

Article

Not peer-reviewed version

Melipona beecheii (Apidae) Propolis Floral Origin from La Gloria Cosautlán de Carvajal, Veracruz, Mexico

[María del Rocío Azcárraga Rossete](#)*, [Karla Samanta Hernández Méndez](#), Betsabé Rodríguez Pérez,
Julieta Grajales Conesa, Tonatiuh Cruz Sánchez

Posted Date: 19 January 2026

doi: 10.20944/preprints202601.1321.v1

Keywords: pollen analysis; botanical origin; Mexican propolis



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a [Creative Commons CC BY 4.0 license](#), which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Melipona beecheii (Apidae) Propolis Floral Origin from La Gloria Cosautlán de Carvajal, Veracruz, Mexico

María del Rocío Azcárraga Rosette ^{1,*}, Karla Samanta Hernández Méndez ¹,
Betsabé Rodríguez Pérez ², Julieta Grajales Conesa ³ and Tonatiuh Cruz Sánchez ²

¹ Laboratorio de Botánica. Facultad de Estudios Superiores Cuautitlán, Campo 4, Universidad Nacional Autónoma de México, Km 2,5 Carretera Cuautitlán-Teoloyucan, San Sebastián Xhala, Cuautitlán Izcalli 54714, Estado de México, México

² Laboratorio de Servicio de Análisis de Propóleos (LASAP®). Facultad de Estudios Superiores Cuautitlán, Campo 4, Universidad Nacional Autónoma de México, Km 2,5 Carretera Cuautitlán-Teoloyucan, San Sebastián Xhala, Cuautitlán Izcalli 54714, Estado de México, México

³ Sci Tech lab UNACH, Escuela de Sistemas Alimentarios, Universidad Autónoma de Chiapas. Blvd. Dr. Manuel Velasco Suárez esq. Blvd. Akishino, INFONAVIT Solidaridad 2000, 30798 Tapachula de Córdova y Ordóñez, Chis

* Correspondence: azcarose@unam.mx; Tel.: +52-5556231999 (ext. 39416)

Abstract

This study aimed to identify and characterize the *Melipona beecheii* propolis botanical origin from La Gloria, Cosautlán de Carvajal, Veracruz, Mexico. We compiled a floristic inventory of 75 foraging species, and their pollen and propolis from nests. The pollen was processed by acetolysis, and each species was analyzed by using optical microscopy resulting in diagnostic micrographs. We counted 1500 pollen grains from the processed propolis, where we identified 25 pollen types; *Mimosa albida*, *Miconia xalapensis*, *Sambucus nigra*, *Coffea arabica*, *Struthantus* aff. *quercicola*, *Trichilia havanensis*, and *Pimenta dioica*, among others. Based on our results we observed that *M. beecheii* preferred *M. albida* for propolis elaboration, even though also used other trees and shrubs with numerous inflorescences, small flowers, and pollen between 9 and 35 µm, which contain phytochemicals with significant biological activity. Finally, it is important to mention that *M. beecheii* is an excellent pollinator that contributes to the regeneration and conservation of biodiversity; its knowledge and management could be incorporated into meliponicultural practices as an ecosystem service that will help to human population conservation in its origin place.

Keywords: pollen analysis; botanical origin; Mexican propolis

1. Introduction

Around the world there are various bee species belonging to the family Apidae [1], which are essential for the continued functioning of life on the planet [2], because of the pollination process, an activity that is part of the physiological development of vegetation [3], and it is estimated that 70% of plants require this process to survive [4–6].

In the tropical and subtropical regions of Africa, the Americas, and Australia, stingless bees are the most abundant and active pollinators [7] where a greater diversity is located in the Americas, with more than 400 described species. Actually, stingless bees nest products are culturally important in this continent, where pot honey, pollen and propolis are used in medicine, ancestral ceremonies [8], and social, economic, and religious activities [9–11]. There are 46 bee species described in Mexico, six are grouped into 16 genera, that are found in Oaxaca, Chiapas, Veracruz, Yucatan, and other states [12,13].

Melipona beecheii Bennett, Xunan Kab, also known as the honey lady, the earth bee is a species that is part of the cosmogony, mythology, and spiritual significance for the Mayan from the Yucatan peninsula and northern Guatemala [14]. This species is also valuable for their pot honey, which is associated with fertility and breast milk production increase [15–17], for heat-cold imbalances [18] and current studies indicated health benefits related to nutritional properties [19]. *Melipona beecheii* is found in a wide distribution in tropical areas of Mexico to Costa Rica [20,21], is also an important pollinator [2,22], and one of the higher stingless bee pot honey producers [11], and also for its wax, pollen and propolis [23].

Propolis is a resinous, balsamic material collected, that is processed by bees and is essential for the nest, its production involves collecting resins from tree bark and flower buds, which are mixed with enzymes added by the bees. Other materials found in propolis include balsams, waxes, essential oils, pollen, spores, algae, plant trichomes, silica, clay, and starch [24,25]. In the nest, propolis is used to seal cracks, protect it from moisture, and combat pathogens due to its antimicrobial and antioxidant properties [26–28].

In humans, propolis is being used since ancient times; the Egyptians used it to preserve certain foods and to embalm bodies [29], Trigona and Melipona propolis I is being used by native people from the southeastern Mexico, as a wound healer and for skin infections, ears, respiratory tract, and intestines, as well as gum inflammation. Its use as a wood preservative, pest repellent, and in human and veterinary medicine [3,27,30–33], Recent studies registered its antiviral, astringent, anti-inflammatory, analgesic, antioxidant, antitumor, immunoregulatory, and hepatoprotective properties; its biological activities are attributed to its diverse phytochemical compounds derived from the plant species from which it is obtained [34–37].

Chemical composition analysis revealed the relationship between its biological activity and the plant species involved [38]. e.g.; β -amirenone, a triterpene obtained from oleoresins of *Bursera* sp. and rosemary (*Rosmarinus officinalis*), has a positive effect on the treatment of skin conditions, hypertension, inflammatory, tumorous, and microbial reactions[39]. In the case of *M. beecheii*, a variety of pentacyclic triterpenes have been detected worldwide [40,41]. Considering that approximately 70% of propolis components are of plant origin, there is a need to identify the plant species of pollen grains involved in propolis, in order to determine the relationship between its phytochemical compounds and the flora [42–46]. Thus, the objective of this study was to determine and characterize the main botanical species that contribute to propolis from the native bee *M. beecheii*, in the community of La Gloria, municipality of Cosautlán de Carvajal, Veracruz, Mexico.

2. Materials and Methods

2.1. Study Area

The community of La Gloria belongs to the municipality of Cosautlán de Carvajal, Veracruz, Mexico, located in the central region, 32 km from Xalapa. It is situated at 19° 20' 56.0"N and -97° 00' 16.0"W, at an altitude of 1176 m above sea level. It has a temperate-humid climate (Cf) [47], with year-round rainfall, an average annual precipitation of 2001-3000 mm, and an average annual temperature of 18° to 22° C (Figure 1). The community is located in an area with tropical sub-deciduous forest and cloud forest vegetation, with seasonal agricultural activity [48]. These types of vegetation exist in Veracruz in discontinuous patches as a transition zone. They are generally dominated by deciduous trees and various woody climbing species, and members of the Bignoniaceae, Fabaceae, and Lorantheae families can be observed [49]. Due to their proximity to these vegetation types, native bee nests can still be found in their natural habitat, and efforts are underway to conserve these species and the flora on which they depend [50].



Figure 1. Location of the community of La Gloria, Cosautlán de Carvajal, Veracruz, Mexico. Map modified from the Government of the State of Veracruz 2019.

2.2. Data Collection

At the invitation of the research project “Evaluation of the antimicrobial potential of propolis from stingless bees of Mexico” (PAPIIT) IN223719, of the Faculty of Higher Studies Cuautitlan, UNAM and, the relationship of the community of La Gloria, Cosautlán, with INANA A. C. “Initiatives for nature”, explorations begin in the region and, the stay from August 27 to 29, 2019, developing field activities in the community, through participant observation [51,52] and construction of dialogue of knowledge [53], with application of open questionnaires on regional meliponiculture and, carrying out a 500 m route for each cardinal point, around the meliponary of the community, base of collection [54] of 75 botanical species and taking samples of their palynomorphs of plants referred by meliponiculturists as foraged by *M. beecheii*; The connotations of abundant, moderate, scarce, and rare were assigned to each species based on observation [55,56]. Propolis was collected according to the Mexican Official Standard NOM-003-SAG/GAN-2017 [57], obtaining representative samples of the stored propolis throughout 2019; 85 g per nest “A” and “B”, preserved in amber glass jars. The floristic inventory was obtained by the botanical identification of the 75 collected species, based on specialized literature [49,58–61] validating the identification in “Plants of the World Online” (POWO) [62] and “The International Plant Name Index” (IPNI) [63], incorporating the botanical material into the Herbarium of the Faculty of Higher Studies Cuautitlan, Campus 4 of the UNAM.

The palynomorphs of the inventoried species were processed by using acetolysis, staining, and preparation of histological slides [64–67], representing each species and forming the initial part of a palynomorph collection at the Faculty of Higher Studies Cuautitlan, UNAM. Using a Carl Zeiss Axiostar Plus optical microscope with an integrated AxioCam ICc 3 camera and the ZEISS ZEN 3.5 software (Blue version). Each palynomorph of the inventoried species was described based on ornamentation type, shape, degree of association, apertures, and equatorial and polar position measurements [68–72], obtaining diagnostic micrographs.

The propolis underwent dilution, water bath, filtration, centrifugation, and decantation processes with xylene, 96% absolute ethyl alcohol, and 70% absolute ethyl alcohol [73]. The palynomorphs present were separated and subjected to acetolysis, staining, and preparation of histological slides [64–67,73]. This material revealed the species represented by their pollen.

From the histological slides of palynomorphs present in the propolis, 1500 pollen grains were counted, and the frequencies of the different palynomorphs were quantified. The botanical species constituting the propolis were determined based on pollen grain characteristics such as ornamentation, shape, size, degree of association, and apertures, in comparison with the same properties of palynomorphs from foraged flora, as well as with bibliographic support [74–79].

Pollen grain sizes, life forms, morphological characteristics, flowering periods, and bibliographic information of the species present in the propolis were analyzed to describe the tendency of *M. beecheii* in its formation [80,81].

3. Results

3.1. Foraging Flora Determination

The seventy-five (75) species collected and reported as foraged by native bees were identified and incorporated into the Herbarium of the Faculty of Higher Studies Cuautitlan (FESC). Histological slides of their pollen grains were also added to the Palinotheque of the FES Cuautitlan Botany Laboratory as a reference collection. The 75 species belong to 39 botanical families. Eight families are considered representative of the surrounding vegetation, as their species are abundant or frequent, with three or more species each: Asteraceae with seven species, Euphorbiaceae with three, Fabaceae with six, Fagaceae with three, Lamiaceae with six, Malvaceae with three, and Rubiaceae and Rutaceae with five each, totaling 38 species, which represents 50.6% of the sampled species. The Asteraceae family is primarily composed of weedy species such as *Aldama dentata* La Llave, *Bidens pilosa* L., and *Melampodium perfoliatum* (Cav.) Kunth, widely distributed in open areas. These plants flower for more than six months of the year and are excellent pollen producers, as their inflorescences contain numerous flowers. Fabaceae, with species like *Inga vera* Kunth, *I. jinicuil* Schltdl., and *Mimosa albida* Humb. & Bonpl. ex Willd., are abundant in the region. The first two provide shade for coffee plantations, while the third is a secondary vegetation species found along roadsides and hillsides. Lamiaceae is represented by species cultivated in family gardens, such as *Agastache mexicana* (Kunth) Lint & Eplin., *Ocimum basilicum* L., and *Salvia leucantha* Cav., which are used in traditional medicine for their essential oil production and their ability to attract bees. Rubiaceae, with *Coffea arabica* L., the main crop in the region, and others such as *Crusea calocephala* DC., *Hamelia patens* Jacq., and *Palicourea padifolia* (Roem. & Schult.) T.N. Taylor & Lorence, which form an important part of the understory. Rutaceae with species cultivated as fruit trees, such as *Citrus aurantiifolia* (Christm.) Swingle, *C. × sinensis* (L) Osbeck, and *C. limetta* Risso. The families Euphorbiaceae, Fagaceae, and Malvaceae, with three species each, form an important part of the tree and shrub layer of the vegetation.

Although some families have only one or two species, they are often visited by numerous bees, as is the case with *Psittacanthus calyculatus* (DC) G. Don and *Struthanthus* sp., Loranthaceae; *Trema micrantha** (L.) Blume, Cannabaceae; and *Cecropia obtusifolia* Bertol., Urticaceae, just for mentioning a few, which are considered as foraged plants. Many of the above species are propagated in the “El Chinini” nursery, which belongs to the Demanos family in the community, who propagate around 110 species [82] as a resource of *Melipona* bees and wildlife, an activity that complements the rescue of native bee nests, from trees felled by logging and deforestation, or others that are at risk in the region surrounding the community, becoming part of the INANA meliponary network, the nursery is considered as a refuge space for six species of stingless bees such as *Plebeia* spp., *Scaptotrigona* spp., *Trigona* spp., among others.

3.2. Propolis Floral Origin

From propolis of *M. beecheii* in the community of La Gloria Cosautlán we identified 25 species of palynomorphs with different percentage of participation (Table 1).

Table 1. Total number of palynomorph species and their percentage in *Melipona beecheii* Bennett propolis from the community of La Gloria, Cosautlán, Veracruz.

Botanical family	Scientific name	Popular name in Mexico	Percentage (%)	Way of life
ALTINGIACEAE	<i>Liquidambar styraciflua</i> L.	Liquidámbar	0.30 %	Tree
ADOXACEAE	<i>Sambucus nigra</i> L.	Sauco	3.20 %	Tree
CANNABACEAE	<i>Trema micrantha</i> (L.) Blume	No reports	1.30 %	Tree
CARICACEAE	<i>Carica papaya</i> L.	Papaya	0.30 %	Herbaceous
CLETHRACEAE	<i>Clethra mexicana</i> DC.	Marangola	0.40 %	Tree
CUPRESSACEAE	<i>Hesperocyparis lusitanica</i> (Mill.) Bartel	Pino	0.70 %	Tree
EUPHORBIACEAE	<i>Ricinus communis</i> L.	Higuerilla	1.20 %	Bush
FABACEAE	<i>Diphysa americana</i> (Mill.) M. Sousa	Quibracho	0.30 %	Tree
	<i>Mimosa albida</i> Humb. & Bonpl. ex Willd.	Dormilona grande	60.20 %	Bush
HYPERICACEAE	<i>Vismia baccifera</i> (L.) Triana & Planch.	Chotillo	0.30 %	Tree
LAMIACEAE	<i>Salvia serotina</i> L.	No reports	0.50 %	Herbaceous
LAURACEAE	<i>Persea schiedeana</i> Nees	Chinine	0.30 %	Tree
LORANTHACEAE	<i>Struthanthus</i> aff. <i>quercicola</i>	Correhuela	2.40 %	Hemiparasite
MELASTOMATACEAE	<i>Miconia xalapensis</i> (Bonpl.) D. Don ex DC.	Tezhuate	15.60 %	Bush
MALVACEAE	<i>Heliocarpus appendiculatus</i> Turcz	Jonote blanco	1.90 %	Tree
MELIACEAE	<i>Cedrela odorata</i> L.	Cedro rojo	1.20 %	Tree
	<i>Trichilia havanensis</i> Jacq.	Rama tinaja	2.30 %	Bush
PRIMULACEAE	<i>Ardisia compressa</i> Kunth	Capulín de mayo	0.20 %	Bush
MYRTACEAE	<i>Psidium guajava</i> L.	Guayaba	0.30 %	Tree
	<i>Pimenta dioica</i> (L.) Merr.	Pimienta	2.00 %	Tree
PINACEAE	<i>Pinus</i> spp.	Pino	0.20 %	Tree
POACEAE	<i>Zea mays</i> L.	Maíz	0.50 %	Herbaceous
RUBIACEAE	<i>Coffea arabica</i> L.	Café Costa Rica	2.60 %	Bush
	<i>Hamelia patens</i> Jacq.	Pasmillo	1.70 %	Bush
RUTACEAE	<i>Citrus</i> spp.	Cítricos	0.10 %	Tree

3.3. Palynomorphs Role

In order to evaluate the potential of the plant resource, only palynomorphs that contribute 2.0% or more to the propolis composition were considered. Seven species meet this percentage, two of

which are considered significant: *Miconia xalapensis* (Bonpl.) D. Don ex DC. (Melastomataceae) and *Mimosa albida* Humb. & Bonpl. ex Willd (Fabaceae), which contribute 75.8% of the pollen in the propolis composition. According to [83], the propolis in this study is a monofloral resource of *M. albida* (Figure 2), as the dominant species, ruling out the possibility of classifying this resource as multifloral; *M. xalapensis* is the secondary pollen; minor pollen includes *Sambucus nigra* L., *Coffea arabica* L., *Struthanthus* aff. *quercicola*, *Trichilia havanensis* Jacq., and *Pimenta dioica* (L.) Merr.; the remaining 18 species as pollen present, due to their low percentages of participation [84–87].

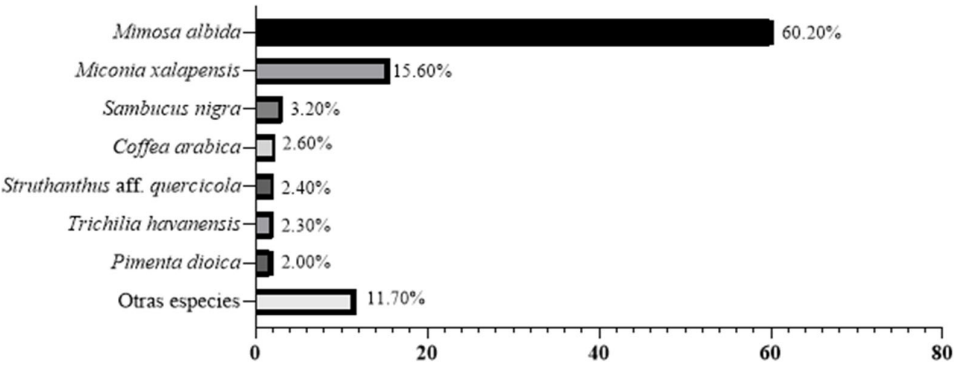


Figure 2. Main species percentage of palynomorph in the propolis of analyzed in *Melipona beecheii* Bennett from La Gloria, Cosautlán, Veracruz.

3.4. Palynomorphs Size

Melipona beecheii preferentially visits plant species whose pollen grains range from 9 to 18 μm , *M. albida*, with the most abundant pollen grain, is the smallest, followed by *M. xalapensis*; other less abundant species include *S. nigra*, *C. arabica*, *S. aff. quercicola*, *T. havanensis*, and *P. dioica*, whose size varies between 15 and 35 μm (Figure 3). Therefore, for propolis production, *M. beecheii* opts for small or slightly medium-sized pollen grains [65].

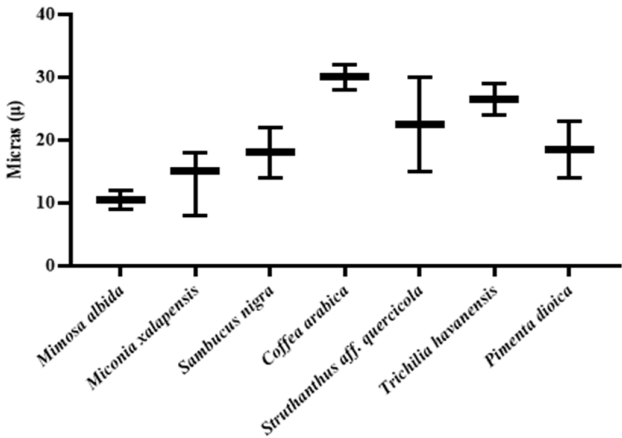


Figure 3. Palynomorphs size of representative species in *Melipona beecheii* Bennett propolis from the community of La Gloria, Cosautlán, Veracruz.

3.5. Palynomorphs from the Main Propolis Species

Palynomorph species with more than 2.0% representation in the propolis of *M. beecheii*, in La Gloria, Cosautlán, Veracruz (Figure 4 and 4A).

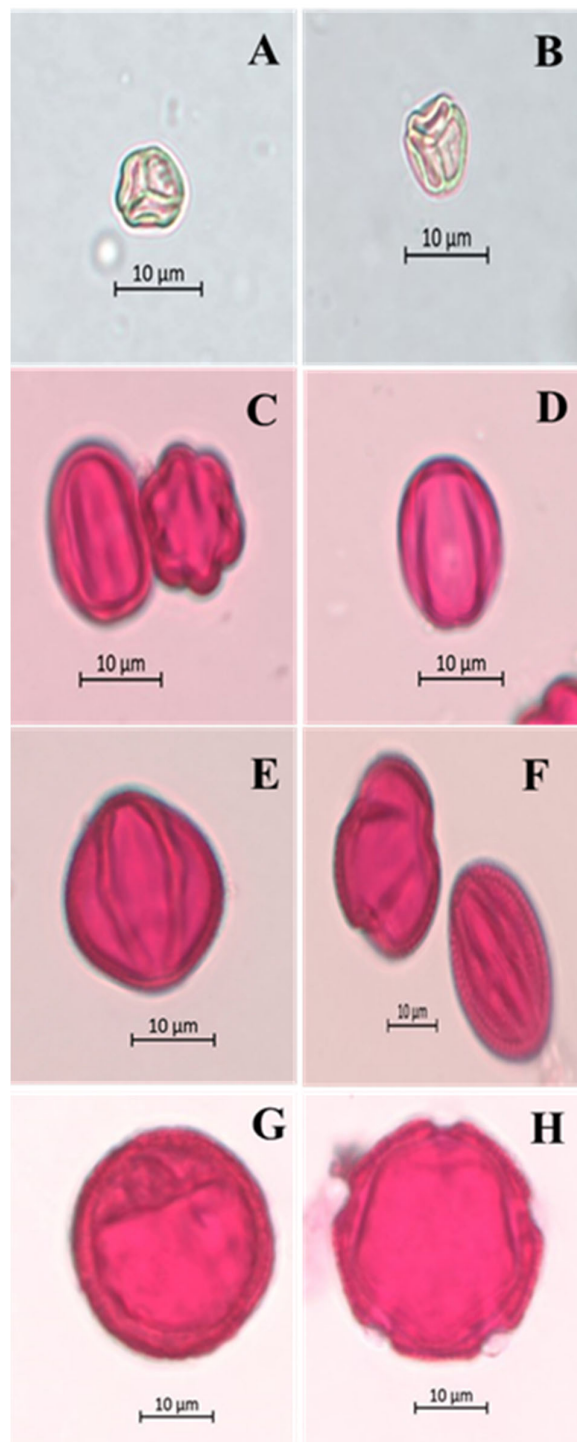


Figure 4. Micrographs in optical microscope X 1000, of pollen extracted from *Melipona beecheii* Bennet propolis from the community of La Gloria, Cosautlán, Veracruz. Fabaceae: A-B. *Mimosa albida* Humb. & Bonpl. ex Willd; Melastomataceae: C-D. *Miconia xalapensis* (Bonpl.) D. Don ex DC.; Adoxaceae: E-F. *Sambucus nigra* L.; Rubiaceae: G-H. *Coffea arabica* L. Photography: María del Rocío Azcárraga Rosette.

Mimosa albida (Figures 4A and 4B). "Spherical tetrads 9–11 μm in diameter. Asymmetric, apolar, inaberturate grains. Exine: $< 0.5 \mu\text{m}$ " [88].

Miconia xalapensis (Figures 4C and 4D). D. Oval, heterocolpate pollen, with three colpoes and three subsidiary colpi. Transverse colp reduced to a circular to slightly elongated endopore 1.0–1.5 μm , with ribs. Exine: tectate, psilate, 1.0 μm thick with a slight thickening towards the equator and apertures. Monad isopolar, radiosymmetric. Prolate; CP: interhexagonal, CE: elliptic. P: 18.8 (18.2–20.0) μm , E: 13.1 (12.8–15.0) μm [89].

Sambucus nigra (Figures 4E and 4F). "Spherical, tricolporate pollen with radial symmetry, isopolar, reticulate exine, grain size 14 to 22 μm " [90]. DP (polar diameter 18–21 μm), DE (equatorial diameter 22–24 μm).

Coffea arabica (Figures 4G and 4H). Polymorphic, radiosymmetric grains, isopolar or heteropolar, tricolporate, stephanocolporate (four colpi) or pericolporate, sometimes syncolpate, oblate-spheroidal to prolate-spheroidal, circular or quadrangular in shape; DE (equatorial diameter) 32–40 μm , DP (polar diameter): 30–38 μm . Exine: 2 μm , granular, perforated, foveolate, fossulate, areolate or reticulate; pores elongated, irregular or circular, sometimes annulate (2–8 $\times$ 3–11 μm). Colpi with irregular margins and of variable length, 3–7 μm wide; sometimes latitudinal colpi occur in the polar or equatorial area [88].

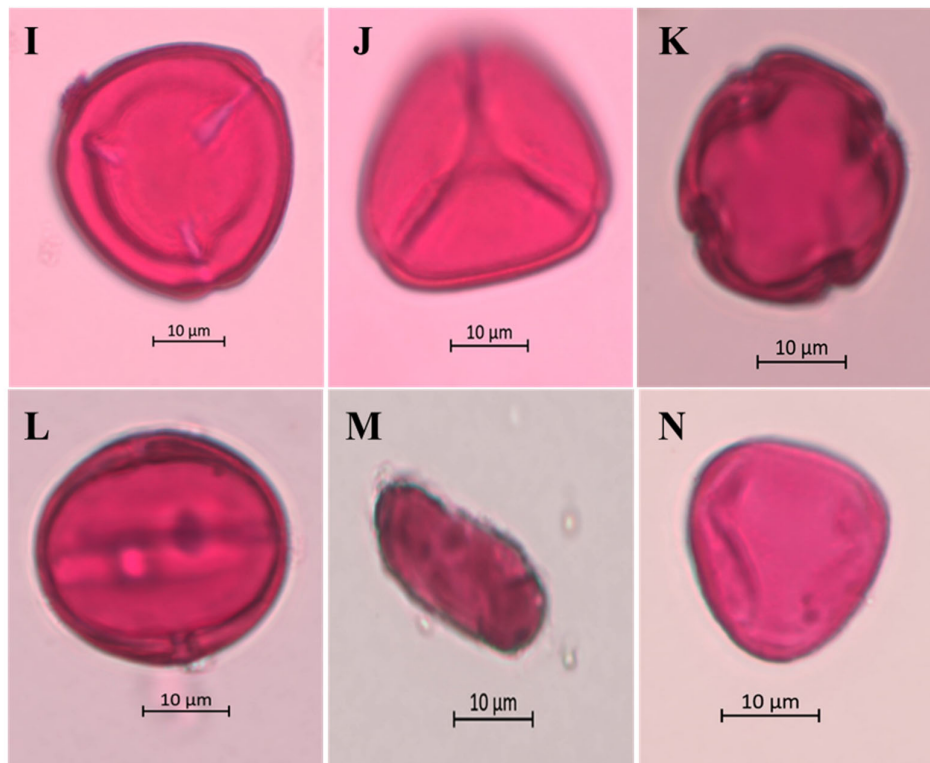


Figure 4A. Micrographs in optical microscope X 1000, of pollen extracted from *Melipona beecheii* Bennet propolis analyzed in the community of La Gloria, Cosautlán, Veracruz. Loranthaceae: I–J. *Struthanthus* aff. *quercicola*; Meliaceae: K–L. *Trichilia havanensis* Jacq.; Myrtaceae: M–N. *Pimenta dioica* (L.) Merr. Photography: María del Rocío Azcárraga Rosette.

Struthanthus aff. *quercicola* (Figures 4I and 4J). Pollen 15–30 μm , oblate, isopolar diplosyndecolporate, with well-developed endoapertures [91]. DP (30–33 μm), DE (39–40 μm).

Trichilia havanensis Jacq. (Figures 4K and 4L). Aperture: tetracolporate or pentacolporate. Long meridional colpus 27 $\times$ 2 μm . Colpus membrane smooth, transverse colpus elliptic-circular 3–4 $\times$ 5–7 μm . Median polar area (0.27). Exine: tectate, psilate with a microreticulate pattern, exine 2 μm thick.

Monad isopolar; radiosymmetric. Shape: prolate spheroidal; CP circular; DE elliptic-circular. Size: 34.7 μm (30-40 μm) E (32.5 7 μm) [92].

***Pimenta dioica* (L.) Merr.** (Figures 4M and 4N). Pollen: Oblate, 11(14.5)17 μm $\times$ 20(21.6)23 μm . P/E 0.67. Triangular view, 19(20.5)22 μm in diameter. Exine: 1.5 μm thick, sexine equal to nexine. Tectate, psilate, with a microreticulate pattern. Apertures: Tricolporate, syncolpate, heteropolar: Colpi 5(9.2)14 μm long $\times$ 1(1.6)3 μm wide, with psilate membranes. The endoaperture is elongated, measuring 3(4)7 μm long $\times$ 1(1.4)2.5 μm wide. On the face opposite the syncolpia, the distance between the colpi is 2(3.2)5 μm . The pollen availability index (PAI) is 0.15, small [74].

3.6. Resource Availability

The pollen resources used by *M. beecheii* to produce its propolis are collected according to their availability throughout the year. Two species are available in bloom for the longest period: *M. albida* and *S. aff. quercicola*, being the first one the most abundant pollen resource. *M. xalapensis*, the second most important component, is available for only two months of the year; however, the bee has access to other species that alternate their flowering periods, covering the entire year (Table 2).

Table 2. Pollen resources available annually for *Melipona beecheii* Bennet propolis elaboration from the community of La Gloria, Cosautlán, Veracruz.

	Ene	Feb	Mzo	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic
<i>Mimosa albida</i>												
<i>Miconia xalapensis</i>												
<i>Sambucus nigra</i>												
<i>Coffea arabica</i>												
<i>Struthantus aff. quercicola</i>												
<i>Trichilia havanensis</i>												
<i>Pimenta dioica</i>												

3.7. Characteristics of Mostly Foraged Species

The most intensively foraged resources correspond to the shrub layer (75.8%). The species that support *M. beecheii* have numerous inflorescences with inconspicuous or small flowers, generally less than 15 mm long, with small to medium-sized pollen. *M. albida* is distributed on slopes and roadsides, *M. xalapensis* and *T. havanensis* in open spaces and along roadsides, *S. aff. quercicola* is a hemiparasite present on different species; all belong to secondary vegetation and are common in the area. *S. nigra*, an introduced species, is scarce; one tree was found in the surveyed area. *P. dioica*, a species of primary vegetation, is common; its distribution is favored by its fruit, which is harvested and sold *C. arabica*, widely distributed, is the main crop of economic importance in the region.

The genus *Mimosa* plays an important role in ethnomedicine due to its nutritional, pharmaceutical, and toxic properties [93]. *M. albida*, enriches and protects the soil where it grows, and contains phytochemical constituents such as triterpenes, steroids, flavonoids, lactones, alkaloids, anthocyanins, naphthoquinones, tannins, phenols, catechins, saponins, reducing sugars, fats, and amino acids [94], making it a widely used species in traditional medicine for cardiovascular, gastrointestinal, renal, and inflammatory problems, as well as in cases of diabetes, cancer, and anxiety. It possesses antioxidant and antibiotic properties and has been reported to have non-fatal toxicity [93,95].

Miconia xalapensis offers significant advantages in the area where it grows, contributing to regeneration, protecting the soil, promoting the germination rate of other species, and fostering

increased diversity. This is due to the production of abundant fruits, which are consumed by birds that disperse the seeds with high germination rates. The establishment of the species reduces habitat fragmentation and contributes to the arrival of new species of both primary and secondary vegetation, which is crucial for passive restoration [96,97]. Its analgesic, anti-inflammatory, antimicrobial, antiparasitic, antitumor, antimutagenic, and antioxidant activity has been evaluated, due to the presence of triterpenes, coumarins, benzoquinones, hydrolyzable tannins, phenolic acids, polyphenols, anthocyanin-type flavonoids and flavone glycosides, as well as cyanogenic glycosides in smaller proportions [98–101].

Sambucus nigra, a species introduced to Mexico, is cultivated in Europe, Canada, Chile, Germany, and New Zealand for its flowers and fruits, which are rich in nutrients, vitamins, and essential oils. These are used in the nutraceutical food industry[102] and in pharmaceuticals for their bioactive properties due to the presence of polyphenols, flavonols, and phenolic acids such as quercetin, kaempferol, and isorhamnetin, along with proanthocyanidins, anthocyanins, terpenes, lecithins, and potentially toxic cyanogenic glycosides. These compounds are present in the young fruits and degrade into cyanidin upon ripening. The species is used in folk medicine for a variety of ailments due to its antioxidant, antimicrobial, antitumor, hepatoprotective, neuroprotective, cardioprotective, and immunostimulatory properties, among others. In Europe, it is an important medicinal species [98,103–105].

Coffea arabica, a species widely cultivated worldwide for its beverage used in food, is recognized for its important use in traditional medicine due to its psychoactive, neurological, antibacterial, antioxidant, anticancer, antiglycemic, anti-arteriosclerosis, anti-inflammatory, and genotoxicity-reducing activity, as well as its ability to control numerous ailments due to its bioactive components derived from phenols and terpenes in its essential oil, with the presence of palmitic, oleic, linoleic, and stearic acids; throughout the plant it presents polyphenols such as chlorogenic acid, diterpenes such as cafestol and kahweol, alkaloids such as caffeine and theobromine, tannins, flavonoids such as quercetin, anthocyanins, isoquercetin, kaempferol, and rutin, terpenoids, cafesterol, amino acids, and histidine [106–109].

Struthanthus quercicola Schltdl. & Cham.) G. Don, a hemiparasitic species with medicinal uses for various ailments, is recognized for its immunoregulatory, antibacterial, antiviral, antioxidant, antineoplastic, and hypoglycemic activity. It does not cause hepatotoxicity and inhibits cell proliferation. It contains numerous bioactive components such as terpenoids, alkaloids, flavonoids, saponins, and tannins; the proportion of these components varies depending on the species it parasitizes [110,111].

Trichilia havenensis, is a food source for birds, which promotes its distribution. It contributes to soil and water conservation and is used as a living barrier on slopes, roads, riparian corridors, and for the restoration of degraded areas. Its wood is used in carpentry, packing crates, and sculpture carving [112]. The bark has potential as an organic pesticide, acting as a molluscicide and insecticide against larvae and insects, due to the presence of limonides, monoterpenes, sesquiterpenes, triterpenes, diterpenes, steroids, coumarins, flavonoids, glycosylates, and lignans, contributing to antibacterial and anticarcinogenic activity [2,113].

Pimenta dioica, a species of economic importance for the production of allspice, is a spice used in food. Its essential oil, the source of its aroma and flavor, exhibits antioxidant and antimicrobial activity against fungi and bacteria, attributed to its high phenol content [29,114,115].

4. Discussion

According to the results, *M. beecheii*, when producing its propolis, does not forage for species present solely based on their frequency or flowering periods, since species from the Asteraceae, Fabaceae, or Lamiaceae families, common in the region with abundant flowering over a prolonged period, do not have significant or representative percentages of their pollen present in the propolis.

Melipona beecheii in La Gloria, Cosautlán, Veracruz, is selective for trees and shrubs of the regional flora with inconspicuous or small flowers, numerous inflorescences, and small pollen, such

as *M. albida*, whose dominant percentage of pollen in its propolis classifies it as monofloral [83], a result similar to [116] for a honey study in Teocelo, a municipality near La Gloria. The phytochemical components present in species with a 2% or higher concentration in propolis are associated with biological activities such as antibacterial, antiviral, antifungal, antioxidant, anti-inflammatory, and immunoregulatory properties, among others [117,118]. The chemical composition and properties of *M. beecheii* propolis in the La Gloria community are influenced by the interdependence and coevolution through mutualism between species [119]. *Melipona beecheii* is an effective pollinator; the presence of at least 25 palynomorph species in its propolis indicates its involvement in the pollination of both wild and cultivated plants. This contributes to the natural regeneration of vegetation, benefiting biodiversity conservation and serving as an indicator of the ecosystem's conservation status [2,113].

The knowledge and management of their populations by the meliponiculturists in La Gloria Cosautlán, Veracruz, incorporated into their culture as an ecosystem service, contributes to the conservation of the human population in their place of origin [17,120] and provides valuable information to science for the management of resources for the benefit of humanity [29,114,115].

5. Conclusions

Melipona beecheii selects *Mimosa albida* from the diverse flora, the dominant pollen species in its propolis, resulting in a monofloral propolis. It is also a good pollinator, foraging on twenty-four other species and thus contributing to the regeneration and conservation of the region's biodiversity. The most frequently visited species exhibit biological activity due to their phytochemical components, which will be significantly reflected in the activity of its propolis. The knowledge and management of its populations, incorporated into the meliponiculture practices as an ecosystem service, contributes to the conservation of the human population in its place of origin. The collected botanical specimens increased the Herbarium's collection; the histological slides and the Palinotheque of the Botany Laboratory, both collections of the Faculty of Higher Studies Cuautitlán, UNAM.

Author Contributions: M.R.A.R and K.S.H.M: collection and analysis of pollen samples in the meliponaries; B.R.P.: analysis of propolis samples; B.R.P., J.G.C. and T.A.C.S.: revision of manuscript; M.R.A.R and T.A.C.S.: funding acquisition. All authors have read and agreed to the published version of the manuscript.

Funding: This research was supported by the Botany Laboratory of the Faculty of Higher Studies Cuautitlán, National Autonomous University of Mexico, which provided facilities, resources, and supplies for its execution, as well as the researchers' own resources. The National Autonomous University of Mexico's Program for Support of Research and Technological Innovation Projects (PAPIIT), Project IN223719, awarded Grant 285319 and supplies to Karla Samanta Hernández Méndez to complete her undergraduate thesis as an Agricultural Engineering student.

Institutional Review Board Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Acknowledgments: To the Botany Laboratory of the National Autonomous University of Mexico, Faculty of Higher Studies Cuautitlán. To the National Autonomous University of Mexico Program for Support of Research and Technological Innovation Projects (PAPIIT) IN223719 "Evaluation of the antimicrobial potential of propolis from stingless bees in Mexico". To INANA A. C. "Initiatives for nature". To the residents of the community of La Gloria Cosautlán de Carbajal, Veracruz, Mexico, particularly the Demanos family. To student Uriel Soriano Contreras for his support in the preparation of the Graphical Abstract.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Challenger, A.; Soberón, J. Los ecosistemas terrestres. In *Capital natural de México*; Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, **2008**; Vol. 1, pp. 87–108.
2. Ravelo, P. K.; Hernández M. F.R.; Paneque, T. I.; Toledo, L.E.; Gutiérrez, H. Relación de la población natural de abejas de la tierra (*Melipona beecheii*) con la flora en el valle San Andrés. *Rev. Cuba. Cienc. For. CFORES* **2014**, *2*, 3.
3. Arnold, N.; Zepeda, R.; Márquez Dávila, M.; Aldasoro Maya, M. *Las abejas sin aguijón y su cultivo en Oaxaca, México con catálogo de especies*; 1; 1° ed.; El Colegio de la Frontera Sur: México, 2018; pp. 1-147.
4. Bradbear, N. fao.org/4/y5110s/y5110s00.htm Available online: <https://www.fao.org/4/y5110s/y5110s00.htm> (accessed on 29 April 2025).
5. Villalón, M.Y.; Leal-Ramos, A.; León, L.E. Acciones estratégicas para el fomento de *Melipona beecheii* en la polinización de agroecosistemas cafetaleros. *Av. Cuba* **2014**, *16*, 296–305.
6. Baena-Díaz, F.; Chévez, E.; Porter-Bolland, L.; Baena-Díaz, F.; Chévez, E.; Porter-Bolland, L. ¿Qué sabemos de las abejas sin aguijón (Hymenoptera: Apidae, Meliponini) en México? Diversidad, Ecología y polinización. *Acta Zool. Mex.* **2023**, *39*, doi:10.21829/azm.2023.3912565.
7. Sakagami, S.F. 4 - Stingless Bees. In *Social Insects*; Hermann, H.R., Ed.; Academic Press, **1982**; pp. 361–423.
8. Michener, C. *The Bees of the World*; 1; 2da ed.; The Johns Hopkins University Press: United States of America, **2007**; pp. 1-972.
9. Kent, R.B. Mesoamerican Stingless Beekeeping. *J. Cult. Geogr.* **1984**, *1*, 14-28. doi:10.1080/08873638409478571.
10. Crane, E. The Past and Present Status of Beekeeping with Stingless Bees. *Bee World* **1992**, *73*, 29–42, doi:10.1080/0005772X.1992.11099110.
11. Pimentel, E.G. Importancia de las abejas sin aguijón, en las familias del área rural de Guatemala. *Rev. Cienc. Multidiscip. CUNORI* **2017**, *1*, 119–120, doi:10.36314/cunori.v1i1.37.
12. México, Un País de Abejas Available online: <https://www.inecol.mx/index.php/divulgacion/ciencia-hoy/mexico-un-pais-de-abejas> (accessed on 1 November 2025).
13. Propóleos Available online: <https://atlasnacionaldelasabejasmx.github.io/atlas/cap4.html> (accessed on 23 May 2025).
14. Sotelo Santos, L.E.; Alvarez Asomoza, C. The Maya Universe in a Pollen Pot: Native Stingless Bees in Pre-Columbian Maya Art. In *Pot-Pollen in Stingless Bee Melittology*; Vit, P., Pedro, S.R.M., Roubik, D.W., Eds.; Springer International Publishing: Cham, 2018; pp. 299–309.
15. Schwarz, H.F.; Bacon, A.L. Stingless Bees (Meliponidae) of the Western Hemisphere: *Lestrimelitta* and the Following Subgenera of *Trigona*: *Trigona*, *Paratrigona*, *Schwarziana*, *Parapartamona*, *Cephalotrigona*, *Oxytrigona*, *Scaura*, and *Mourella*. *Bulletin of the AMNH*; v. 90. **1948**.
16. Jong, H. de The Land of Corn and Honey: The Keeping of Stingless Bees (Meliponiculture) in the Ethno-Ecological Environment of Yucatan (Mexico) and El Salvador. *Univ. Utrecht* **1999**.
17. Quezada-Euán, J.J.G.; Nates-Parra, G.; Maués, M.M.; Roubik, D.W.; Imperatriz-Fonseca, V.L. The Economic and Cultural Values of Stingless Bees (Hymenoptera: Meliponini) among Ethnic Groups of Tropical America. *Sociobiology* **2018**, *65*, 534–557, doi:10.13102/sociobiology.v65i4.3447.
18. Chapman, A.M.; Montemayor, F. *Puertos de Intercambio En Mesoamérica Prehispánica*. 1° ed.; Instituto Nacional de Antropología e Historia, México, **1959**; pp. 1-71.
19. Guaita Gavilanes, M.G.; Martínez Castillo, M.; Hernández Zavala, A.; Guaita Gavilanes, M.G.; Martínez Castillo, M.; Hernández Zavala, A. La miel de abejas sin aguijón: una medicina diferente. *Epistem. Sonora* **2023**, *17*, 49–59, doi:10.36790/epistemus.v17i34.242.
20. Quezada-Euán, J.J.G.; Paxton, R.J.; Palmer, K.A.; Itzá, W. de J.M.; Tay, W.T.; Oldroyd, B.P. Morphological and Molecular Characters Reveal Differentiation in a Neotropical Social Bee, *Melipona Beecheii* (Apidae: Meliponini). *Apidologie* **2007**, *38*, 247–258, doi:10.1051/apido:2007006.
21. Roubik, D.W.; De Camargo, J.M.F. The Panama Microplate, Island Studies and Relictual Species of *Melipona* (Melikerria) (Hymenoptera: Apidae: Meliponini). *Syst. Entomol.* **2012**, *37*, 189–199, doi:10.1111/j.1365-3113.2011.00587.x.
22. Cane, J. Habitat Fragmentation and Native Bees: A Premature Verdict? *Conserv. Ecol.* **2001**, *5*, 1-10. doi:10.5751/ES-00265-050103.

23. España, A.D.H.; Moran, O.A.P.; Kumul, R.G.C. Compuestos bioactivos presentes en geopropóleos de *Melipona beecheii* y su potencial uso en la medicina tradicional. *Desde el Herbario CICY*. **2023**, *15*, 33-37.
24. Barth, O.M. Melissopalynology in Brazil: A Review of Pollen Analysis of Honeys, Propolis and Pollen Loads of Bees. *Sci. Agric.* **2004**, *61*, 342–350, doi:https://doi.org/10.1590/S0103-90162004000300018.
25. Propóleos. Available online: https://atlas-abejas.agricultura.gob.mx/cap4.html (accessed on 1 November 2025).
26. Ghisalberti, E.L. Propolis: A Review. *Bee World* **1979**, *60*, 59–84, doi:10.1080/0005772X.1979.11097738.
27. Marcucci, M.C. Propolis: Chemical Composition, Biological Properties and Therapeutic Activity. *Apidologie* **1995**, *26*, 83–99, doi:10.1051/apido:19950202.
28. Chuttong, B.; Lim, K.; Praphawilai, P.; Danmek, K.; Maitip, J.; Vit, P.; Wu, M.-C.; Ghosh, S.; Jung, C.; Burgett, M.; et al. Exploring the Functional Properties of Propolis, Geopropolis, and Cerumen, with a Special Emphasis on Their Antimicrobial Effects. *Foods* **2023**, *12*, 3909, doi:10.3390/foods12213909.
29. Kuropatnicki, A.K.; Szliszka, E.; Krol, W. Historical Aspects of Propolis Research in Modern Times. *Evid.-Based Complement. Altern. Med. ECAM* **2013**, *2013*, 964149, doi:10.1155/2013/964149.
30. Petit, J.-L. Propóleo Para Cuidar Frutales. *Fertil. Tierra Rev. Agric. Ecológica* **2004**, *15*, 13–15.
31. Roman, S.; Palos, E.; Mateescu, C. Treatment of Some Gynaecological Diseases with Apitherapeuti-Cal Products. *Proc XXXII Int Congr Apic. Rio Jan. Braz. Apimondia Buchar. Rom.* **1989**, 215–216.
32. Stojko, R.; Stojko, A. Uso de Preparados Apiterapéuticos En La Ginecología. *Proc 33rd Int Congr Apic. Beijing China Apimondia Buchar. Rom.* **1993**, 142–143.
33. Tushevskii, V.F.; Porokhnyak, L.A.; Tikhonov, A.I.; Budnikova, T.M. Morphological Aspects of the Hepatoprotective Effect of Propolis Tablets. **1991**. 70-71.
34. Campos, J.F.; Santos, H.F. dos; Bonamigo, T.; Domingues, N.L. de C.; Souza, K. de P.; Santos, E.L. dos Stingless Bee Propolis: New Insights for Anticancer Drugs. *Oxid. Med. Cell. Longev.* **2021**, *2021*, 2169017, doi:10.1155/2021/2169017.
35. Pazin, W.M.; Mônaco, L. da M.; Soares, A.E.E.; Miguel, F.G.; Berretta, A.A.; Ito, A.S. Antioxidant Activities of Three Stingless Bee Propolis and Green Propolis Types. *J. Apic. Res.* **2017**, *56*, 40-49, doi: 10.1080/00218839.2016.1263496
36. Portal, A.S.; Cordova, C.M.M. de; Portal, A.S.; Cordova, C.M.M. de Propolis from *Meliponinae*: A Highway from Ancient Wisdom to the Modern Medicines. In *Melittology - New Advances*; IntechOpen, 2023.
37. Rodríguez Pérez, B.; Canales Martínez, M.M.; Penieres Carrillo, J.G.; Cruz Sánchez, T.A. Composición química, propiedades antioxidantes y actividad antimicrobiana de propóleos mexicanos. *Acta Univ.* **2020**, *30*, 1-29, doi:10.15174/au.2020.2435.
38. Ruiz Ruiz, J.C.; Pacheco López, N.A.; Rejón Méndez, E.G.; Samos López, F.A.; Medina Medina, L.; Quezada-Euán, J.J.G. Phenolic Content and Bioactivity as Geographical Classifiers of Propolis from Stingless Bees in Southeastern Mexico. *Foods* **2023**, *12*, 1434, doi:10.3390/foods12071434.
39. Hernández Melgar, A.G. Caracterización de Los Compuestos Mayoritarios de Una Muestra de Geopropóleo, Producido Por *Melipona Beecheii* En Coatepec Veracruz. Licenciatura, Facultad de Química, México, UNAM, 2015.
40. Ramón-Sierra, J.; Peraza-López, E.; Rodríguez-Borges, R.; Yam-Puc, A.; Madera-Santana, T.; Ortiz-Vázquez, E. Partial Characterization of Ethanolic Extract of *Melipona Beecheii* Propolis and *in Vitro* Evaluation of Its Antifungal Activity. *Rev. Bras. Farmacogn.* **2019**, *29*, 319–324, doi:10.1016/j.bjp.2019.04.002.
41. Yam-Puc, A.; Santana-Hernández, A.A.; Yah-Nahuat, P.N.; Ramón-Sierra, J.M.; Cáceres-Farfán, M.R.; Borges-Argáez, R.L.; Ortiz-Vázquez, E. Pentacyclic Triterpenes and Other Constituents in Propolis Extract from *Melipona Beecheii* Collected in Yucatan, México. *Rev. Bras. Farmacogn.* **2019**, *29*, 358–363, doi:10.1016/j.bjp.2019.01.006.
42. Farré, R.; Frasset, I.; Sánchez, A. El própolis y la salud. *Ars Pharm. Internet* **2004**, *45*, 21–43.
43. Vargas-Sánchez, R.D.; Peñalba-Garmendia, M.C.; Sánchez-Escalante, J.J.; Torrescano-Urrutia, G.R.; Sánchez-Escalante, A. Pollen Profile of Propolis Produced on the Eastern Edge of the Sonoran Desert in Central Sonora, Mexico. *Acta Botánica Mex.* **2016**, *114*, 69–85.

44. Ramírez, E.; Pacheco-Palomo, K.; Moguel Ordóñez, Y.; Moreno, R.; Godínez-García, L. Angiosperm Resources for Stingless Bees (Apidae, Meliponini): A Pot-Pollen Melittopalynological Study in the Gulf of Mexico. In *Pot-Pollen in Stingless Bee Melittology*; 2018; pp. 111–130..
45. Herrera-López, M.G.; Richomme, P.; Peña-Rodríguez, L.M.; Calvo-Irabien, L.M. Bee Species, Botanical Sources and the Chemical Composition of Propolis from Yucatan, Mexico. *J. Chem. Ecol.* **2023**, *49*, 408–417, doi:10.1007/s10886-023-01429-y.
46. Pérez-Morfi, A.; Ramírez-Arriaga, E.; Canto, A. Comparative Analysis of Melipona Beecheii Pollen Foraging Preferences in Deciduous, Semi-Deciduous, and Semi-Evergreen Tropical Forests of the Yucatan Peninsula. *Apidologie* **2025**, *56*, 1–21, doi:10.1007/s13592-025-01202-y.
47. García, E. *Modificaciones al Sistema de Clasificación Climática de Köppen*, 5° ed.; Universidad Nacional Autónoma de México, México, 2004; pp. 1-97.
48. INEGI MAPA DIGITAL DE MÉXICO 2014. <http://gaia.inegi.org.mx/mdm6/?v=bGF0OjE5LjMxMzk0LGxvbjotOTYuODk0MTYsejo3LGw6YzM1MHxjdXN2Ng==> (archived on 15 July 2024).
49. Rzedowski, J. Análisis preliminar de la flora vascular de los bosques mesófilos de montaña de México. *Acta Bot. Mex.* **1996**, 25–44.
50. SEFIPLAN SISTEMA DE INFORMACIÓN MUNICIPAL. Available online: <http://ceieg.veracruz.gob.mx/wp-content/uploads/sites/21/2016/05/Cosautl%C3%A1n-de-Carvajal.pdf> (accessed on 29 April 2025).
51. Bernard, H.R. Métodos de Investigación En Antropología. *Entrevistas No Estructuradas Semiestructuradas*, 2da ed.; Altamira PRESS, USA, **1995**, 147–166.
52. Izquierdo, G.M. Informantes y muestreo en investigación cualitativa. *Investig. Andina* **2015**, *17*, 1148–1150.
53. Leff, E. Complejidad, racionalidad ambiental y diálogo de saberes. *Congr. Int. Interdiscip. Particip. Animac. E Interv. Socioeducativa* Barcelona, España, 2006. 1-12.
54. González González, J.; Novelo Maldonado, E. Algas. In *Manual de Herbario. Administración y manejo de colecciones, técnicas de recolección y preparación de ejemplares botánicos*, 1° ed.; Lot & F. Chiang., Eds.; Universidad Nacional Autónoma de México, México, **1986**: 47-54.
55. Araujo-Mondragón, F.; Redonda-Martínez, R.; Araujo-Mondragón, F.; Redonda-Martínez, R. Flora melífera de la región centro-este del municipio de Pátzcuaro, Michoacán, México. *Acta Botánica Mex.* **2019**, doi:10.21829/abm126.2019.1444.
56. May, T.; Rodríguez, S. Plantas de Interés Apícola En El Paisaje: Observaciones de Campo y La Percepción de Apicultores En República Dominicana. *Rev. Geogr. Am. Cent.* **2012**, *1*, 133-162.
57. SAGARPA NORMA Oficial Mexicana NOM-003-SAG/GAN-2017, Propóleos, producción y especificaciones para su procesamiento. https://www.dof.gob.mx/normasOficiales/6794/sagarpa11_C/sagarpa11_C.html (archived 12 November 2024)
58. Cornejo-Tenorio, G.; Manríquez, G.I.; Colín, S.S. *Flora de Los Tuxtlas: Guía Ilustrada*, 1° ed.; Universidad Nacional Autónoma de México, 2019; pp.1-500.
59. EncicloVida Búsqueda por región Available online: <https://enciclovida.mx/explora-por-region> (accessed on 29 April 2025).
60. Gómez-Pompa, A.; Krömer, T.; Castro-Cortés, R. Atlas de la flora de Veracruz: Un patrimonio natural en peligro. Universidad Veracruzana. Available online: <https://libros.uv.mx/index.php/UV/catalog/book/FC135> (accessed on 29 April 2025).
61. Villegas, D.G.; Bolaños, M.A.; Miranda, J.A.; Sandoval, H.R.; Lizama, M.J.M. *Flora Nectarífera y Polinífera En El Estado de Veracruz. México*, 2° ed.; SAGARPA, México, **2003**; pp. 1-130.
62. Plants of the World Online | Kew Science Available online: <https://powo.science.kew.org/> (accessed on 31 October 2025).
63. International Plant Names Index Available online: <https://www.ipni.org/> (accessed on 31 October 2025).
64. de Rivas, S. *Polen y Esporas Introducción a La Palinología y Vocabulario Palinológico*. 1°ed.; H. Blume, México, **1978**; 1-219.
65. Erdtman, G. *Handbook of Palynology: Morphology, Taxonomy, Ecology. An Introduction to the Study of Pollen Grains and Spores*; 1° ed.; København Munksgaard, 1969; pp. 1-486.

66. González Gutierrez, K.; Mosquera Mosquerall, H. Estandarización de la acetólisis de Erdtman (1969) para el análisis palinológico de muestras fecales de murciélagos polinizadores (Phyllostomidae: Glossophaginae-Lonchophyllinae). *Revista Tumbaga* **2016**, *1*, 49-61.
67. Sánchez, L. Métodos Palinológicos de Análisis. Doc. No Publ. *Cent. Investig. Apícolas Trop. CINAT-UNA Heredia Costa Rica* **2001**.
68. Soejarto, D.D.; Fonnegra, R. Polen: Diversidad en formas y tamaños. *Actual. Biológicas* **1972**, *1*, 2-13, doi:10.17533/udea.acbi.330775.
69. Muller, J. Form and Function in Angiosperm Pollen. *Ann. Mo. Bot. Gard.* **1979**, *66*, 593-632, doi:10.2307/2398913.
70. Moreno Patiño, J.E.; Roubik, D.W. *Pollen and Spores of Barro Colorado Island*. 1° ed.; Missouri Botanical Garden, St. Louis, Missouri, USA, 1991; pp. 1-278
71. Punt, W.; Hoen, P.P.; Blackmore, S.; Nilsson, S.; Le Thomas, A. Glossary of Pollen and Spore Terminology. *Rev. Palaeobot. Palynol.* **2007**, *143*, 1-81, doi:10.1016/j.revpalbo.2006.06.008.
72. Barrantes-Vásquez, A.; Sánchez-Chaves, L.; Hernández-Sánchez, G.; Flores, W.M.; Barrantes-Vásquez, A.; Sánchez-Chaves, L.; Hernández-Sánchez, G.; Flores, W.M.- Principales plantas de importancia alimenticia para la abeja nativa sin aguijón *Trigona fulviventris* (Guérin-Méneville) en Pocosol, Guanacaste, Costa Rica. *Rev. For. Mesoam. Kurú* **2019**, *16*, 13-23, doi:10.18845/rfmk.v16i38.3992.
73. Sandoval, E. *Técnicas Aplicadas al Estudio de La Anatomía Vegetal*, 1° ed.; UNAM, México, 2005; pp. 1-273.
74. Alfaro Bates, R.; González Acereto, J.A.; Ortiz Diaz, J.J.; Burgos Pérez, A.I.; Martínez Hernández, E.; Ramírez Arriaga, E. *Caracterización palinológica de mieles de la península de Yucatán*; 1° ed.; Coordinación General de Extensión, UNAM: Yucatán, México, 2010; 1-144.
75. Flores, R. Identificación de Granos de Polen de Algunas Familias Comunes En El Área Central de La República de Guatemala., Licenciatura. Universidad de San Carlos de Guatemala-USAC: Guatemala, 1989.
76. Moriano Huillca, M.O. Palinología de la flora actual en el área de influencia del sitio arqueológico de Salapunku, Santuario Histórico de Machupicchu, Cusco. Licenciatura. Cusco, Perú, 2022.
77. Palacios-Chávez, R.; Arreguín-Sánchez, M.D. la L.; Quiroz-García, D.L. Morfología de los granos de polen de la subfamilia Caesalpinioideae (Leguminosae) del Valle de Mexico. *POLIBOTÁNICA* **1996**, *1*, 16-21.
78. Ramos Díaz, A.; Noriega Trejo, R.; Sánchez Contreras, Á.; San Román Ávila, D.; Góngora Chin, R.; Rodríguez Buenfil, I. *Catálogo de los principales tipos polínicos encontrados en las mieles producidas en la Península de Yucatán*, 1° ed.; FOMIX: Yucatán, México, 2015; 1-114.
79. Villanueva-Gutiérrez, R.; Roubik, D.W.; Colli-Ucán, W.; Tuz-Novelo, M. The Value of Plants for the Mayan Stingless Honey Bee *Melipona Beecheii* (Apidae: Meliponini): A Pollen-Based Study in the Yucatán Peninsula, Mexico. In *Pot-Pollen in Stingless Bee Melittology*; Vit, P., Pedro, S.R.M., Roubik, D.W., Eds.; Springer International Publishing: Cham, 2018; pp. 67-76.
80. Fonte, L.; Milera, M.; Demedio, J.; Blanco, D. Selectividad de Pecoreo de La Abeja Sin Aguijón *Melipona Beecheii* Bennett En La EEPF "Indio Hatuey", Matanzas. *Pastos Forrajes* **2012**, *35*, 333-342.
81. Mendieta Izquierdo, G. Informantes y Muestreo En Investigación Cualitativa. *Investig. Andina* **2015**, *17*, 1148-1150.
82. Catálogo de Árboles Para Las Abejas Available online: https://issuu.com/inanaac/docs/catalogo_inana_digital (accessed on 30 April 2025).
83. Ramírez-Arriaga, E.; Navarro-Calvo, Lidia Amelia; and Díaz-Carbajal, E. Botanical Characterisation of Mexican Honeys from a Subtropical Region (Oaxaca) Based on Pollen Analysis. *Grana* **2011**, *50*, 40-54, doi:10.1080/00173134.2010.537767.
84. Engel, M.S.; Dingemans-Bakels, F. Nectar and pollen resources for stingless bees (Meliponinae, Hymenoptera) in Surinam (South America). *Apidologie* **1980**, *11*, 341-350, doi:10.1051/apido:19800402.
85. Iwama, S.; Melhem, T.S. The pollen spectrum of the honey of *Tetragonisca angustula angustula latreille* (APIDAE, Meliponinae). *Apidologie* **1979**, *10*, 275-295, doi:10.1051/apido:19790305.
86. Ramalho, M.; Kleinert-Giovannini, A.; Imperatriz-Fonseca, V.L. Utilization of floral resources by species of *Melipona* (Apidae, Meliponinae): floral preferences. *Apidologie* **1989**, *20*, 185-195, doi:10.1051/apido:19890301.

87. Sommeijer, M.J.; Rooy, G. a. D.; Punt, W.; Bruijn, L.L.M.D. A comparative study of foraging behavior and pollen resources of various stingless bees (Hym., Meliponinae) and honeybees (HYM., apinae) in Trinidad, WEst-indies. *Apidologie* **1983**, *14*, 205–224, doi:10.1051/apido:19830306.
88. Montoya-Pfeiffer, P.M.; León-Bonilla, D.; Nates-Parra, G. Catálogo de polen en mieles de *Apis mellifera* provenientes de zonas cafeteras en la Sierra Nevada de Santa Marta, Magdalena, Colombia. *Rev. Acad. Colomb. Cienc. Exactas Físicas Nat.* **2014**, *38*, 364–384.
89. Padilla Vargas, P.J. Etnobotánica de las especies utilizadas por la abeja *Scaptotrigona Mexicana* en Cuetzalan del Progreso, Puebla, México. Master of Sciences, Santa Cruz Xoxocotlán, Oaxaca, México, **2015**.
90. Council for Agricultural Research and Economics (CREA) Available online: <https://www.fao.org/mountain-partnership/members/detail/council-for-agricultural-research-and-economics-crea/en> (accessed on 31 October 2025).
91. Feuer, S.M.; Kuijt, J. Fine Structure of Mistletoe Pollen VI. Small-Flowered Neotropical Loranthaceae. *Ann. Mo. Bot. Gard.* **1985**, *72*, 187, doi:10.2307/2399176.
92. Sánchez-Dzib, Y. de los A.; Sosa-Nájera, S.; Lozano-García, M. del S. Morfología Polínica de Especies de la Selva Mediana Subperennifolia en la Cuenca del Río Candelaria, Campeche. *Bol. Soc. Botánica México* **2009**, 83–104.
93. Majeed, I.; Rizwan, K.; Ashar, A.; Rasheed, T.; Amarowicz, R.; Kausar, H.; Zia-Ul-Haq, M.; Marceanu, L.G. A Comprehensive Review of the Ethnotraditional Uses and Biological and Pharmacological Potential of the Genus *Mimosa*. *Int. J. Mol. Sci.* **2021**, *22*, 7463. doi: 10.3390/ijms22147463
94. Quezada García, M.W.; Rivera Martinez, M. del P. Determinación de fitoconstituyentes de la raíz y hojas de *mimosa albida* procedentes de Conache – La Libertad. Licenciatura, Universidad Nacional de Trujillo, Trujillo, Perú, **2015**.
95. Quiñonez-Bastidas, G.N.; Navarrete, A. Mexican Plants and Derivates Compounds as Alternative for Inflammatory and Neuropathic Pain Treatment—A Review. *Plants* **2021**, *10*, 865, doi:10.3390/plants10050865.
96. Hernández-Dávila, O.A.; Laborde, J.; Sosa, V.J.; Díaz-Castelazo, C. Interaction Network between Frugivorous Birds and Zoochorous Plants in Cloud Forest Riparian Strips Immersed in Anthropic Landscapes. *Avian Res.* **2022**, *13*, 100046, doi:10.1016/j.avrs.2022.100046.
97. Pérez-Cadavid, A.; Rojas-Soto, O.R.; Bonilla-Moheno, M.; Pérez-Cadavid, A.; Rojas-Soto, O.R.; Bonilla-Moheno, M. Effect of Seed Ingestion by Birds on the Germination of Understorey Species in Cloud Forest. *Rev. Mex. Biodivers.* **2018**, *89*, 1167–1175, doi:10.22201/ib.20078706e.2018.4.2612.
98. Cunha, W.R.; Martins, C.; Ferreira, D. da S.; Crotti, A.E.M.; Lopes, N.P.; Albuquerque, S. In Vitro Trypanocidal Activity of Triterpenes from *Miconia* Species. *Planta Med.* **2003**, *69*, 470–472, doi:10.1055/s-2003-39719.
99. Gontijo, D.C.; Gontijo, P.C.; Brandão, G.C.; Diaz, M.A.N.; de Oliveira, A.B.; Fietto, L.G.; Leite, J.P.V. Antioxidant Study Indicative of Antibacterial and Antimutagenic Activities of an Ellagitannin-Rich Aqueous Extract from the Leaves of *Miconia Latecrenata*. *J. Ethnopharmacol.* **2019**, *236*, 114–123, doi:10.1016/j.jep.2019.03.007.
100. Jara, M.R.A.; Molero, H.R.L.; Landeo, E.C.; Segovia, J.C.P. Contenido de fenoles totales, flavonoides y capacidad antioxidante de tres especies endémicas del género *Miconia* del departamento de Ayacucho – 2019. *Investigación* **2020**, *28*, 245–251, doi:10.51440/unsch.revistainvestigacion.28.2.2020.415.
101. Spessoto, M.A.; Ferreira, D.S.; Crotti, A.E.M.; Silva, M.L.A.; Cunha, W.R. Evaluation of the Analgesic Activity of Extracts of *Miconia Rubiginosa* (Melastomataceae). *Phytomedicine* **2003**, *10*, 606–609, doi:10.1078/094471103322331629.
102. Młynarczyk, K.; Walkowiak-Tomczak, D.; Łysiak, G.P. Bioactive Properties of *Sambucus Nigra* L. as a Functional Ingredient for Food and Pharmaceutical Industry. *J. Funct. Foods* **2018**, *40*, 377–390, doi:10.1016/j.jff.2017.11.025.
103. Liu, D.; He, X.-Q.; Wu, D.-T.; Li, H.-B.; Feng, Y.-B.; Zou, L.; Gan, R.-Y. Elderberry (*Sambucus Nigra* L.): Bioactive Compounds, Health Functions, and Applications. *J. Agric. Food Chem.* **2022**, *70*, 4202–4220, doi:10.1021/acs.jafc.2c00010.

104. Sidor, A.; Gramza-Michałowska, A. Advanced Research on the Antioxidant and Health Benefit of Elderberry (*Sambucus Nigra*) in Food – a Review. *J. Funct. Foods* **2015**, *18*, 941–958, doi:10.1016/j.jff.2014.07.012.
105. Torabian, G.; Valtchev, P.; Adil, Q.; Dehghani, F. Anti-Influenza Activity of Elderberry (*Sambucus Nigra*). *J. Funct. Foods* **2019**, *54*, 353–360, doi:10.1016/j.jff.2019.01.031.
106. ALAsmari, K.M.; Zeid, I.M.A.; Al-Attar, A.M. Medicinal Properties of *Arabica Coffee* (*Coffea Arabica*) Oil: An Overview. *Adv. Life Sci.* **2020**, *8*, 20–29, doi:10.62940/als.v8i1.1024.
107. Babova, O.; Occhipinti, A.; Maffei, M.E. Chemical Partitioning and Antioxidant Capacity of Green Coffee (*Coffea Arabica* and *Coffea Canephora*) of Different Geographical Origin. *Phytochemistry* **2016**, *123*, 33–39, doi:10.1016/j.phytochem.2016.01.016.
108. Bisht, S.; Sisodia, S.S. *Coffea Arabica*: A Wonder Gift to Medical Science. *J. Nat. Pharm.* **2010**, *1*, 58–65. doi: 10.4103/2229-5119.73595
109. Pérez-Hernández, L.M.; Chávez-Quiroz, K.; Medina-Juárez, L.Á.; Gámez Meza, N. Phenolic Characterization, Melanoidins, and Antioxidant Activity of Some Commercial Coffees from *Coffea Arabica* and *Coffea Canephora*. *J. Mex. Chem. Soc.* **2012**, *56*, 430–435.
110. Alcántara-Quintana, L.E.; Arjona-Ruiz, C.; de Loera, D.; Gamboa-León, R.; Terán-Figueroa, Y. In Vitro Inhibitory and Proliferative Cellular Effects of Different Extracts of *Struthanthus Quercicola*: A Preliminary Study. *Evid. Based Complement. Alternat. Med.* **2022**, *2022*, 9679739, doi:10.1155/2022/9679739.
111. Arjona-Ruiz, C.; Juarez-Flores, B.; Gamboa-León, R.; de Loera, D. Antidiabetic Activity and Hepatotoxic Effect of Aqueous Extracts of *Struthanthus Quercicola*. *Rev. Bras. Farmacogn.* **2022**, *32*, 472–477, doi:10.1007/s43450-022-00263-9.
112. Nápoles, N.E.R.; Puentes, D.A.; Arias, Y.T. Relations between morphological-functional and ecological characteristics of Cuban native species of Meliaceae: strategy for forestry management. *Acta Botánica Cuba.* **2016**, *215*, 2–23.
113. Biesmeijer, J.; Roberts, S.; Reemer, M.; Ohlemüller, R.; Edwards, M.; T, P.; Ap, S.; Sg, P.; R, K.; Cd, T.; et al. Parallel Declines in Pollinators and Insect-Pollinated Plants in Britain and the Netherlands. *Science* **2006**, *313*, 351–354. doi:10.1126/science.1127863.
114. Ambi, A.; Bryan, J.; Borbon, K.; Centeno, D.; Liu, T.; Chen, T.P.; Cattabiani, T.; Traba, C. Are Russian Propolis Ethanol Extracts the Future for the Prevention of Medical and Biomedical Implant Contaminations? *Phytomedicine* **2017**, *30*, 50–58, doi:10.1016/j.phymed.2017.03.006.
115. Rojczyk, E.; Klama-Baryła, A.; Łabuś, W.; Wilemska-Kucharzewska, K.; Kucharzewski, M. Historical and Modern Research on Propolis and Its Application in Wound Healing and Other Fields of Medicine and Contributions by Polish Studies. *J. Ethnopharmacol.* **2020**, *262*, 113159, doi:10.1016/j.jep.2020.113159.
116. Ortiz Reyes, L.Y.; Quiroz-García, D.L.; Arreguín-Sánchez, M.L.; Fernández Nava, R. Origen botánico y caracterización fisicoquímica de la miel de meliponinos (Apidae:Meliponini) de Teocelo, Veracruz, México. *Polibotánica* **2022**, 153–170, doi:10.18387/polibotanica.54.10.
117. Fischer, G.; Conceição, F.R.; Leite, F.P.L.; Dummer, L.A.; Vargas, G.D.; Hübner, S. de O.; Dellagostin, O.A.; Paulino, N.; Paulino, A.S.; Vidor, T. Immunomodulation Produced by a Green Propolis Extract on Humoral and Cellular Responses of Mice Immunized with SuHV-1. *Vaccine* **2007**, *25*, 1250–1256, doi:10.1016/j.vaccine.2006.10.005.
118. Sosa López, Á.A.; Cabrera, M.G.; Álvarez, M.Y. Vegetación de origen como parámetro de caracterización microbiana de los propóleos. *J. Selva Andina Biosph* **2016**, *4*, 3–23.
119. Bascompte, J.; Jordano, P. Plant-Animal Mutualistic Networks: The Architecture of Biodiversity. *Annu. Rev. Ecol. Evol. Syst.* **2007**, *38*, 567–593, doi:10.1146/annurev.ecolsys.38.091206.095818.
120. Cortés, L.E.U.C.; Rivas, J.A.M. Conocimiento local de las abejas sin aguijón (APIDAE: meliponini) entre los mayas lacandones de Metzabok, Chiapas, México. *ETNOBIOLOGÍA* **2023**, *21*, 71–85.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.