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Research article

Bee flora, botanical and geographical origin of *Apis mellifera* honey in the Colombian Massif, department of Cauca

Flora apícola, origen botánico y geográfico de mieles de *Apis mellifera* en el Macizo Colombiano, departamento del Cauca

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ABSTRACT

The recognition of apicultural flora around beehives allows for the identification of the botanical origin of honey, adding value to the product. In the present study, the objective was to identify the apicultural floral offering, and botanical and geographical origin of *Apis mellifera* L. honey in two municipalities located in the Colombian Massif, Cauca department. For this purpose, a floristic inventory was conducted in four apiaries in the municipalities of Almaguer and La Vega, from which information was obtained on vegetation cover and the available apicultural floral offering. Additionally, melissopalynological analyses were carried out on 36 honey samples from 28 apiaries in the region. Based on the floristic inventory, 103 melliferous species distributed in 83 genera and 30 families were recorded, with Asteraceae, Fabaceae, Rubiaceae, and Malvaceae being the most representative. The area showed a predominance of nectar-pollen-producing species, while the frequency of visits and the concentration of sugars in the nectar were mostly classified as medium range, these two variables were positively related. According to melissopalynological analyses, the most common taxa were Asteraceae, Fabaceae, and Malvaceae, and multifloral honeys were slightly more abundant than monofloral honeys. This new knowledge will facilitate the conditions for offering honey with a designation of origin for the Colombian Massif.

Keywords: Beekeeping, honeybee, melissopalynology, pollen.

RESUMEN

El reconocimiento de la flora apícola en torno a los apiarios permite identificar el origen botánico de la miel, aportando valor agregado al producto. En el presente estudio se planteó como objetivo identificar la oferta floral apícola y origen botánico y geográfico de mieles de *A. mellifera* en dos municipios del Macizo Colombiano, departamento del Cauca. Para ello, se realizó un inventario florístico en cuatro apiarios de los municipios de Almaguer y La Vega, a partir del cual se obtuvo información sobre las coberturas vegetales y la oferta floral apícola disponible. Adicionalmente, se efectuó el análisis melisopalinológico a 36 muestras de miel, provenientes de 28 apiarios de la región. Derivado del inventario florístico se registraron 103 especies melíferas distribuidas en 83 géneros y 30 familias, siendo las más representativas Asteraceae, Fabaceae, Rubiaceae y Malvaceae. En la zona hubo predominancia de especies nectaro -poliníferas, mientras la frecuencia de visitas y la concentración de azúcares en el néctar se clasificaron mayoritariamente en rango medio, estas dos variables se relacionaron positivamente. De acuerdo con el análisis melisopalinológico los taxones más comunes fueron Asteraceae, Fabaceae y Malvaceae, las mieles multiflorales fueron ligeramente más abundantes que las de tipo monofloral. Este nuevo conocimiento facilitará las condiciones para la oferta de mieles con denominación de origen para el Macizo Colombiano.

Palabras clave: Apicultura, melisopalinología, miel de abeja, polen.

INTRODUCTION

Honey is usually the main apicultural product, produced from the nectar of flowers or extrafloral resources produced by botanical species. Variations in the botanical origin of nectar and honeydew often impact the sensory, physicochemical, and nutritional properties of honey (Gok *et al.,* 2015; Insuasty-Santacruz *et al.,* 2016; Recklies *et al.,* 2021)water activity, electric conductivity, colour, hydroxymethyl furfural, acidity, pH, proline, diastase and invertase. The differentiation of honey based on its geographical and botanical origin has become a global trend for adding value to hive products (Wang and Li, 2011; Nates-Parra *et al.,* 2013; Ballco *et al.,* 2022).

Colombia has high apicultural production potential due to its environmental conditions and diversity of flora. Therefore, there is a need to characterize production areas in terms of climate, flora, and hive products as an expansion strategy in the beekeeping market (Cadena Productiva de las Abejas y la Apicultura en Colombia [CPAA], 2011).

However, in the country, productivity is low because the majority of beekeepers operate on a small scale and reside in rural areas with significant challenges, related with technification, beekeeping sanitation, and product characterization (CPPA, 2011; Tapiero-Cuéllar and Salamanca-Grosso, 2016). Colombian apiculture has yet to fully leverage its high potential in monofloral honeys due to the limited characterization and differentiation of its products. There are specific cases such as Encenillo honey in the Boyacá region (Salamanca *et al.,* 2017), and Eucalyptus honey in Villanueva, Casanare (Ortega-Bonilla *et al.,* 2016)but also to increase its exploitation considering its quality and distinctive features. Physicochemical parameters are basic factors that determine the final quality of honey. The objective of this research was to assess commercial eucalyptus honeys developed with Apis mellifera in the region of Villanueva (Colombia.

In the Cauca department, studies have focused on determining apicultural floral offerings, primarily in areas near the city of Popayán (Sánchez and Burbano, 2010; Montoya *et al.,* 2017). However, there are few studies on the origin and botanical determination of honey (Muñoz-Galíndez, 2022).

Therefore, the objective of this study was to identify the apicultural floral offering and botanical and geographical origin of *A. mellifera* honey in two municipalities of the Colombian Massif in the Cauca Department. This knowledge contributes to identifying botanical parameters for product differentiation, strengthening beekeeping activities in strategic ecosystems of the Cauca Department.

MATERIALS AND METHODS

Study area and sampling site

The study area encompassed the municipalities of La Vega and Almaguer in the Colombian Massif, located in the southeast of the Cauca Department. The area has an average temperature of 16 °C, southwest winds at 6 km/h, relative humidity ranging from 75 % to 85 %, and an average altitude of 2.136 m. s. n. m. for La Vega and 2.312 m. a. s. l. for Almaguer (Fig. 1). Four apiaries were selected in each municipality, belonging to the Asociación de Apicultores del Macizo Colombiano - APIMACIZO. The apiaries were located within an altitude range of 1.550 to 2.250 m s. n. m.

Analysis of vegetation cover and floral composition.

Satellite images were selected for each apiary using Google Earth Pro software. These images allowed for the visual identification of land cover within and around each apiary using the CORINE Land Cover methodology (Rodríguez *et al.,* 2015). Data processing was carried out using ArcGIS 10.4 software. The identified land covers were grouped into four main categories: natural forest, secondary vegetation or scrubland, grassland, and crops.

To determine the composition of the apicultural flora at each site, surveys were conducted along the vegetation covers within a 1 km radius, with the location of the beehives as the central reference point (Silva and Restrepo, 2012).

Three criteria were used for the selection of a plant species of apicultural importance: direct observation of *A. mellifera* visits to the plants during the surveys, species recognized by the beekeepers as attractive to bees, and species reported in the literature. Taxonomic identification was carried out using keys, botanical identification guides, comparison with herbarium specimens available online, and assistance from experts in the field.

Floral resources for *A. mellifera*

According to the methods in Silva and Restrepo (2012), in each of the apiaries 30 plant species were selected and their phenological observations were conducted every 15 days for 12 months, starting in November 2020, and ending in November 2021. five individuals of each species were selected for flowering records.

The estimation of resource availability, frequency of *A. mellifera* visits, and nectar sugar concentration were carried out according to the method described by Silva and Restrepo (2012). The frequency of bee visits to flowers was counted within a 1 m^2 area for five minutes, and the measurement of sugar concentration (°Brix) in regurgitated bee nectar was done using a handheld refractometer. For this, an entomological net was utilized to capture one to three bees, which were previously observed collecting nectar.

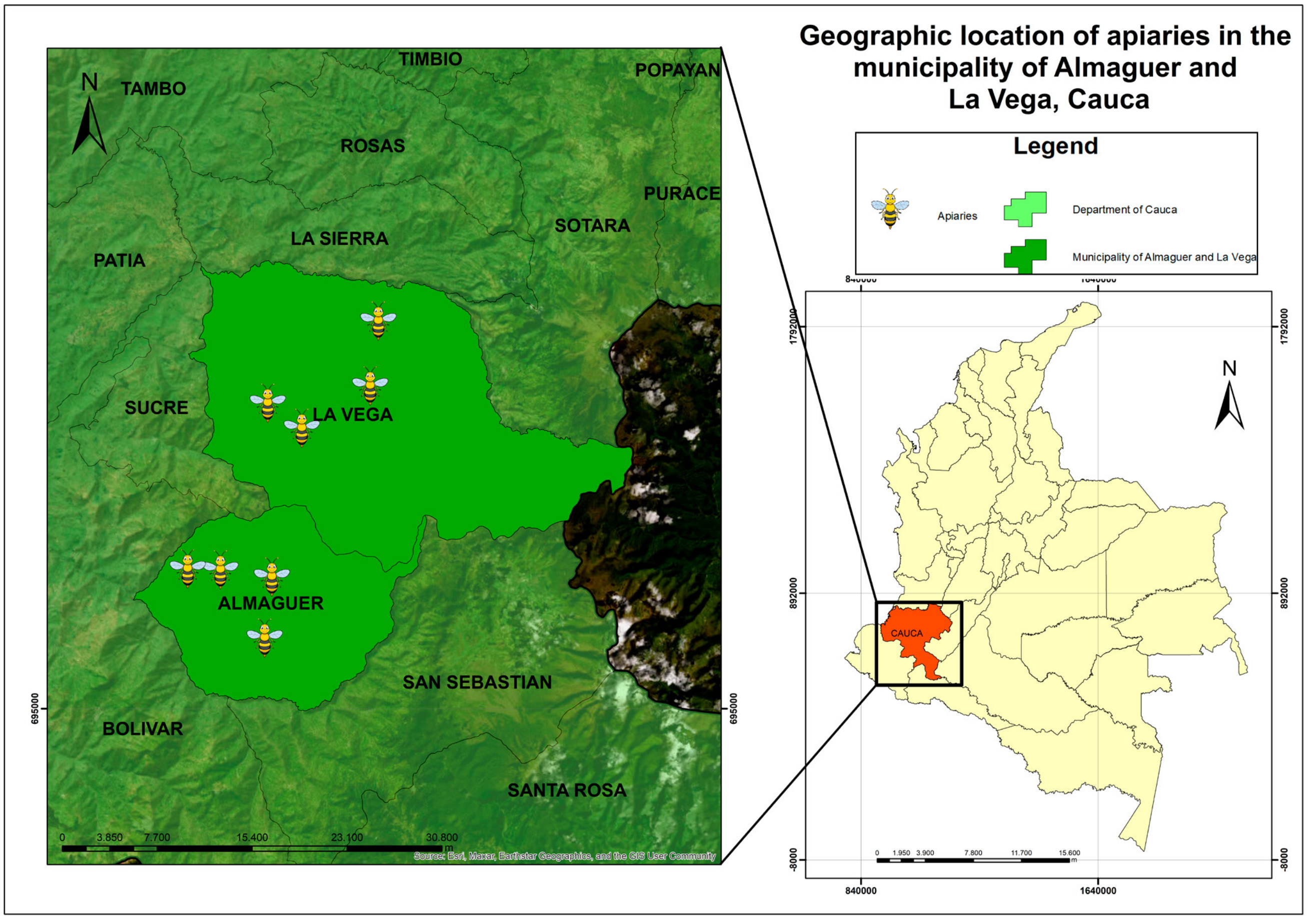

Figure 1. Study area, geographic location of apiaries in the municipalities of La Vega and Almaguer, Cauca, Colombia.

Afterwards each bee was carefully placed on the prism of the refractometer, with fingers a light pressure was done in its thorax to induce the regurgitation of nectar, finally the reading was made.

To determine and classify species according to their apicultural importance, the methodology proposed by Sánchez (1995) and adapted by Sánchez and Burbano (2010) was employed, the parameters selected were: resource offered (nectar or pollen), frequency of visits, concentration of sugars in the nectar, bibliographic report for each species and the frequency with which the species was found in the study area. Values from one to three points for each parameter, with the following range: low (one point), medium (two points), and high (three points), thus yielding values between five and 15 for each species. The classification criteria based on the scores obtained were low beekeeping value (five-eight points), sustaining species (nine-12 points), and harvesting species (13-15 points).

Botanical origin

Between November 2020 and November 2021, 36 honey samples from *A. mellifera* were collected from APIMACIZO apiaries in the municipalities of La Vega (25 samples) and Almaguer (11 samples). A 200 g honey sample was collected from each apiary during the harvest season, distributed as follows: February-March: 11 samples; April-June: nine samples; July-September: nine samples; October-November: seven samples; these samples were stored in glass containers at room temperature. They were subsequently processed and analyzed at the Laboratory of Microbiological and Physicochemical Analysis of Foods (LAMFA) at the National Apprentice Service (SENA) in the Valle del Cauca region.

Samples were prepared according to the acetolysis technique developed by Erdtman, (1986). For that, 10 g of honey was weighed and diluted in 10 ml of distilled water, and put in a water bath for 15 minutes, under continuous agitation. Subsequently, it was centrifuged at 2500 revolutions per minute (rpm), for ten minutes, until a pollen sediment was obtained, to which 10 ml of glacial acetic acid was added, the solution was centrifuged again, and the supernatant was discarded. The sediment obtained was added 1.7 ml of acetolic solution per tube, placed in a water bath carefully stirred for three minutes, and then centrifuged for three minutes at 2500 rpm, discarding the supernatant solution. The precipitate was washed with distilled water and ethyl alcohol, which was then was centrifuged for five minutes. A pollen sample was then taken with a piece of glycerin gelatin to generate permanent plates.

Once the sample mounts were prepared, 300 pollen grains per slide were counted (Nates-Parra *et al.,* 2013). Based on this information, pollen class frequencies were established according to Loveaux *et al*. (1978), which are: predominant pollen (> 45 %); secondary pollen (16-45 %); minor important pollen (3-15 %); minor pollen (between >1 and <3 %); and present (≤ 1 %). Additionally, the relative frequency of occurrence (RFO) of pollen types in all the samples was estimated based on Caccavari and Fagúndez, (2010). Only plant species associated with pollen types with an RFO value greater than 10% were considered significant to honeybee foraging.

Samples in which a single type of pollen was represented ≥ 45 % were classified as monofloral, while those in which none reached this percentage were classified as multifloral (Loveaux *et al.,* 1978).

For the observation of the slides, an OPTIKA microscope with a panoramic 100x objective was used. The identification of palynomorphs was carried out by comparison with material available in specialized literature (Velásquez and Rangel-Ch, 1995; Velásquez, 1999; Giraldo *et al.,* 2011; Nates-Parra *et al.,* 2013; Montoya-Pfeiffer *et al.,* 2014; da Silva *et al.,* 2020).

For a better understanding of differences in bee pollen composition throughout the altitudinal gradient, the apiaries were selected according to their altitudinal location to encompass four altitudinal zones: Zone one: 1600–1800 m. s. n. m. (nine samples); Zone two: 1801–2000 m. s. n. m. (eight samples); Zone three: 2001–2200 m. s. n. m. (eight samples); Zone four: 2200-2400 m. s. n. m. (11 samples).

Data analysis

The data were analyzed using Past software version 4.13. The relationship between the concentration of degrees Brix and the frequency of visits by *A. mellifera* was determined using the Spearman correlation coefficient. To evaluate significant differences in the species composition between two municipalities, a non-parametric one-way analysis of similarities (ANOSIM) test was performed using the Jaccard index, with a significance level of p<0.05. The Shannon-Wiener diversity index (H') and the evenness index of Pielou (J') were used to measure the level of diversity and evenness, respectively, of floral resources used by *A. mellifera* for each altitudinal zone. Statistical difference in the Shannon-Wiener diversity index value of each altitudinal zone was estimated using a t-test modified by Hutcheson, (1970).

RESULTS

Analysis of vegetation cover and floral composition

Among the identified vegetation cover types, grassland was predominant with 54.49 ha (36.6 %), followed by natural forest (49.26 ha, 33 %), secondary vegetation (26 ha, 17.5 %), and crops (19 ha, 12.8 %). Although crops and secondary vegetation had smaller areas, in them were found 81% of botanical species with high beekeeping value (Annex 1).

A total of 103 plant species were recorded in the vegetation cover, distributed across 31 families and 83 genera (Annex 1). The most abundant families were Asteraceae (22 spp.), followed by Fabaceae (ten spp.), Rubiaceae (eight spp.), and Malvaceae (six spp.). From 31 registered families 35% were represented by a single species. In terms of growth habit, 40 species were shrubs, 30 were trees, and 33 were herbs.

According to the ANOSIM test, the species composition between the municipalities did not show a significant difference (R = -0.04, p > 0.05). When apiaries were grouped according to altitude (group one: 1550 to 1900 m. s. n. m.; group two: 1901 to 2250 m. s. n. m.), a significant difference was found (R = 0.47, p <0.05).

Offering floral resources

An important flowering period was identified, starting in September and extending until February. During this time, 79 % of the species presented flowering. The lowest number of flowering species occurred from June to August (41 %) (Fig. 2).

Regarding the resources offered to *A. mellifera*, it was found that 51 plant species (50 %) were nectar and pollen producing species, 39 were nectariferous (38 %), and 13 were polliniferous (12 %). Sixteen families provided both nectar and pollen, with Asteraceae being the most representative with 15 species, followed by Fabaceae and Malvaceae with five species each, and Melastomataceae and Myrtaceae with four species each. As for nectariferous families, Rubiaceae and Verbenaceae were the most representative with six species

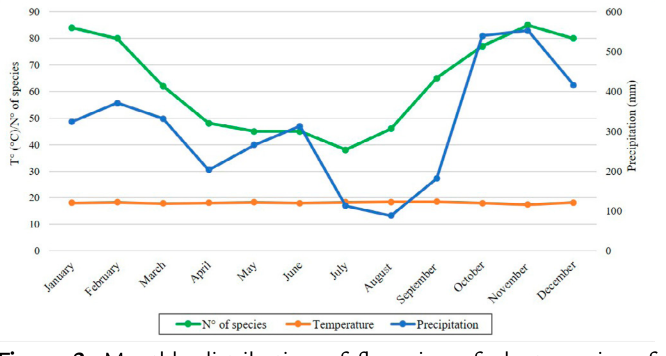

Figure 2. Monthly distribution of flowering of plant species of beekeeping importance in the Colombian Massif, Department of Cauca.

Table 1. Frequency of *A. mellifera* visits to bee flora and concentration of sugars in nectar.

Common name	Family	Species	Visit frequency	Brix degrees	Flowering Month											
					J	F	M	A	M	J	J	A	S	O	N	D
Moco	Actinidiaceae	*Saurauia scabra*	4	30	X					X	X	X	X	X	X	X
Insulina	Acanthaceae	*Justicia secunda*	4								X	X	X	X	X	
Nacedero		*Trichanthera jigantea*	5	29	X							X	X	X		
Mango	Anacardiaceae	*Mangifera indica*	3	39	X									X		
Salvia amarga	Asteraceae	*Austroeupatorium inulifolium*	3		X	X	X	X			X	X	X	X	X	X
Armanga		*Baccharis trinervis*	7	46	X	X	X						X	X	X	X
Pacunga		*Bidens* pilosa	4	39	X	X	X	X	X	X	X	X	X	X	X	X
Lechuguilla		*Emilia sonchifolia*	4	22	X	X	X	X	X	X	X	X	X	X	X	X
Chicharrón		*Calea sessiliflora*	3	23	X	X	X	X	X				X	X	X	X
Salvia morada		*Chromolaena tacotana*	2	18	X	X	X	X						X	X	X
Yerba de Puerco		*Elephantopus mollis*	2	22	X	X	X	X	X	X						X
Falso diente de león		*Hypochaeris radicata*	2	26	X	X	X	X	X	X	X	X	X	X	X	X
Candelillo		*Pseudelephantopus spiralis*	1		X	X	X	X	X	X	X			X	X	X
Mariposo		*Steiractinia sodiroi*	6	39	X	X					X	X	X	X	X	X
Botón de oro		*Tithonia diversifolia*	5	46	X	X	X	X	X	X	X	X	X	X	X	X
Clavelón		*Zinnia peruviana*	3		X	X	X	X	X	X				X	X	X
Encino	Cunnoniaceae	*Weinmannia pubescens*	3												X	X
Paja Estrella	Cyperaceae	*Rhynchospora nervosa*	3	35	X	X	X	X	X	X	X	X	X	X	X	X
Coca	Erythroxylaceae	*Erythroxylum* sp.	10	35									X	X	X	
Chilco rojo	Escalloniaceae	*Escallonia paniculata*	5		X	X					X	X	X	X	X	X
Sangregado	Euphorbiaceae	*Croton gossypiifolius*	4	44	X	X			X	X	X			X	X	X
Sangregado		*Croton* sp.	4	45	X	X	X				X	X	X	X	X	X
Algarrobo	Fabaceae	*Acacia angustissima*	3		X	X	X	X				X	X	X	X	X
Garbasillo		*Cajanus cajan*	4	56	X	X							X	X	X	X
Carbonero		*Calliandra pittieri*	4	24	X	X			X				X	X	X	X
Leucaena		*Leucaena leucocephala*	4		X	X	X	X	X					X	X	X
Guamo		*Inga densiflora*	5	46		X	X					X	X	X	X	
Sarza		Mimosa albida	5		X	X	X	X	X	X					X	X
Cargadita	Lamiaceae	*Hyptis atrorubens*	4	21	X	X	X	X	X	X						X
Zanca de mula		*Hyptis mutabilis*	5	22	X	X	X	X	X					X	X	X
Aguacate	Lauraceae	*Persea americana*	9	47		X	X						X	X		
Guayacán de Manizales	Lythraceae	*Lafoensia acuminata*	4		X	X	X								X	X
Resucitado Campana	Malvaceae	*Abutilon insigne*	8	31	X	X	X	X	X	X	X	X	X	X	X	X
Balso blanco		*Heliocarpus americanus*	5		X	X	X	X	X	X	X	X	X	X	X	X
Campanilla		*Pavonia mutisii*	2		X											X
Escoba		Sida spinosa	4	18	X		X	X	X				X	X	X	X
Escoba		*Sida rhombifolia*	3	18	X	X	X	X	X	X				X	X	X
Morochillo	Melastomataceae	*Miconia caudata*	4	28	X	X	X						X	X	X	X
Mortiño		*Miconia theizans*	3	28	X	X	X								X	X

(*Continue*)

Common name	Family	Species	Visit frequency	Brix degrees	Flowering Month											
					J	F	M	A	M	J	J	A	S	O	N	D
Eucalipto		*Eucalyptus grandis*	7		X	X	X				X	X	X	X	X	X
Eucalipto rojo	Myrtaceae	*Eucalyptus camaldulensis*	9		X	X			X	X		X	X	X	X	X
Arrayán		*Myrcia popayanensis*	5						X	X	X	X	X	X	X	
Guayabo agrio		Psidium guineense	4	40	X	X									X	X
Pomorroso		*Syzygium jambos*	2	19	X	X	X						X		X	X
Braquiaria	Poaceae	*Brachiaria decumbens*	5	42		X	X	X	X			X	X	X	X	X
Maíz		*Zea mays*	8	54		X	X									
Blanquita	Polygonaceae	*Persicaria punctata*	1		X	X	X	X	X						X	X
Ulluquillo		*Polygonum nepalense*	6	53	X	X	X	X	X	X	X			X	X	X
Mora	Rosaceae	*Rubus glaucus*	4	23	X	X	X	X	X	X				X	X	X
Café		*Coffea arabica*	9	56		X			X			X	X	X	X	
Montesito	Rubiaceae	*Spermacoce cf. capitata*	2	34	X	X	X	X	X	X	X	X	X	X	X	X
Borreria		*Spermacoce remota*	3	22	X	X	X	X	X	X	X			X	X	X
Estrellita		*Richardia scabra*	2	23	X	X	X	X	X					X	X	X
Limón	Rutaceae	*Citrus limon*	4	33				X	X	X	X		X	X	X	X
Naranjo		*Citrus sinensis*	4	38								X	X	X	X	
Huesillo	Salicaceae	*Banara cf. ulmifolia*	7	57										X	X	X
Mote	Sapindaceae	*Allophylus mollis*	11	64											X	X
Pendo	Verbenaceae	*Citharexylum kunthianum*	6	34	X	X									X	X
Verbena azul		Stachytarpheta cayennensis	3	32	X	X	X	X	X	X	X	X	X	X	X	X

each. Nine families included pollen-producing species, with Fabaceae being the most abundant with three species, followed by Piperaceae, Poaceae, and Primulaceae with two species each.

The frequency of visits by *A. mellifera* to 59 plant species was estimated (Table 1). Of these, 20 (34 %) had a low frequency (<3 bees per m^2 in five minutes), 34 (54 %) had a medium frequency (four-seven bees), and five (12 %) had a high frequency (>8 bees). The species with the highest visits were *Allophylus mollis* (Kunth) Radlk (11 bees) and *Erythroxylum* sp. (ten bees).

The concentration of sugars in the nectar was estimated for 42 species (Table 1). Among them, 9 % had a low concentration (<21 °Brix), 88 % had a medium concentration (22-60 **°Brix**), and 2 % were classified as high (>60 **°Brix**). The species with the highest values were *A. mollis* (64 **°Brix**) and *Banara ulmifolia* (Kunth) Benth (57 **°Brix**). During the study, measurements were also taken for the extrafloral secretion of *Zea mays* L. (54 **°Brix**), which was utilized by *A. mellifera* in one of the apiaries. The concentration of sugars in the nectar and the frequency of visits showed a positive correlation ($r = 0.64$, $p < 0.05$, $n = 43$), although this relationship was moderate.

Out of the total recorded species, 23 (22 %) were classified as species of low apicultural value, 63 (61 %) as sustaining species, and 17 (17 %) were classified as harvesting species (Annex 1). Sustaining species mainly consisted of weeds and shrubs in secondary areas, while harvest species included cultivated plants and native trees.

Botanical origin

A total of 72 pollen types were identified, of which 39 were classified to the species level, 24 to the genus level, and nine to the family level. These were distributed among 27 botanical families, with Asteraceae being the most represented (11 pollen types), followed by Fabaceae (ten pollen types), Malvaceae (seven pollen types), and Sapindaceae (five pollen types) (Annex 2). 64 % of the morphotypes corresponded to native species, 24 % to introduced or naturalized species, and the remaining 12 % could not be classified into any category due to limited taxonomic information.

Regarding growth habits, 25 % of the pollen types corresponded to shrub species, 25 % to small and medium-sized trees, 21 % to herbs, 10 % to climbers, and 4 % to palms. The remaining 15 % could not be classified into any category as they were not identified at the species level.

Some pollen types corresponded to known polliniferous plant groups. These pollen types were considered in honey analysis, given that, some pollineferous species produce extrafloral nectar which are used by *A. mellifera*, for example *Z. mays* and *Cecropia* sp.

Zone one presented 40 pollen types in total (Shannon-Weaver Index H' = 3.27) (Annex 2), with a predominance of *Mimosa albida* Willd., *B. pilosa* L., *A. mollis*, *Baccharis* *trinervis* (Lam.) Pers., *Hypochaeris radicata* L., *Cupania* sp and *Acmella ciliata* (Kunth) Cass (Fig. 3). Two monofloral honeys corresponding to *M. albida* and *B. trinervis*, respectively. The other seven samples were classified as multifloral.

For zone two, a total of 21 pollen types were obtained (H' = 2.57), of which those with the highest relative abundance were Moraceae type one, *Heliocarpus americanus* L., *Melochia* sp, *Croton* sp, *Cupania* sp, *Bidens Pilosa* L., *B. trinervis* and Anacardiaceae type one. A total of six monofloral honey samples were recorded, corresponding respectively to *Croton* sp, *H. americanus*, Anacardiaceae type one, *Melochia* sp., and two samples for Moraceae type one.

Zone three presented 31 types (H' = 2.95); the most abundant were Anacardiaceae type 1, *Austroeupatorium inulifolium* (Kunth), *Carludovica palmata* Ruiz & Pav, *M. albida*, *Holcus lanatus* L., *Z. mays*, *A. mollis* and *Cupania* sp. Of the eight samples, four were monofloral belonging to Anacardiaceae type one, *Z. mays*, *M. albida* and *A. mollis*.

Zone four recorded 42 species (H' = 3.21), Anacardiaceae type two, *Erythroxylum* sp, *B. trinervis*, Moraceae type one and *Cupania* sp were the most abundant pollen types. Monofloral honeys were derived from Anacardiaceae type two, Moraceae type one and *Erythroxylum* sp. The remaining eight samples were classified as multifloral honeys.

According to the frequency of occurrence, few pollen types stood out as important (RFO > 10 %). None of them were classified in the "*very frequent*" category which is equivalent to being present in >50 % of the samples, however the most common were *B. trinervis*, *B. pilosa*, *M. albida*, *H. americanus*, Moraceae type one, *A. mollis* and *Cupania* sp (Annex 2).

The Hutcheson t-test revealed significant differences between diversity index values in all the altitudinal zones ($p < 0.001$), except between zone one and four (Table 2). It should be noted that zones one and four were the most diverse (H' = 3.27 and 3.21 respectively), while zone two had the lowest richness and diversity of pollen types (species richness S = 21; H' = 2.57). In general, there was a high uniformity in all the zones J' = 0.89, 0.84, 0.86 and 0.85 (Annex 2).

DISCUSSION

Analysis of vegetation cover and floral composition

Secondary vegetation harbored a large portion of melliferous species richness, with herbs and shrubs predominating in this type of cover, which explains the high representation of these growth habits in the study. Similar results have been reported in municipalities in the central and northern regions of the Cauca department (Sánchez and Burbano, 2010; Montoya *et al.,* 2017). In relation to this, Brosi *et al*. (2008)the most important group of pollinators, to land-use change. In particular, there are no published studies of the effects of tropical forest fragmentation on entire bee communities. 2. We examined bee community responses to forest fragment size, shape, isolation and landscape context (forest variables state that *A. mellifera* shows a greater preference for disturbed areas rather than forested areas.

Crop cover was also important for apicultural production, both for cultivated species and associated weeds or arvense plants, with the latter considered to be of great melliferous value (Grimau *et al.,* 2014; Waykar *et al.,* 2014).

In this study, the Asteraceae and Fabaceae families were the most abundant. Similar results have been reported by Forcone and Muñoz (2009); Montoya *et al*. (2017), González-Suárez *et al*. (2020). According to Nates-Parra *et al*. (2013), these families are among the most important for *A. mellifera* in different regions of the world. The preference by honeybees for these families is due to floral characteristics, such as a supply of nectar, an abundant amount of pollen per floral unit, and easy access and the manipulation of the anthers (Chamorro *et al.,* 2017).

Offered resources

The period between June and August showed the lowest flowering of melliferous species, which coincided with the lowest precipitation in the study area. A similar result was reported by Vivas-Quila *et al*. (2008), who identified these months as critical for beekeeping production in the municipality of Popayán due to decreased rainfall. A similar pattern has been documented in other parts of the world, such as India and México (Waykar and Baviskar, 2015; González *et al.,* 2023).

The peak flowering coincided with the rainy season in the region (September-December). However, despite the availability of floral resources, they could not be optimally exploited by *A. mellifera* due to the high precipitation recorded in the study area. According to Waykar and Baviskar (2015), the foraging activity of honeybees is closely influenced by weather conditions, primarily rainfall and wind. This highlights the importance of developing planned and climate-resilient beekeeping practices, which involves maintaining diversified vegetation cover around apiaries to ensure the availability of quality resources throughout the year, especially during adverse periods for production (Vivas-Quila *et al.,* 2008; Waykar and Baviskar, 2015).

Regarding the available resources, the group of nectar-polliniferous species was predominant in this study, similar results were reported in the works of Waykar *et al*. (2014); Insuasty-Santacruz *et al*. (2016); Montoya *et al*. (2017) suggesting that *A. mellifera* has a strong preference for plants that offer both floral resources.

The frequency of visits by *A. mellifera* to the flora was mostly classified as medium. This result was because the majority of plants were reported as sustaining species, which are exploited less frequently and intensively by honeybees. Similar results were recorded by Sánchez and Burbano (2010) and Montoya *et al*. (2017) in the Cauca Department. In this regard, Forcone and Muñoz (2009)Argentina. With the aim of surveying the availability of sources of nectar and pollen in the northwest of Santa Cruz, the flowering phenology of 113 species from Los Antiguos Valley was recorded. The plants studied belonged to 36 families, from which the most represented in the flowering offer were Asteraceae, Fabaceae, Brassicaceae and Rosaceae. Of the total species surveyed, 47 are native, 40, naturalized and 26 cultivated. Peak flowering was registered at the end of November and beginnings of December with the maximum number of species in full flowering. Introduced plants dominated the flowerings during most of the apicultural period, except in the second half of October and during November, when native plants prevailed. Thirty-two species frequently visited by Apis mellifera L. were registered, three of them belonged to characteristic flora from the steppe: Mulinum spinosum (Cav. express that *A. mellifera* visits a large number of plants but focuses its foraging effort on very few species, especially during periods of abundance when it is highly selective.

The plant species with the highest frequency of visits in this study differed from those reported by Sánchez and Burbano (2010) and Montoya *et al*. (2017). This can be explained according to Bänsch *et al*. (2020)in particular as wild pollinators are in decline. Temporal and spatial variation of flower resources affects foraging decisions of wild and honey bees. To optimise crop pollination management a better understanding of potential competition for pollinators in mass- and minor-flowering crops is needed. We combined waggle dance decoding, pollen load analysis and field surveys to identify the habitat preferences and pollen use of honey bees in response to spatio-temporal changes in resource availability. Observation hives were placed on the edge of eleven fields of blooming strawberries (mean 2.24 ha because bees exploit resources differently in each site, with foraging activity being conditioned by resource availability in the landscape and its accessibility (distance from the apiary and climatic conditions).

When evaluating the sugar concentration in nectar, the highest grouping range was between 21 to 60 degrees Brix. To this, Roubik and Buchmann (1984)tribe Meliponini state that *A. mellifera* prefer nectars with higher sugar concentration due to the caloric reward they obtain from their search.

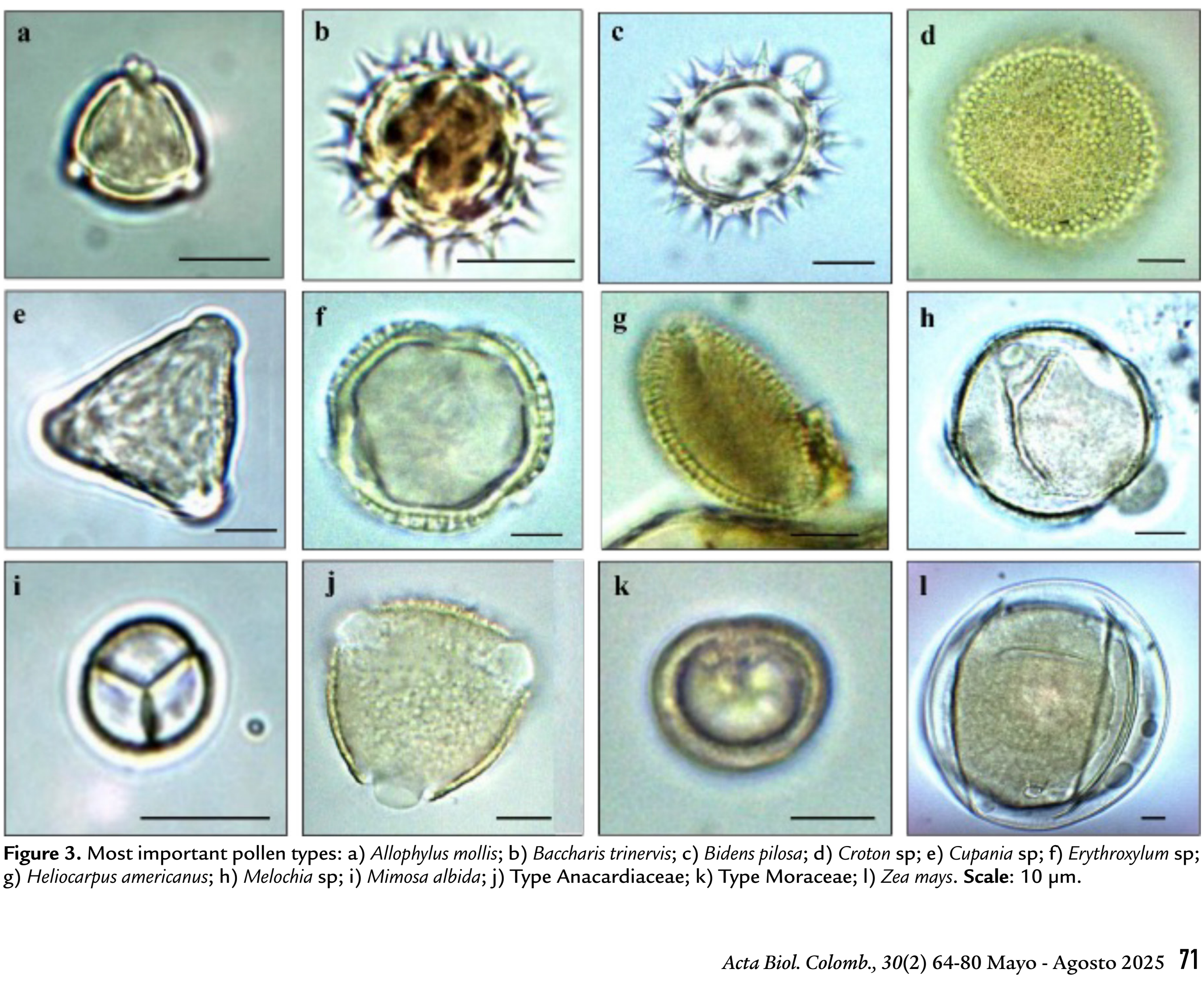

Figure 3. Most important pollen types: a) *Allophylus mollis*; b) *Baccharis trinervis*; c) *Bidens pilosa*; d) *Croton* sp; e) *Cupania* sp; f) *Erythroxylum* sp; g) *Heliocarpus americanus*; h) *Melochia* sp; i) *Mimosa albida*; j) Type Anacardiaceae; k) Type Moraceae; l) *Zea mays*. **Scale**: 10 µm.

Table 2. Hutcheson t test for each pair of assessed altitude ranges.

Altitude m. a. s. l.	1801-2000	2001-2200	2201-2400
1600-1800	3.27 2.57 P<0.001	3.27 2.95 P<0.001	3.27 3.21 p>0.01
1801-2000		2.57 2.95 P<0.001	2.57 3.21 P<0.001
2001-2200			2.95 3.21 P<0.001
2201-2400			3.21

On the other hand, the record of sugar concentration for the extrafloral fluid of *Z. mays* is not new, despite being widely recognized as a polliniferous species. Authors such as Castellanos-Potenciano *et al*. (2012) have documented reports of this species as nectariferous due to sugars that accumulate at the base of the leaves, which are occasionally exploited by honey bees.

In this study, weed flora was mostly classified as sustaining species due to their ability to produce flowering in any month of the year. These results are consistent with those obtained by Waykar *et al*. (2014) who reported that weed plants represent a constant source of resources during periods of low nectar and pollen flow. According to Silva and Restrepo (2012), supporting species are essential for beekeeping since they favor hives in obtaining food for sustenance during critical or scarcity periods.

As for the nectar and pollen harvesting species, these were mainly present in cultivated areas and secondary vegetation, highlighting *C. arabica, Erythroxylum* sp., I. *densiflora, P. americana,* and *T. diversifolia*. These species play a key role in honey production for the region. In this sense, Sánchez (1995) and Sánchez and Burbano (2010) validate the role of crops as abundant sources of resources, from which hive products are derived. In the same vein, Bänsch *et al.* (2020) argue that honeybees prefer to forage in sites with a high density of flowers, for example in crops, from which they can obtain a greater amount of pollen and nectar.

Species with high beekeeping value such as *S. sodiroi*, *C. gossypiifolius*, *M. albida*, *H. americanus*, *A. mollis* and *B. ulmifolia* were found mainly in secondary vegetation, reaffirming the importance of this cover for bee production, these results coincide with those reported by Montoya *et al*. (2017) and González-Avilés *et al*. (2023) who reported this cover as one of the most diverse and with species of high beekeeping value, harboring herbs, shrubs and small trees. This heterogeneity broadens the floral offer for *A. mellifera*.

A. mollis and *B. ulmifolia* are newly reported as melliferous. These two species belong to genera that have already been referenced as important in beekeeping, Valandia *et al*. (2012) reported the species *Banara guianensis* Aubl. as a key species for production in Cauca and Huila. Similarly, Méndez *et al*. (2021) reported *Allophylus edulis* Radlk. ex Warm. as the most important resource for bees in a locality in Argentina.

Botanical origin

The results of the melissopalynological analysis are consistent with the floristic inventory, in which species from the Asteraceae, Fabaceae, and Malvaceae families showed higher species richness. In particular, the first two families have been consistently reported as representative in honey samples due to their diversification in the American tropics (Caccavari and Fagúndez, 2010; Nates-Parra *et al.,* 2013; Montoya-Pfeiffer *et al.,* 2014; Muñoz-Galíndez, 2022).

Notably, the pollen types from the families Anacardiaceae, Moraceae, Arecaceae and Cyclanthaceae identified in the melissopalynological analysis were not reported in the floristic inventory. This could be related to the origin of the honey samples taken from 28 apiaries, while the floristic inventory was done in eight apiaries, indicating the need to sample other areas to gain a more comprehensive understanding of the regional bee flora.

The diversity of pollen types observed in the analyzed samples demonstrates the generalist habit of *A. mellifera*, which has been documented by other authors in the Andean ecosystems of Colombia (Nates-Parra *et al.,* 2013; Chamorro *et al.,* 2017; Casas-Restrepo *et al.,* 2021)Cundinamarca, Santander and Magdalena, by its geographical and botanical origin. Melissopalynological analyses were made of 184 honey samples obtained from 131 localities. A discriminant analysis and comparisons between the species composition of honey samples were made to find geographical and botanical origin differences. A total of 297 pollen species distributed in 69 families was found, being Mimosa sp., Cecropia sp., Eucalyptus sp., Piper sp. and Quercus humboldtii the most representatives. The major families were Fabaceae, Asteraceae, Myrtaceae, Rubiaceae, Fagaceae and Melastomataceae. Six honey groups differentiated by its geographical origin were found: Altiplano Cundiboyacense, Medio Chicamocha, Sumapaz, Bajo Chicamocha, Sierra Nevada de Santa Marta and Comunera Province. In a broader scale, honeys from the Andean and sub-Andean regions could be differentiated as well. Between the honey types differentiated by its botanical origin, the most important were monofloral honeys of Trifolium pratense, Coffea arabica, Eucalyptus sp., Inga sp. and Heliocarpus americanus, Asteraceae oligofloral honeys and mixtures of Q. humboldtii honeydew and floral nectar (Eucalyptus sp., Brassicaceae Type, Asteraceae.

Types such as *Mimosa albida*, *B. trinervis*, *A. mollis*, *Cupania* sp. were among the most abundant and frequent along the entire altitudinal gradient, being very common floristic components in the region, mainly associated with secondary vegetation cover. These species were important for obtaining monofloral and multifloral honey in the study area.

The lower richness and diversity of pollen types in zone two (1801- 2000 m. s. n. m.), concerning other zones, can be explained by the fact that in this altitudinal band, the highest number of monofloral samples were obtained, in which Moraceae type one, *H. americanus* and *Croton* sp. pollen were particularly abundant.

In this study *H. americanus y Croton* sp. were recorded in stubble cover and early secondary forests, presenting prolonged flowering cycles, and offering mainly nectar to *A. mellifera*. This finding highlight the high potential of this altitudinal zone for the monofloral honey production of *H. americanus*, a species that has been referenced as distinctive distinctive from the sub-Andean region of Colombia (Nates-Parra *et al.,* 2013).

Other important species for obtaining honey were *A. mollis* and *Cupania* sp., in this regard, **Méndez et al.**, (2021) reported the Sapindaceae family as a key for beekeeping production, *Allophylus* is considered one of the genera with the highest melliferous value in localities of Argentina and Brazil.

M. albida has been reported in monofloral and multi floral honey specifically in the municipalities of Totoró and Piendamó in the department of Cauca. Additionally, in these same honey samples, *B. trinervis* was found to be present as a secondary component (Muñoz-Galíndez, 2022).

Finally, regarding the identification of monofloral honey from *Erythroxylum* sp. in zone four, this finding offers an opportunity for further studies to characterize it, given the Colombian government's current interest in regulating alternative uses of the coca plant.

CONCLUSIONS

The Colombian Massif has a variety of vegetation cover types that support beekeeping, with secondary vegetation and crops being particularly important for hosting the highest diversity of bee-flora species. The families with the highest species richness, both in the floristic study and in the melissopalynological analysis, were Asteraceae, Fabaceae, and Malvaceae, from which both monofloral and multifloral honey were obtained.

The high number of nectar- and pollen-producing species reported indicates the potential of the region for pollen and honey production. *Allophylus mollis* is considered a key native species in the beekeeping production of the area, as it was the most frequently visited by *A. mellifera* and had the highest sugar concentration in its nectar. Additionally, its pollen was classified as frequent in honey samples, appearing in 22% of total analyzed samples.

The melissopalynological analysis shows the influence of the native flora in the botanical composition of the honeys of the Colombian Massif. Some monofloral honey samples revealed difficulties in determining the associated pollen types, such as the Moraceae type and Anacardiaceae types, which requires continuing with botanical characterization of honey in the region.

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AUTHOR'S PARTICIPATION

Both authors contributed equally to the production of the article:

Contributions A.A.C.: Conceptualization; Methodology; Writing - original draft - review & editing; Supervision; Project administration. D.A.V.P.: Data curation; Formal analysis; Investigation; Writing - original draft - review & editing; Prepared all figures. J.L.T.C.: Conceptualization; Writing - original draft - review & editing; Managed funding.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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Annex 1. Inventory of honey plant species in Almaguer and La Vega, Cauca, Colombia.

Common name	Family	Specie	GH[1]	O	C	AF	OR	AI
Insulina	Acanthaceae	*Justicia secunda*	SH	NA	CR	1	N	S
Nacedero		*Trichanthera jigantea*	T	NA	F	2	N/P	S
Moco	Actinidiaceae	*Saurauia scabra*	T	NA	F	4	N/P	S
Mango	Anacardiaceae	*Mangifera indica*	T	I	CR	1	N	S
Botoncillo	Asteraceae	*Acmella oppositifolia*	H	NA	CR	4	N/P	BV
Hierba de chivo		*Ageratum conyzoides*	H	NA	CR	1	N	BV
Salvia amarga		*Austroeupatorium inulifolium*	SH	NA	SV	7	N/P	S
Chilca		*Baccharis latifolia*	SH	NA	SV	2	N	S
Chilca rusia		*Baccharis nitida*	SH	NA	SV	1	N	S
Armanga		*Baccharis trinervis*	SH	NA	SV	3	N/P	S
Pacunga		*Bidens pilosa*	H	NA	CR	8	N/P	C
Chicharrón		*Calea sessiliflora*	SH	NA	SV	2	N/P	S
Salvia morada		*Chromolaena tacotana*	SH	NA	SV	2	N	S
Yerba de puerco		*Elephantopus mollis*	H	NA	CR	1	N	BV
Lechuguilla		*Emilia sonchifolia*	H	NA	CR	7	N/P	S
Guasca		*Galinsoga quadriradiata*	H	NA	CR	3	N/P	BV
Diente de león		*Hypochaeris radicata*	H	I	CR	5	N/P	S
Margarita		*Leucanthemum vulgare*	H	I	CR	2	N/P	BV
Botoncillo		*Melampodium divaricatum*	H	NA	CR	3	N/P	BV
Candelillo		*Pseudelephantopus spiralis*	H	NA	CR	2	N	BV
		Sigesbeckia jorullensis	H	NA	CR	1	N/P	BV
Mariposo		*Steiractinia sodiroi*	SH	NA	SV	6	N/P	C
		Stevia ovata	H	NA	SV	1	N	BV
Ruda de gallinazo		*Tagetes apetala*	H	NA	G	2	N	BV
Diente de león		*Taraxacum officinale*	H	I	CR	1	N/P	S
Botón de oro		*Tithonia diversifolia*	SH	I	CR	5	N	C
Clavelón		*Zinnia peruviana*	H	NA	CR	1	N/P	BV
Falso guácimo	Cannabaceae	*Trema micrantha*	T	NA	CR	1	P	S
Nogal cafetero	Cordiaceae	*Cordia alliodora*	T	NA	CR	1	N	S
Palo negro		*Cordia cylindrostachya*	SH	NA	SV	2	N	BV
Encino	Cunoniaceae	*Weinmannia pubescens*	T	NA	F	1	N	C
Paja estrella	Cyperaceae	*Rhynchospora nervosa*	H	NA	G	4	N	S
Carbonero frio	Ericaceae	*Befaria mathewsii*	SH	NA	SV	1	N	BV
Coca	Erythroxylaceae	*Erythroxylum* sp.	SH	NA	CR	3	N	C
Chilco rojo	Escalloniaceae	*Escallonia paniculata*	SH	NA	SV	5	N	S
Sangregado	Euphorbiaceae	*Croton gossypiifolius*	SH	NA	SV	5	N/P	C
Sangregado		*Croton hibiscifolius*	SH	NA	SV	1	N/P	S
Lechero		*Euphorbia laurifolia*	SH	N	SV	1	N/P	BV

(*Continue*)

Common name	Family	Specie	GH[1]	O	C	AF	OR	AI
Algarrobo	Fabaceae	*Acacia angustissima*	SH	NA	SV	2	N/P	S
Guandul		*Cajanus cajan*	SH	I	CR	1	N	S
Carbonero		*Calliandra pittieri*	T	NA	G	2	N/P	S
Chachafruto		*Erythrina edulis*	T	NA	CR	1	N	S
Guamo macheto		*Inga densiflora*	T	NA	CR	6	N/P	C
Guamo churimbo		*Inga edulis*	T	NA	CR	2	N/P	C
Leucaena		*Leucaena leucocephala*	T	NA	CR	1	N/P	S
Sarza		*Mimosa albida*	SH	NA	SV	7	P	C
Guarango		*Mimosa quitensis*	SH	NA	G	3	P	S
Vainillo		*Senna papillosa*	T	NA	F	2	P	BV
Roble	Fagaceae	*Quercus humboldtii*	T	NA	F	1	P	S
Cargadita	Lamiaceae	*Hyptis atrorubens*	H	NA	CR	6	N	S
Zanca de mula		*Hyptis mutabilis*	H	NA	R	2	N	S
Jigua	Lauraceae	*Nectandra reticulata*	T	NA	F	1	N	BV
Aguacate		*Persea americana*	T	I	CR	2	N	C
Escobilla	Lythraceae	*Cuphea racemosa*	H	NA	G	5	N	BV
Guayacán de Manizales		*Lafoensia acuminata*	T	NA	G	4	N/P	S
Resucitado campana	Malvaceae	*Abutilon insigne*	SH	I	CR	3	N/P	S
Balso blanco		*Heliocarpus americanus*	T	NA	SV	7	N	C
Campanilla		*Pavonia mutisii*	SH	NA	SV	1	N/P	S
Escoba babosa		*Pavonia paniculta*	SH	NA	SV	2	N/P	BV
Escoba		*Sida rhombifolia*	H	I	CR	8	N/P	S
Escoba		*Sida spinosa*	H	I	CR	2	N/P	S
Mortiño	Melastomataceae	*Miconia aeruginosa*	SH	NA	SV	3	P	S
Morochillo		*Miconia caudata*	T	NA	SV	2	N/P	S
Morochillo blanco		*Miconia stenostachya*	SH	NA	SV	5	N/P	S
Siete cueros		*Miconia theizans*	SH	NA	SV	5	N	S
Oreja de ratón		*Tibouchina longifolia*	H	NA	SV	1	N/P	BV
Eucalipto rojo	Myrtaceae	*Eucalyptus camaldulensis*	T	I	CR	1	N/P	S
Eucalipto		*Eucalyptus grandis*	T	I	CR	2	N/P	S
Arrayán		*Myrcia popayanensis*	T	NA	G	5	N	C
Guayabo agrio		*Psidium guineense*	SH	NA	SV	3	N/P	S
Pomorroso		*Syzygium jambos*	T	I	CR	2	N	S
Cordoncillo	Piperaceae	*Piper aequale*	SH	NA	F	1	P	S
Cordoncillo		*Piper aduncum*	SH	NA	SV	2	P	S
Pasto braquiaria	Poaceae	*Brachiaria decumbens*	H	I	G	4	N/P	C
Yaraguá		*Melinis minutiflora*	H	I	G	1	P	S
Maíz		*Zea mays*	H	I	CR	2	P	C
Ulluquillo	Polygonaceae	*Polygonum nepalense*	H	I	CR	3	N	S
Blanquita		*Persicaria punctata*	H	NA	CR	1	N	BV
Cucharo blanco	Primulaceae	*Myrsine coriacea*	SH	NA	SV	2	P	BV
Cucharo		*Myrsine guianensis*	T	NA	SV	1	P	S

(*Continue*)

Common name	Family	Specie	GH[1]	O	C	AF	OR	AI
Mispero	Rosaceae	*Eriobotrya japonica*	T	I	CR	1	N	S
Mora de monte		*Rubus cf. urticifolius*	H	NA	SV	4	N/P	S
Mora de castilla		*Rubus glaucus*	SH	NA	CR	1	N/P	S
Frambuesa		*Rubus rosifolius*	H	I	SV	1	N/P	S
Cascarillo	Rubiaceae	*Cinchona pubescens*	T	NA	F	1	N	S
Café		*Coffea arabica*	SH	I	CR	5	N	C
Cascarillo negro		*Macrocnemum pubescens*	T	NA	F	2	N	S
Ojo de pava		*Palicourea cf. Thyrsiflora*	SH	NA	F	2	N	BV
Estrellita		*Richardia scabra*	H	NA	CR	3	N	S
Borreria		*spermacoce remota*	H	NA	CR	3	N	S
Montesito		*Spermacoce cf. capitata*	T	NA	CR	3	N	S
Limón	Rutaceae	*Citrus limon*	SH	I	CR	3	N/P	S
Naranja		*Citrus sinensis*	T	I	CR	1	N/P	S
Ratoncillo	Salicaceae	*Banara cf. ulmifolia*	SH	NA	F	4	N/P	C
Mote	Sapindaceae	*Allophylus mollis*	T	NA	F	2	N	C
Mestizo		*Cupania latifolia*	T	NA	F	2	P	S
Yarumo	Urticaceae	*Cecropia ulmifolia*	T	NA	SV	1	P	S
Pendo	Verbenaceae	*Citharexylum* kunthianum	SH	NA	SV	2	N	S
Venturosa		*Lantana camara*	SH	NA	SV	3	N	S
Murupacha		*Lantana hirta*	SH	NA	SV	1	N	BV
Murupacha		*Lantana cf. trifolia*	SH	NA	SV	2	N	S
Verbena negra		*Stachytarpheta cayennensis*	H	NA	CR	5	N	S
Verbena blanca		*Verbena litoralis*	H	NA	CR	1	N	S

[1]GH: Growth habit; T: Tree; SH: Shrub; H: Herb. O: Origin; NA: Native; I: Introduced. C: Coverage; F: Forest; CR: Crop; G: Grassland; SV: Secondary vegetation. AF: Absolute Frequency (number of apiaries where the species was found); OR: Offered resource; N: Nectar; P: Pollen; N/P: Nectar and Pollen; AI: Apicultural Importance; BV: Low value; S: Sustenance; C: Harvest.

Annex 2. Types of pollen and their abundance and frequency relative in the 36 honey samples analyzed in Almaguer and La Vega, Cauca, Colombia.

Family	Pollen Types	I	II	III	IV	RFO	FC
Anacardiaceae	Type 1		5.66	8.88	1.00	11	LF
	Type 2				9.09	3	R
Arecaceae	Type 1				5.18	6	R
	Type *Bactris*	3.52				3	R
	Geonoma interrupta	3.52				3	R
	Austroeupatorium inulifolium		1.46	7.83	1.15	11	LF
	Acmella ciliata	4.96		2.26	0.64	11	LF
	Baccharis trinervis	5.81	5.08	4.83	6.39	31	F
	Bidens pilosa	9.30	8.67	3.71	0.67	25	F
	Type *Critonia*				1.36	3	R
	Eirmocephala brachiata				0.33	3	R
	Emilia sonchifolia				2.06	6	R
	Hypochaeris radicata	4.44			2.73	11	LF
	Lepidaploa canescens				1.36	3	R
	Type *Mikania*				0.70	3	R
	Vernonanthura patens				0.33	3	R
Cannabaceae	*Trema micrantha*				3.64	3	R
Cyclanthaceae	*Carludovica palmata*	3.56		7.42	0.06	11	LF
Dillinaceae	*Davilla kunthii*	3.93				3	R
Erythroxylaceae	*Erythroxylum* sp.	1.00			9.70	14	LF
Escalloniaceae	*Escallonia paniculata*	1.44		0.67		8	R
Euphorbiaceae	Euphorbia hirta				0.36	3	R
	Ricinus communis	2.59		2.25	1.67	11	LF
	Sapium glandulosum	1.30		0.50		6	R
	Type *Croton*	2.11	9.79	0.50	1.21	19	LF
Fabaceae	*Aeschynomene americana*				0.91	3	R
	Gliricidia sepium		1.37			3	R
	Mimosa albida	10.26	2.12	5.75	5	28	F
	Phaseolus vulgaris	2.52				3	R
	Type *Acacia*	0.22				3	R
	Type *Inga*		0.33		1.15	6	R
	Type *Mimosa*			0.13		3	R
	Type *Senna*			0.13		3	R
	Type *Trifolium*	2.52				3	R
	Type 1				0.06	3	R
Lamiaceae	*Hyptis mutabilis*				0.36	3	R
	Type *Salvia*				2.91	6	R
Lauraceae	*Persea americana*	0.63		2.92		8	R
Malvaceae	*Guazuma ulmifolia*	1.30				3	R
	Heliocarpus americanus	1.30	14.0	0.46	3.61	22	F
	Type *1*	1.00			1.82	6	R
	Type *Corchorus*	0.22	2.29			6	R
	Type *Hibiscus*				0.91	3	R

(*Continue*)

Family	Pollen Types	I	II	III	IV	RFO	FC
	Type *Melochia*	0.44	7.92	0.33	0.97	17	LF
	Type *Sida*	1.30	2.29			6	R
Melastomataceae	Type *1*	3.93		3.50		11	LF
	Type *Miconia* sp.1			0.33		3	R
	Type *Miconia* sp. 2			0.75		3	R
Moraceae	Type *1*	0.41	19.7	2.25	12.4	25	F
	Type *Trophis*			0.08		3	R
Myrtaceae	*Myrcia splendens*	0.48		1.29		6	R
	Syzygium jambos	0.48		1.29		6	R
	Type *Myrcia*				1.03	3	R
Oleaceae	*Fraxinus chinensis*	1.22	0.50	2.25	1.21	14	R
Poaceae	*Holcus lanatus*	1.07		12.3		6	R
	Pennisetum purpureum			0.54		6	R
	Zea mays		3.67	0.04	8.33	6	R
Proteaceae	*Roupala montana*		0.1			3	R
Rosaceae	*Type Rubus*	0.33				3	R
Rubiaceae	*Coffea arabica*				2.03	3	R
	Spermacoce verticillata				0.18	3	R
	Type *Spermacoce*	0.22	1.54		0.12	11	LF
	Warszewiczia coccinea	0.22			0.91	6	R
Rutaceae	Type *Citrus*			4.17		3	R
Sapindaceae	*Allophylus mollis*	7.37	5.63	8	3.97	22	F
	Type 1	2.22		0.67	1.76	8	R
	Type 2	2.89				3	R
	Type Cupania	5.70	6.5	5.67	6.52	28	F
	Type *Paullinia*	2.89			0.33	6	R
Solanaceae	*Brugmansia pittieri*	0.07				3	R
Urticaceae	Type *Cecropia*		1.38		2.18	6	R
Vitaceae	*Vitis tiliifolia*	1.30				3	R
Total pollen grains		2700	2400	2400	3300	10800	
Pollen types richness		40	21	31	42	72	
Shanon–Wienner		3.27	2.57	2.95	3.21		
Pielou		0.89	0.84	0.86	0.85		

[1] Relative abundance (RA) (I–V): I: zone one (1600–1800 m. a. s. l); II: zone two (1801–2000 m. a. s. l); III: zone three (2001–2200 m. a. s. l); IV: zone four (2201–2400 m. a. s. l); RFO: Relative frequency of occurrence; FC: Frequency class: F: Frequent; LF: Low frequent; R: Rare.