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 Otonteppec 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-Santin, 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 caruncle (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

| 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 |

Table 1. The most representative melliferous flora families of Veracruz, Mexico.
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
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       | Life-form | Status | Reference                                                                 |
|-------------------------|----------------------------------------|--------|--------|-----------------|-----------|--------|---------------------------------------------------------------------------|
| Acanthaceae             | Avicennia germinans (L.) L.            | ✓      | ✓      | April-July      | Tree      | Native | Castellanos-Pepecano et al. (2012); Nienbro-Rocas et al. (2010); Villegas et al. (2000) |
| Acanthaceae             | Bravaisia integerrima (Sprun. Standl.)|        |        | January-April   | Tree      | Native | Nienbro-Rocas et al. (2015); Ramírez-Ariaga et al. (2018)                |
| Acanthaceae             | Chrysumallesia (Usca) Kunth & Cermans |        |        | January-March   | Tree      | Native | Nienbro-Rocas et al. (2010); Villegas et al. (2000)                      |
| Amaranthaceae           | Chamissoa altissima (Jacq.) Kunth     | ✓      | ✓      | February-April  | Native    | Shrub  | Villegas et al. (2000)                                                   |
| Apocynaceae             | Asclepias curassavica L.               |        |        | April-May       | Herb      | Herb   | Villegas et al. (2000)                                                   |
| Apocynaceae             | Plumeria rubra L.                     | ✓      | ✓      | May-August      | Herbaceous| Herb   | Villegas et al. (2000)                                                   |
| Apocynaceae             | Tabernaemontana cintifolia L.          |        |        | September-December | Tree | Herbaceous | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Apocynaceae             | Iresine diffusa Humb. & Bong. ex Wild.|        |        | January-March   | Shrub     | Shrub  | Villegas et al. (2000)                                                   |
| Anacardiaceae           | Spondias mombin L.                    |        |        | April-May       | Tree      | Native | Castellanos-Pepecano et al. (2012); Nienbro-Rocas et al. (2010); Villegas et al. (2000) |
| Apocynaceae             | Tabernaemontana cintifolia L.          |        |        | September-December | Tree | Herbaceous | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Arecaceae               | Acrocomia aculeata (Jacq.) Lodd ex Mart |        |        | March-September | Arborescent| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asparagaceae            | Echeandia albiflora (Schltldl. & Cham.) M. Martens & Galeotti |        |        | March-June      | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asparagaceae            | Nolina parviflora (Kunth) Hems.       |        |        | January-March   | Arborescent| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asparagaceae            | Yucca gigantea Lem.                   |        |        | January-April   | Arborescent| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asteraceae              | Agaritum matucanum Mill.              |        |        | All year        | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asteraceae              | Ambrosia peruviana Wild                |        |        | All year        | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asteraceae              | Biddensia ploa L.                     |        |        | All year        | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asteraceae              | Bidens expansa L.                     |        |        | All year        | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |
| Asteraceae              | Bidens reptans (L.) G. Don             |        |        | All year        | Herbaceous| Native | Villegas et al. (2000); Contreras-Oliva et al. (2018); Nienbro-Rocas et al. (2018) |

References:
- Castellanos-Pepecano et al. (2012)
- Nienbro-Rocas et al. (2010)
- Villegas et al. (2000)
| Family                | Plant species                  | Pollen | Nectar | Flowering       | Status  | Life-form        | Reference                                      |
|----------------------|--------------------------------|--------|--------|-----------------|---------|------------------|-----------------------------------------------|
| **Asteraceae**       | **Bidens triplinervia Kunth**  | X      |        | December-March  | Native  | Herbaceous       | Villegas et al. (2000)                        |
|                      | **Chromolaena odorata (L.) R.M. King & H. Rob.** |        |        |                 |         |                  |                                               |
|                      | **Elephantopus mollis Kunth**  | X      |        | September-December | Native  | Herbaceous       | Bonet y Vergara (2016)                        |
|                      | **Helianthus sp.**              | X      |        |                 |         | Herbaceous       | Contreras-Oliva et al. (2018)                 |
|                      | **Helioptis buphthalmoides (Jacq.) Dunal** |        |        |                 |         | Herbaceous       | Bonet y Vergara (2016)                        |
|                      | **Melampodium divaricatum (Rich.) DC.** | X      |        | August-December  | Native  | Herbaceous       | Villegas et al. (2000)                        |
|                      | **Montana grandiflora Alamán ex DC.** | X      |        | January-March   | Native  | Shrub            | Villegas et al. (2000)                        |
|                      | **Parthenium fruticosum Less.** | X      |        |                 | Native  | Shrub            | Contreras-Oliva et al. (2018)                 |
|                      | **Pluchea odorata (L.) Cass**   | X      |        | September-December | Native  | Shrub            | Villegas et al. (2000)                        |
|                      | **Sanvitalia procumbens Lam.**  | X      |        | August-January  | Native  | Herbaceous       | Villegas et al. (2000)                        |
|                      | **Simsia amplexicaulis (Cav.) Pers.** | X      |        | September-December | Native  | Herbaceous       | Hernández-Villa et al. (2020) Villegas et al. (2000) |
|                      | **Simsia eurylepis S. F. Blake** | X      |        | October-December | Native  | Herbaceous       | Villegas et al. (2000)                        |
|                      | **Smallanthus maculatus (Cav.) H. Rob.** | X      |        | August-October  | Native  | Herbaceous       | Bonet y Vergara (2016)                        |
|                      | **Tithonia tubiformis (Jacq.) Cass.** | X      |        | December-March  | Native  | Herbaceous       | Hernández-Villa et al. (2020) Villegas et al. (2000) |
|                      | **Tridax procumbens L.**        | X      |        | December-March  | Native  | Herbaceous       | Villegas et al. (2000)                        |
|                      | **Verbena sp.**                 | X      |        | January-March   | Native  | Shrub            | Contreras-Oliva et al. (2018)                 |
|                      | **Vernonia sp.**                | X      |        |                 | Native  | Herbaceous       | Contreras-Oliva et al. (2018)                 |
|                      | **Vernonanthera patens (Kunth) H. Rob.** | X      |        | January-April   | Native  | Shrub            | Villegas et al. (2000)                        |
|                      | **Viguiera dentata (Cav.) Spreng.** | X      |        | August-December  | Native  | Herbaceous       | González (2014) Villegas et al. (2000)        |
|                      | **Viguiera grammatoglossa D.C.** | X      |        | August-February | Native  | Shrub            | Villegas et al. (2000)                        |
| **Balsaminaceae**    | **Impatiens walleriana Hook. f.** | X      |        | January-June    | Naturalized  | Herbaceous       | Bonet y Vergara (2016)                        |
| **Berberidaceae**    | **Berberis trifolia Schult. & Schult. f.** | X      |        | January-March   | Native  | Herbaceous       | Villegas et al. (2000)                        |
| **Bignoniaceae**     | **Handroanthus chrysanthus (Jacq.) S. O. Grose** | X      |        | January-March   | Native  | Tree             | Villegas et al. (2000)                        |
|                      | **Tabebuia rosea (Bertol.) DC.** | X      |        | February-April  | Native  | Tree             | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
|                      | **Tecoma stans (L.) Juss. ex Kunth** | X      |        | All year        | Native  | Shrub            | Canto et al. (2017) Villegas et al. (2000)    |
| **Bixaceae**         | **Cochlospermum vitifolium (Willd.) Spreng.** | X      |        | December-May    | Native  | Tree             | Niembro-Rocas et al., (2010); Villegas et al. (2000) |
|                      | **Cordia alliodora (Ruiz & Pav.) Oken** | X      |        | August-April    | Native  | Tree             | Contreras-Oliva et al. (2018); Niembro-Rocas et al. (2010); Villegas et al. (2000) |
|                      | **Cordia dentata Poir.**        | X      |        | All year        | Native  | Tree             | Villegas et al. (2000)                        |
|                      | **Cordia megalantha S.F. Blake** | X      |        | February-May    | Native  | Tree             | Villegas et al. (2000)                        |
| Plant species       | Flowering                  | Pollen | Nectar | Status | Life-form | Reference                              |
|---------------------|---------------------------|--------|--------|--------|-----------|----------------------------------------|
| **Brassicaceae**     |                           |        |        |        |           |                                        |
| Brassica napus L.    | X                         |        | X      |        | Native    | Villegas et al. (2000)                 |
| Brassica nigra (L.)  | W.D.J. Koch               | X      | x      |        | Herbaceous| Contreras-Olea et al. (2018); Villegas et al. (2000) |
| Raphanus sativus L.  |                           | x      | x      |        | Herbaceous| Villegas et al. (2000)                 |
| **Burseraceae**      |                           |        |        |        |           |                                        |
| Bursera simaruba (L.)| Sarg.                     |        | X      | February-August | Native Tree | Contreras-Olea et al. (2018); Herrera-López et al. (2019); Villegas et al. (2000) |
| **Cactaceae**        |                           |        |        |        |           |                                        |
| Cilindropuntia imbricata (Haw.) F.M. Knuth | X | x | January-April | Native | Shrub | Villegas et al. (2000) |
| Opuntia stricta (Haw.) Haw. | X | x | February | Native | Shrub | Villegas et al. (2000) |
| **Convolvulaceae**   |                           |        |        |        |           |                                        |
| Ipomoea arborescens Humb. & B. Bonpl. | X | x | December-March | Native | Tree | Villegas et al. (2000) |
| Ipomoea carnea subsp. fistulosa (Mart. ex Choisy) | X | x | November-May | Native | Shrub | Villegas et al. (2000) |
| Ipomoea indica (Burm.) Merr. | X | x | All year | Native | Vine | Villegas et al. (2000) |
| Ipomoea triloba L. | X | x | October-February | Native | Herbaceous | Villegas et al. (2000) |
| Merremia dissecta (Jacq.) Hallier | X | x | April-November | Native | Vine | Villegas et al. (2000) |
| Sisyrinchium cernuum | X | x | All year | Native | Herbaceous | Villegas et al. (2000) |
| **Cannabaceae**      |                           |        |        |        |           |                                        |
| Trema micrantha (L.) Blume | X | x | December-April | Native | Tree | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
| **Chloranthaceae**   |                           |        |        |        |           |                                        |
| Hedyosmum mexicanum | C. Cordem. | X | x | Native | Shrub | Ramírez-Arhaga et al. (2018) |
| **Combretaceae**     |                           |        |        |        |           |                                        |
| Combretum farinosum Kunth | X | x | December-March | Native | Tree | Villegas et al. (2000) |
| Conocarpus erectus L. | X | x | All year | Native | Herbaceous | Villegas et al. (2000) |
| Laguncularia racemosa (L.) C.F. Gaertn. | X | x | February-May | Native | Tree | Villegas et al. (2000) |
| **Convolvulaceae**   |                           |        |        | April-June | Native | Villegas et al. (2000) |
| Ipomoea arborescens Humb. & B. Bonpl. | X | x | July-October | Native | Shrub | Villegas et al. (2000) |
| Ipomoea carnea subsp. fistulosa (Mart. ex Choisy) | X | x | November-May | Native | Herbaceous | Villegas et al. (2000) |
| Ipomoea indica (Burm.) Merr. | X | x | All year | Native | Vine | Villegas et al. (2000) |
| Ipomoea triloba L. | X | x | October-February | Native | Herbaceous | Villegas et al. (2000) |
| Merremia dissecta (Jacq.) Hallier | X | x | April-November | Native | Vine | Villegas et al. (2000) |
| **Crassulaceae**     |                           |        |        |        |           |                                        |
| Sedum praealtum A. DC. | X | x | All year | Native | Herbaceous | Villegas et al. (2000) |

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**References:**
- Contreras-Olea et al. (2018)
- Herrera-López et al. (2019)
- Villegas et al. (2000)
- Lopez-Ferrari et al. (2010)
- Niembro-Rocas et al. (2010)
- Canto et al. (2017)
- Canto et al. (2020)
- Canto et al. (2021)
- López-Ferrari et al. (2010)
| Plant species | Family | Pollen | Nectar | Flowering | Life-form | Status | Reference |
|---------------|--------|--------|--------|-----------|-----------|--------|-----------|
| Luffa aegyptiaca | Cucurbitaceae | X | X | All year | Vine | Exotic | Villegas et al. (2000) |
| Momordica charantia | Cucurbitaceae | X | X | All year | Vine | Exotic | Villegas et al. (2000) |
| Sicyos microphyllus | Cucurbitaceae | X | | September-December | Native Herbaceous | Native Tree | Villegas et al. (2000) |
| Cypripedium pubescens | Cypripedium | X | X | All year | Shrub | Exotic | Villegas et al. (2000) |
| Cytisus scoparius | Fabaceae | X | X | October-December | Native Herbaceous | Native Shrub | Villegas et al. (2000) |
| Delphinium elatum | Plumbaginaceae | X | X | June-July | Native Herbaceous | Native Shrub | Villegas et al. (2000) |
| Euphorbia schellefeldii | Euphorbiaceae | X | X | March-June | Native Tree | Exotic Tree | Villegas et al. (2000) |
| Ricinus communis | Euphorbiaceae | X | X | All year | Exotic Shrub | Exotic Shrub | Villegas et al. (2000) |
| Bauhinia divaricata | Fabaceae | X | X | All year | Native Shrub | Native Shrub | Villegas et al. (2000) |
| Caesalpinia cacalaco | Fabaceae | X | X | November-February | Native Tree | Native Tree | Villegas et al. (2000) |
| Cajanus cajan | Fabaceae | X | X | September-February | Exotic Shrub | Exotic Shrub | Villegas et al. (2000) |
| Cassia fistula | Fabaceae | X | X | February-April | Exotic Tree | Native Tree | Villegas et al. (2000) |
| Cassia grandis | Fabaceae | X | X | February-May | Native Tree | Native Shrub | Villegas et al. (2000) |
| Chamaecrista sp. | Fabaceae | X | X | | Exotic Shrub | Native Shrub | Villegas et al. (2000) |
| Delonix regia | Fabaceae | X | X | April-July | Exotic Tree | Native Shrub | Villegas et al. (2000) |
| Dalbergia brownii | Fabaceae | X | X | September-December | Native Herbaceous | Native Tree | Villegas et al. (2000) |
| Desmodium adscendens | Fabaceae | X | X | | Native Herbaceous | Native Shrub | Villegas et al. (2000) |
| Family     | Plant species                                      | Pollen | Nectar | Flowering          | Status   | Life-form     | Reference                                      |
|------------|----------------------------------------------------|--------|--------|--------------------|----------|--------------|-----------------------------------------------|
| Fabaceae   | Desmodium canescens (L.) DC.                      | X      |        | April-July         | Exotic   | Herbaceous   | Bonet y Vergara (2016)                         |
| Fabaceae   | Desmodium tortuosum (Sw.) DC.                     | X      |        |                    | Native   | Herbaceous   | Contreras-Oliva et al. (2018)                 |
| Fabaceae   | Enterolobium cyclocarpum (Jacq.) Griseb.          | X      | X      | March-May          | Native   | Tree         | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
| Fabaceae   | Eysenhardtia polystachya (Ortega Sarg.)           | X      | X      | September-October  | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Gliricidia sepium (Jacq.) Kunth ex Walp.          | X      | X      | December-April     | Native   | Tree         | Niembro-Rocas et al. 2010; Villegas et al. (2000) |
| Fabaceae   | Haematoxylum brasiletto H. Karst.                 | X      | X      | February-March     | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Haematoxylum campechianum L.                      | X      | X      | September-March    | Native   | Tree         | Gónzalez, (2014); Villegas et al. (2000)      |
| Fabaceae   | Inga inicuil Schltdl. & Cham. ex G. Don           | X      | X      | February-April     | Native   | Tree         | Niembro-Rocas et al. 2010; Villegas et al. (2000) |
| Fabaceae   | Inga vera Willd.                                   | X      | X      | April-May          | Native   | Tree         | Niembro-Rocas et al. 2010; Villegas et al. (2000) |
| Fabaceae   | Leucaena diversifolia (Schltld.) Benth.           | X      |        | August-December    | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Leucaena lanceolata S. Watson                     | X      |        |                    | Native   | Shrub        | Villegas et al. (2000)                        |
| Fabaceae   | Leucaena sp.                                      | X      |        |                    | Native   | Tree         | Ramírez-Arriaga et al. (2018)                |
| Fabaceae   | Lonchocarpus guatemalensis Benth.                 | X      |        | February-May       | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Lonchocarpus sp.                                  | X      |        |                    | Native   | Tree         | Ramírez-Arriaga et al. 2018                  |
| Fabaceae   | Lysoloma acapulcense (Kunth) Benth.               | X      | X      | March-May          | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Mimosa albida Humb. & Bonpl. ex Wild.             | X      |        | August-November    | Native   | Shrub        | Villegas et al. (2000)                        |
| Fabaceae   | Mimosa pigra L.                                   | X      |        | March-July         | Native   | Shrub        | Villegas et al. (2000)                        |
| Fabaceae   | Mimosa pudica L.                                  | X      |        | September-November | Native   | Herbaceous   | Bonet y Vergara (2016)                        |
| Fabaceae   | Mimosa scabrella Benth.                           | X      |        | December-January   | Exotic   | Shrub        | Villegas et al. (2000)                        |
| Fabaceae   | Piscidia piscipula (L.) Sarg.                     | X      | X      | May-July           | Native   | Tree         | Niembro-Rocas et al. 2010; Canto et al. (2017); Villegas et al. (2000) |
| Fabaceae   | Pithcellobium dulce (Roxb.) Benth.                | X      | X      | November-May       | Native   | Shrub        | Niembro-Rocas et al. 2010; Contreras-Oliva et al. (2018); Villegas et al. (2000) |
| Fabaceae   | Pithcellobium insigne Micheli ex Donn. Sm.        | X      | X      | January-March      | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Prosopis juliflora (Sw.) DC.                      | X      | X      | January-April      | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Trifolium repens L.                               | X      | X      | All year           | Naturalized | Herbaceous | Villegas et al. (2000)                        |
| Fabaceae   | Vachellia pringlei (Rose) Seigler & Ebinger       | X      | X      | February-May       | Native   | Tree         | Villegas et al. (2000)                        |
| Fabaceae   | Verbesina turbacensis Kunth.                      | X      | X      | November-January   | Native   | Shrub        | Villegas et al. (2000)                        |
| Fabaceae   | Vicia sativa L.                                   | X      |        | January-March      | Native   | Herbaceous   | Villegas et al. (2000)                        |
| Plant species | Family | Life-form | Status | Pollen | Nectar | Flowering |
|---------------|--------|-----------|--------|--------|--------|-----------|
| Fagaceae | Quercus spp. | Tree | Native | X | X | June |
| Hypoxidaceae | Hypoxidaceae | Herbaceous | Native | X | X | February-May |
| Juglandaceae | Juglans pyriformis Liebm. | Tree | Native | X | X | February-October |
| Loranthaceae | Ocimum sp. | Herbaceous | Native | X | X | June-October |
| Miconiaceae | Miconia sp. | Herbaceous | Native | X | X | February-October |
| Lauraceae | Girona nudaflora (Hems.) Koehne | Tree | Native | X | X | December-April |
| Lythraceae | Heliocarpus pallidus Rose | Tree | Native | X | X | January-June |
| Malvaceae | Malvaviscus arboreus Cav. | Shrub | Native | X | X | December-April |
| Melastomataceae | Pachira aquatica Aubl. | Shrub | Native | X | X | December-April |
| Meliaceae | Trichilia lucens Jacq. | Tree | Native | X | X | December-April |
| Metastemonaceae | Micronia sp. | Tree | Native | X | X | December-April |
| Plant species | Family | Pollen | Nectar | Flowering | Life-form | Status | Reference |
|---------------|--------|--------|--------|-----------|-----------|--------|-----------|
| Muntingia calabura L. | Muntingiaceae | X | X | X | All year | Native | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
| Callistemon citrinus (Curtis) Skeels | Myrtaceae | X | X | X | December-April | Exotic | Villegas et al. (2000) |
| Eucalyptus globulus Labill. | Myrtaceae | X | X | X | May-July | Native | Villegas et al. (2000) |
| Eugenia mexicana Steud. | Myrtaceae | X | X | X | May-August | Native | Villegas et al. (2000) |
| Syzygium jambos (L.) Alston | Myrtaceae | X | X | X | February-July | Naturalized Tree | Villegas et al. (2000) |
| Pisonia aculeata L. | Nyctaginaceae | X | X | X | January-April | Exotic Shrub | Villegas et al. (2000) |
| Ligustrum lucidum W. T. Aiton | Oleaceae | X | X | X | March-June | Exotic Tree | Villegas et al. (2000) |
| Lopezia hirsuta Jacq. | Onagraceae | X | X | X | November-January | Native Herbaceous | Villegas et al. (2000) |
| Brachyaria plantaginea Link & Otto | Poaceae | X | X | X | All year | Native | Villegas et al. (2000) |
| Antigonon leptopus Hook. & Arn | Polygonaceae | X | X | X | August-December | Native Vine | Villegas et al. (2000) |
| Coccoloba uvifera (L.) L. | Pontederiaceae | X | X | X | February-April | Native Shrub | Villegas et al. (2000) |
| Grevillea robusta A. Cunn. ex R. Br. | Proteaceae | X | X | X | March-April | Exotic Tree | Villegas et al. (2000) |
| Gouania lupuloides (L.) Urb. | Rhamnaceae | X | X | X | September-November | Native Shrub | Villegas et al. (2000) |
| Ziziphus sp. | Rutaceae | X | X | X | June | Native Shrub | Villegas et al. (2000) |
| Calycophyllum candidissimum (Vahl) DC. | Rutaceae | X | X | X | October-January | Native Tree | Villegas et al. (2000) |
| Ixora coccinea L. | Rutaceae | X | X | X | November-January | Exotic Shrub | Villegas et al. (2000) |
| Family          | Plant species           | Pollen | Nectar | Life-form | Status | Flowering | Reference                                      |
|----------------|-------------------------|--------|--------|-----------|--------|-----------|------------------------------------------------|
| Rubiaceae      | Murraya paniculata (L.) Jack | X      | X      | Native    | Native | April-June| Villegas et al. (2000)                          |
|                | Spermacoce confusa      | X      | X      | Native    | Native | September-December | Villegas et al. (2000)                         |
| Sapindaceae    | Sapindus sapconia L.     | X      | X      | Native    | Native | August    | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
|                | Coryphantha sp.         | X      | X      | Native    | Native | November-January | Villegas et al. (2000)                          |
|                | Talisia oviformis (Kunth) Radlk. | X      | X      | Native    | Native | February-May | Villegas et al. (2000)                          |
|                | Thouinia paucidentata K. Radlk. | X      | X      | Native    | Native | February-April | Villegas et al. (2000)                          |
| Sapotaceae     | Manilkara zapota (Spec.) P. Royen | X      | X      | Native    | Native | June-October | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
| Malvaceae      | Waltheria indica L.      | X      | X      | Native    | Native | January-March | Villegas et al. (2000)                          |
| Scrophulariaceae| Buddleja cordata Kunth  | X      | X      | Native    | Native | May-June | Niembro-Rocas et al. (2010); Villegas et al. (2000) |
| Solanaceae     | Solanum rostratum Dunal | X      | X      | Native    | Native | May-September | Villegas et al. (2000)                          |
|                | Solanum sp.             | X      | X      | Native    | Native | January-March | Villegas et al. (2000)                          |
|                | Waltheria indica L.      | X      | X      | Native    | Native | All year  | Villegas et al. (2000)                          |
|                | Cecropia obtusifolia Bent. | X      | X      | All year  | All year| All year  | Villegas et al. (2000)                          |
|                | Aloysia virgata (Ruiz & Pav) Pers. | X      | X      | All year  | All year| All year  | Villegas et al. (2000)                          |
| Urticaceae     | Tribulus cistoides L.    | X      | X      | Native    | Native | September-January | Villegas et al. (2000)                          |
|                | Tribulus terrestris L.   | X      | X      | Native    | Native | September-April | Villegas et al. (2000)                          |
| Verbenaceae    | Phyla nodiflora Mill. K. Kunt. ex Wunderlin & B.F. Hansen | X      | X      | Native    | Native | All year  | Villegas et al. (2000)                          |
|                | Tribulus cistoides L.    | X      | X      | Native    | Native | All year  | Villegas et al. (2000)                          |
| Zygophyllaceae | Tribulus terrestris L.   | X      | X      | Native    | Native | Naturalized | Villegas et al. (2000)                          |
### Appendix 2. Crops pollinated by bees in Mexico.

| Family          | Crop                                      | Common name | Pollen | Nectar | Flowering          | Status          | Reference                                      |
|-----------------|-------------------------------------------|-------------|--------|--------|--------------------|-----------------|------------------------------------------------|
| Anacardiaceae   | Mangifera indica L.                       | “mango”     | X      | X      | November-March     | Naturalized     | Meléndez et al. (2018); Villegas et al. (2000) |
|                 | Spondias mombin L.                        | “jobo”      | X      |        | March-May          | Native          | Villegas et al. (2000)                          |
|                 | Spondias purpurea L.                      | “ciruelo”   | X      | X      | December-March     | Native          | Villegas et al. (2000)                          |
| Areceae         | Cocos nucifera 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      | Helianthus annuus L.                      | “girasol”   | X      | X      | March-July         | Native          | Villegas et al. (2000)                          |
| Brassicaceae    | Brassica napus L.                         | “canola”    | X      | X      | September-December| Exotic          | Villegas et al. (2000)                          |
| Caricaceae      | Carica papaya L.                          | “papaya”    | X      | X      | All year           | Native          | Badillo-Montaño et al. (2019); Villegas et al. (2000) |
| Convolvulaceae  | Ipomoea batatas (L.) Lam.                 | “carmote”   | X      | X      | July-April         | Native          | Villegas et al. (2000)                          |
| Fabaceae        | Medicago sativa L.                        | “alfalfa”   | X      |        | All year           | Exotic          | Villegas et al. (2000)                          |
|                 | Phaseolus coccineus L.                    | “ayocote”   | X      |        | September-October  | Native          | Villegas et al. (2000)                          |
|                 | Tamarindus indica L.                      | “tamarindo” | X      |        | May-November       | Naturalized     | Villegas et al. (2000)                          |
| Lauraceae       | Persea americana Mill.                   | “aguacate”  | X      |        | February-May       | Native          | Meléndez et al. (2018); Villegas et al. (2000) |
| Malpighiaceae   | Byrsonima crassifolia (L.) Kunth          | “nanche”    | X      | X      | March-June         | Native          | Villegas et al. (2000)                          |
| Malvaceae       | Gossypium hirsutum L.                     | “algodón”   | X      | X      | August, February,  | Natural         | Canto et al. (2017)                              |
|                 |                                          |             |        |        | May               |                 |                                                 |
| Musaceae        | Musa paradisiaca L.                       | “plátano”   | X      | X      | All year           | Naturalized     | Villegas et al. (2000)                          |
| Myrtaceae       | Pedilium guajava L.                       | “guayaba”   | X      | X      | April-June         | Native          | Villegas et al. (2000)                          |
| Poaceae         | Zea mays L.                               | “maíz”      | X      | X      | February-March,    | Natural         | Villegas et al. (2000)                          |
|                 |                                           |             |        |        | July-August        |                 |                                                 |
| Proteaceae      | Macadamia integrifolia Maiden & Betche    | “macadarnia”| X      |        | January-March      | Exotic          | Villegas et al. (2000)                          |
| Family         | Crop               | Common name                  | Pollen | Nectar | Flowering         | Status  | Reference                        |
|----------------|--------------------|-------------------------------|--------|--------|-------------------|---------|-----------------------------------|
| Rosaceae       | Crataegus mexicana DC. | "tejocote" X                 |        | X      | March-May         | Native  | Villegas et al. (2000)            |
|                | Malus pumila Mill.  | "manzano" X                  |        | X      | December-February | Exotic  | Villegas et al. (2000)            |
|                | Prunus domestica L. | "ciruelo" X                  |        | X      | February-April    | Exotic  | Villegas et al. (2000)            |
|                | Prunus persica (L.) Batch | "durazno" X                |        | X      | February-March    | Exotic  | Villegas et al. (2000)            |
|                | Prunus communis L.  | "zarzaparrilla" X            |        | X      | January-March     | Exotic  | Villegas et al. (2000)            |
|                | Rubus idaeus L.    | "zorzal" X                    |        | X      | April-June        | Native  | Villegas et al. (2000)            |
|                | Ceratonia siliqua var. siliqua | "fuy" X                |        | X      | January-March     | Exotic  | Villegas et al. (2000)            |
|                | Citrus maxima (Burm.) Merr. | "toronja" X            |        | X      | December-February | Exotic  | Villegas et al. (2000)            |
|                | Citrus reticulata Blanco | "mandarina" X           |        | X      | June-February     | Exotic  | Villegas et al. (2000)            |
|                | Citrus × sinensis (L.) Osbeck | "naranja" X         |        | X      | January-March     | Exotic  | Villegas et al. (2000)            |
|                | Litchi chinensis Sonn. | "jabuticaba" X          |        | X      | "Chile"           | Native  | Villegas et al. (2000)            |
| Rutaceae       | citrus × aurantifolia (Christm.) Sinigaglia | "zapotillo blanco" X |        | X      | All year          | Native  | Villegas et al. (2000)            |
|                | Citrus × maxima (Burm.) Merr. | "limon agro" X      |        | X      | December-February | Exotic  | Villegas et al. (2000)            |
| Solanaceae     | Capsicum annuum L.  | "chile" X                    |        | X      | All year          | Native  | Villegas et al. (2000)            |
|                | Solanum lycopersicum L. | "batata" X               |        | X      | All year          | Native  | Villegas et al. (2000)            |