírez-Arriaga et al. (2018)

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Muntingiaceae	<i>Muntingia calabura</i> L.		X	All year	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
Myrtaceae	<i>Callistemon citrinus</i> (Curtis) Skeels		X	December-April	Exotic	Shrub	Villegas et al. (2000)
	<i>Eucalyptus globulus</i> Labill.		X		Exotic	Tree	Villegas et al. (2000)
	<i>Eugenia capuli</i> (Schitdl. & Cham.) Hook. & Arn.	X		May-July	Native	Shrub	Contreras-Oliva et al. (2018)
	<i>Eugenia mexicana</i> Steud.	X	X	May-August	Native	Shrub	Villegas et al. (2000)
Nyctaginaceae	<i>Syzgium jambos</i> (L.) Alston		X	February-July	Naturalized	Tree	Villegas et al. (2000)
	<i>Pisonia aculeata</i> L.		X	January-April	Exotic	Shrub	Villegas et al. (2000)
Oleaceae	<i>Ligustrum lucidum</i> W. T. Aiton	X	X	March-June	Exotic	Tree	Villegas et al. (2000)
Onagraceae	<i>Lopezia hirsuta</i> Jacq.		X	November-January	Native	Herbaceous	Villegas et al. (2000)
Papaveraceae	<i>Argemone mexicana</i> L.	X	X	January-April	Native	Herbaceous	Villegas et al. (2000)
	<i>Argemone platyceras</i> Link & Otto	X	X		Native	Herbaceous	Villegas et al. (2000)
Piperaceae	<i>Piper</i> sp.	X		All year	Native	Shrub	Ramírez-Arriaga et al. (2018)
Platanaceae	<i>Platanus mexicana</i> Moric.	X		January-May	Native	Tree	Ramírez-Arriaga et al. (2018)
Poaceae	<i>Brachiaria plantaginea</i> (Link) Hitchc.	X		May-November	Native	Herbaceous	Bonet y Vergara (2016)
	<i>Panicum</i> sp.	X			Native	Herbaceous	Bonet y Vergara (2016)
	<i>Paspalum conjugatum</i> P.J. Bergius	X			Native	Herbaceous	Bonet y Vergara (2016)
	<i>Paspalum virgatum</i> L.	X			Native	Herbaceous	Bonet y Vergara (2016)
	<i>Pseudechinolaena polystachya</i> (Kunth) Stapf	X		All year	Native	Herbaceous	Bonet y Vergara (2016)
					Native	Herbaceous	Bonet y Vergara (2016)
Polygonaceae	<i>Antigonon leptopus</i> Hook. & Arn		X	August-December	Native	Vine	Villegas et al. (2000)
Pontederiaceae	<i>Coccoloba uvifera</i> (L.) L.	X	X	February-April	Native	Shrub	Contreras-Oliva et al. (2018); Villegas et al. (2000)
	<i>Pontederia sagittata</i> C. Presl		X	January-March	Native	Herbaceous	Villegas et al. (2000)
Proteaceae	<i>Grevillea robusta</i> A. Cunn. ex R. Br.	X	X	March-April	Exotic	Tree	Villegas et al. (2000)
Resedaceae	<i>Reseda odorata</i> L.		X	September-December	Exotic	Herbaceous	Villegas et al. (2000)
Rhamnaceae	<i>Gouania lupuloides</i> (L.) Urb.		X	September-November	Native	Shrub	Villegas et al. (2000)
	<i>Ziziphus</i> sp.	X		June	Native	Shrub	Ramírez-Arriaga et al. (2018)
Rhizophoraceae	<i>Rhizophora mangle</i> L.		X	All year	Native	Tree	Villegas et al. (2000)
Rosaceae	<i>Prunus serotina</i> Ehrh.		X	January-March	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
Rubiaceae	<i>Calycophyllum candidissimum</i> (Vahl) DC.		X	October- January	Native	Tree	Villegas et al. (2000)
	<i>Ixora coccinea</i> L.		X	November-January	Exotic	Shrub	Villegas et al. (2000)

Family	Plant species	Pollen	Nectar	Flowering	Status	Life-form	Reference
Rubiaceae	<i>Murraya paniculata</i> (L.) Jack		X	April-June	Exotic	Tree	Villegas et al. (2000)
	<i>Spermaceoce confusa</i> Rendle		X	September-December	Native	Herbaceous	Villegas et al. (2000)
Sapindaceae	<i>Acer negundo</i> L.	X		February-March	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Cupania</i> sp.	X		August	Native	Tree	Ramirez-Arriaga et al. (2018)
	<i>Sapindus saponaria</i> L.		X	August-March	Native	Tree	Villegas et al. (2000)
	<i>Serjania</i> sp.	X			Native	Shrub	Contreras-Oliva et al. (2018)
	<i>Serjania racemosa</i> Schumacher.		X	November-January	Native	Shrub	Villegas et al. (2000)
	<i>Talisia oliviformis</i> (Kunth) Radlk.		X	February-May	Native	Tree	Villegas et al. (2000)
	<i>Thouinia paucidentata</i> Radlk.	X			Native	Tree	Ramirez-Arriaga et al. (2018)
	<i>Thouinidium decandrum</i> (Bonpl.) Radlk.		X	February-April	Native	Tree	Villegas et al., (2000)
	<i>Manilkara zapota</i> (L.) P. Royen		X	June-October	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
	<i>Pouteria</i> sp.	X		May	Native	Tree	Contreras-Oliva et al. (2018); Niembro-Rocas et al. (2010)
Scrophulariaceae	<i>Buddleja cordata</i> Kunth	X	X	March-October	Native	Tree	Niembro-Rocas et al. (2010); Villegas et al. (2000)
Solanaceae	<i>Solanum rostratum</i> Dunal		X	May-September	Native	Herbaceous	Villegas et al. (2000)
	<i>Solanum</i> sp.	X			Native	Herbaceous	Contreras-Oliva et al. (2018)
Malvaceae	<i>Waltheria indica</i> L.		X	January-March	Native	Herbaceous	Villegas et al. (2000)
Urticaceae	<i>Cecropia peltata</i> L.		X	All year	Native	Tree	Villegas et al. (2000)
	<i>Cecropia obtusifolia</i> Bertol.	X		All year	Native	Tree	Ramirez-Arriaga et al. (2018)
Verbenaceae	<i>Aloysia virgata</i> (Ruiz & Pav.) Pers.		X	All year	Exotic	Shrub	Villegas et al. (2000)
	<i>Lantana camara</i> L.		X	All year	Native	Shrub	Villegas et al. (2000)
	<i>Lippia myriocephala</i> Schtdl. & Cham.		X	September-January	Native	Tree	Villegas et al. (2000)
	<i>Phyla fruticosa</i> (Mill.) K. Kenn. ex Wunderlin & B.F. Hansen		X	All year	Native	Herbaceous	Villegas et al. (2000)
Zygophyllaceae	<i>Tribulus cistoides</i> L.	X	X	September-March	Native	Herbaceous	Parra-Tabla et al. (2019) Villegas et al. (2000)
	<i>Tribulus terrestris</i> L.		X	January-April	Naturalized	Herbaceous	Villegas et al. (2000)

Appendix 2. Crops pollinated by bees in Mexico.

Family	Crop	Common name	Pollen	Nectar	Flowering	Status	Reference
Anacardiaceae	<i>Mangifera indica</i> L.	"mango"	X	X	November-March	Naturalized	Meléndez et al. (2018); Villegas et al. (2000)
	<i>Spondias mombin</i> L.	"jobo"		X	March-May	Native	Villegas et al. (2000)
	<i>Spondias purpurea</i> L.	"ciruelo"	X	X	December-March	Native	Villegas et al. (2000)
Arecaceae	<i>Cocos nucifera</i> L.	"cocotero"	X	X	All year	Naturalized	Castellanos-Potenciano et al. (2012); Meléndez et al. (2018); Ramírez-Arriaga et al. (2018); Villegas et al. (2000)
Asteraceae	<i>Helianthus annuus</i> L.	"girasol"	X	X	March-July	Native	Villegas et al. (2000)
Brassicaceae	<i>Brassica napus</i> L.	"canola"	X	X	September-December	Exotic	Villegas et al. (2000)
Caricaceae	<i>Carica papaya</i> L.	"papaya"	X	X	All year	Native	Badillo-Montaño et al. (2019) Villegas et al. (2000)
Convolvulaceae	<i>Ipomoea batatas</i> (L.) Lam.	"camote"	X	X	July-April	Native	Villegas et al. (2000)
Cucurbitaceae	<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai	"sandía"		X	All year	Exotic	Villegas et al. (2000)
	<i>Cucurbita ficifolia</i> Bouché	"calabaza"		X	May-August	Native	Villegas et al. (2000)
	<i>Cucurbita maxima</i> Duchesne	"calabaza"	X	X	May-August	Exotic	Villegas et al. (2000)
	<i>Cucumis melo</i> L.	"melón"		X	January-June	Exotic	Villegas et al. (2000)
	<i>Cucurbita moschata</i> Duchesne	"calabaza"	X			Native	(eléndez et al. (2018)
	<i>Cucumis sativus</i> L.	"pepino"	X	X	January-June	Exotic	Villegas et al. (2000)
	<i>Sechium edule</i> (Jacq.) Sw.	"chayote"		X	All year	Native	Villegas et al. (2000)
	<i>Diospyros digyna</i> Jacq.	"zapote negro"		X	March-June	Naturalized	Villegas et al. (2000)
Euphorbiaceae	<i>Hevea brasiliensis</i> (Willd. ex A. Juss.) Müll. Arg.	"hule"		X	February-April	Exotic	Villegas et al. (2000)
Fabaceae	<i>Medicago sativa</i> L.	"alfalfa"		X	All year	Exotic	Villegas et al. (2000)
	<i>Phaseolus coccineus</i> L.	"ayocote" "frijol colorado"		X	September-October	Native	Villegas et al. (2000)
	<i>Tamarindus indica</i> L.	"tamarindo"		X	May-November	Naturalized	Villegas et al. (2000)
Lauraceae	<i>Persea americana</i> Mill.	"aguacate"		X	February-May	Native	Meléndez et al. (2018); Villegas et al. (2000)
Malpighiaceae	<i>Byrsonima crassifolia</i> (L.) Kunth	"nanche"	X	X	March-June	Native	Villegas et al. (2000)
Malvaceae	<i>Gossypium hirsutum</i> L.	"algodón"	X	X	August, February, May	Native	Canto et al. (2017)
Musaceae	<i>Musa paradisiaca</i> L.	"plátano"	X	X	All year	Naturalized	Villegas et al. (2000)
Myrtaceae	<i>Psidium guajava</i> L.	"guayaba"	X	X	April-June	Native	Villegas et al. (2000)
Poaceae	<i>Zea mays</i> L.	"maíz"	X	X	February-March, July-August	Native	Villegas et al. (2000)
Proteaceae	<i>Macadamia integrifolia</i> Maiden & Betche	"macadamia"		X	January-March	Exotic	Villegas et al. (2000)

Family	Crop	Common name	Pollen	Nectar	Flowering	Status	Reference
Rosaceae	<i>Crataegus mexicana</i> DC.	"tejocote"	X	X	March-May	Native	Villegas et al. (2000)
	<i>Eriobotrya japonica</i> (Thunb.) Lindl.	"nispero"		X	December-February	Naturalized	Villegas et al. (2000)
	<i>Malus pumila</i> Mill.	"manzana"	X	X	February-March	Exotic	Villegas et al. (2000)
	<i>Prunus domestica</i> L.	"ciruelo"	X	X	February-April	Exotic	Villegas et al. (2000)
	<i>Prunus persica</i> (L.) Batsch	"durazno"		X	February-April	Exotic	Villegas et al. (2000)
	<i>Pyrus communis</i> L.	"pera"		X	February-March	Exotic	Villegas et al. (2000)
	<i>Rubus eriocarpus</i> Liebm.	"zarzamora", "mora"		X	January-March	Native	Villegas et al. (2000)
Rubiaceae	<i>Coffea arabica</i> L.	"café"		X	April-June	Exotic	Ramírez-Arriaga et al. (2018); Villegas et al. (2000)
Rutaceae	<i>Casimiroa edulis</i> La Llave	"zapote blanco"		X	January-February	Native	Villegas et al. (2000)
	<i>Citrus x aurantiifolia</i> (Christm.) Swingle	"limón agrio"	X	X	All year	Exotic	Villegas et al. (2000)
	<i>Citrus maxima</i> (Burm.) Merr.	"toronja"	X	X	December-February	Exotic	Villegas et al. (2000)
	<i>Citrus reticulata</i> Blanco	"mandarina"		X	June-February	Exotic	Villegas et al. (2000)
	<i>Citrus x sinensis</i> (L.) Osbeck	"naranja"		X	June-February	Exotic	Villegas et al. (2000)
Sapindaceae	<i>Litchi chinensis</i> Sonn.	"lichi"	X	X	January-March	Exotic	Villegas et al. (2000)
	<i>Nephelium lappaceum</i> L.	"rambután"	X			Exotic	Meléndez et al. (2018)
Solanaceae	<i>Capsicum annuum</i> L.	"chile"	X			Native	Meléndez et al. (2018); Villegas et al. (2000)
	<i>Solanum lycopersicum</i> L.	"jitomate"	X		All year	Native	Meléndez et al. (2018)