RESEARCH ARTICLE

Between flowers, humans, and honeybees: Local ecological knowledge associated with apiculture in two areas of Silípica department, Santiago del Estero, Argentina

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The production of honey for consumption is one of humans' most intriguing activities in biocultural terms. Studies on Local Ecological Knowledge linked to Apiculture with *Apis mellifera* (LEKHA) are limited, particularly in Santiago del Estero (northern Argentina). In this work, we compared the LEKHA of beekeeping families in two different landscapes that show distinct socio-ecological characteristics: "rainfed" and "irrigation." Through semi-structured and free interviews and the construction of local calendars, together with 85% of the beekeepers of these zones, we investigated the LEKHA, honeybee flora and methods of acquisition and transmission of management knowledge and practices. Participants mentioned 96 honeybee flora species (63 in rainfed and 71 in irrigation), mainly native species, which provide with nectar and pollen. The apicultural and floral calendar was similar in these two areas, although the areas differed in the time of year certain activities were carried out and the richness and abundance of plant strata. This similarity could be related mainly to the strong cultural attachment of inhabitants to some elements of their native "Monte" landscape which, despite having undergone some anthropic modifications, remains functional for beekeeping. The LEKHA in both areas was learned idiosyncratically and by oblique transmission. We show how an activity related to the environment recreates and stimulates environmental knowledge, such that flowers, honeybees, and people form a bond of mutual care.

Keywords: Apiculture, Social learning, Floral calendar, Honeybee flora, Family agriculture

Introduction

Beekeeping with *Apis mellifera* L. has been a key activity for humanity since about 3000 BCE (Kritsky, 2017), constituting a rich source of nutritious food, medicines, and raw materials for industry (Lietaer, 2009), and even attaining mythical and religious symbolism (Fernández Uriel, 1988; Bradbear, 2004). Despite its enormous cultural and economic importance, the current decline in commercial bee colonies is currently the subject of a global alert—even the highly technical beekeeping production is being affected (Dahlgreen, 2014; Andrews, 2019; Cilia, 2020). Bees are under threat from several factors: changes in land use, the use of herbicides and pesticides (Piffero Câmara, 2019; Cilia, 2020; Bloom et al., 2021), and climate change (Wolowski et al., 2019; Cilia, 2020; DiDonato and Gareau, 2022), among others.

The theoretical framework that enables us to evaluate the relationship between beekeepers and the landscape is the Local Ecological Knowledge associated with Honeybee Apiculture (LEKHA). We are particularly interested in LEKHA, as part of Local Ecological Knowledge, which has been defined as a cumulative body of knowledge, practices, and beliefs associated with the relationship between human beings and their environment, which evolves by means of adaptive processes and is transmitted culturally from one generation to the next (Berkes et al., 2000). In particular, LEKHA comprises a set of specific knowledge that includes the recognition of honeybee plants and practices to manage honeybees (Carrizo et al., 2015; Cilla et al., 2018).

Smallholder beekeepers manage their environment and resources with LEKHA, a holistic, dynamic set of information that brings together local experiences, values, and perceptions (Toledo and Barrera-Bassols, 2009; Ladio, 2017). However, little attention has been paid to the role of LEKHA in shaping individuals' perceptions and responses to environmental change. The focus on LEKHA held by small-scale producers working on marginal lands

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and relying mainly on traditional practices and knowledge is crucial because of their direct dependence on the environment for survival.

In the semiarid Chaco region, a xeric area of Northwest Argentina, the province of Santiago del Estero (Argentina), and in particular the region of Silípica, beekeeping is an important sociocultural activity performed by small producers with a subsistence economy (Cilla et al., 2018; Céspedes et al., 2021). The region presents two landscapes which differ in agronomic terms: one with no irrigation, called the rainfed area, and the other irrigated by channels, known as the irrigation area (Caumo et al., 2014; Angella, 2015).

In the rainfed areas, there are predominantly family subsistence livestock farms, mainly goats and pigs (Alberti and Martínez, 2011). The area has landscapes with strong environmental pressures due to overgrazing and deforestation for firewood and charcoal production, defining a floristic composition in which only certain native tree and shrub species predominate. In the case of the irrigated area, the main activity of the family farms is irrigated agriculture. The main crops grown are alfalfa, squash, and watermelon, as well as onions and sweet potatoes, among other vegetables (Paz, 2018; Schefer, 2019). Thus, natural and anthropogenic vegetation, mainly herbaceous, coexist in irrigated landscapes. The differences in productive activities, landscape, and dominant species lead us to ask how these bioculturally contrasting environments are reflected in the knowledge of honeybee flora and apiary management.

In both areas, beekeeping is a growing activity supported by the government. Beekeeping provides nutritious products such as honey, beeswax, royal jelly, and propolis. In addition, the sale of these honeybee products provides a complementary source of income for the small farmers who live in both areas (Céspedes et al., 2021). However, controversy has been raised about the negative impact of honeybee keeping on the native bees and on the native vegetation (Mallinger et al., 2017). Therefore, it is necessary to use responsible and sustainable beekeeping practices that are in harmony with conservation (Alaux et al., 2019).

Comparative studies of LEKHA in bioculturally contrasting environments are scarce, and have shown the influence of multidimensional factors. May and Rodríguez (2012a) found that beekeepers place great importance on the role of honeybee flora in the activity, depending on the level of modification of the environment and the subsistence activities which are carried out. Thus in this way, people who live in better conserved areas value forest species most, whereas those who live in areas with more intense agricultural activity value the crops and their associated species most.

Most studies on local ecological knowledge about apiculture have focused on native social native bee species (meliponas) in indigenous and rural societies (Posey, 1983; Nogueira-Neto, 1997; Costa Neto and Olivera, 2000; Costa-Neto, 2002; Vit et al., 2004; Modro et al., 2009; Medrano and Rosso, 2010; Zamudio et al., 2010; Zamudio and Hilgert, 2011; Kamienkowski and Arenas, 2012; Kujawska et al., 2012; Flores, 2017; Geisa and Hilgert, 2019). Except for a few studies (Modro et al., 2009; Zamudio, 2012; García et al., 2019), little attention has been paid, from an ethnobiological perspective, to apiculture with "foreign" species like *A. mellifera*. This species has been studied mainly with an agronomic and productivist approach (Lema and Delgado, 2000; Centro Regional de Estudios Económicos de Bahía Blanca [CREEBBA], 2003a, 2003b, 2005, 2006a, 2006b, 2008; Goslino, 2011; Frígoli, 2013; Travadelo et al., 2014; Sáez et al., 2015; Goslino, 2017; Sáez et al., 2017).

In Santiago del Estero, with regard to LEKHA, three studies were carried out in different areas of the province: two by Palacios and collaborators (2017; 2018) and one by Cilla and collaborators (2018), which analyze knowledge of the honeybee flora richness. However, integration of the sociocultural and vegetational aspects has been little considered, particularly in terms of the knowledge, perception and practices held by small farmers in distinct socio-environments (Adal et al., 2015).

LEKHA is central to beekeepers (Silva and Restrepo, 2012). They acquire knowledge and familiarity with their environment and establish personal relationships with plants and honeybees every day of their lives. Thus, the diversity and dominance of honeybee flora species, variations in their availability throughout the year, the flowering calendar, and the different habitats in which they grow are focal areas of their knowledge (Kumsa and Takele, 2014; Coh-Martínez et al., 2019). All these experiences are acquired through different mechanisms of learning and social transmission of the information (Lozada et al., 2006; Park and Youn, 2012; Uchiyama et al., 2017). There are different models of cultural transmission and learning of local ecological knowledge about apiculture (Zamudio, 2012). Enabling (idiosyncratic learning) and enculturation can principally take place vertically, horizontally, or obliquely (Cavalli-Sforza et al., 1982; Hewlett and Cavalli-Sforza, 1986). Vertical enculturation of knowledge refers to the transmission of knowledge from parents to children, horizontal when it occurs between peers of the same generation and oblique when it is between people of different generations (Hewlett and Cavalli-Sforza, 1986).

The main questions were: What does the beekeepers' LEKHA consist of? Is the same honeybee flora cited by beekeepers in the rainfed and irrigation areas? What is the cultural importance of honeybee flora for beekeepers? Does the cultural significance of honeybee species differ between areas? What are the practices and how are the apiaries organized during the apicultural calendar in each area? How is flowering temporally structured in each area according to the beekeepers' LEKHA? How is knowledge of LEKHA acquired and transmitted among beekeepers?

Materials and methods

Study area

Silípica department is situated in the west Mediterranean semiarid region of Santiago del Estero, Argentina (27° 58′–28° 20′ S and 64° 05′–64° 34′ W) (**Figure 1**). The vegetation corresponds to the Forest–Shrub complex of the Centre of the Semiarid Chaco subregion (Morello et al., 2012), locally called "Monte," composed of a mosaic

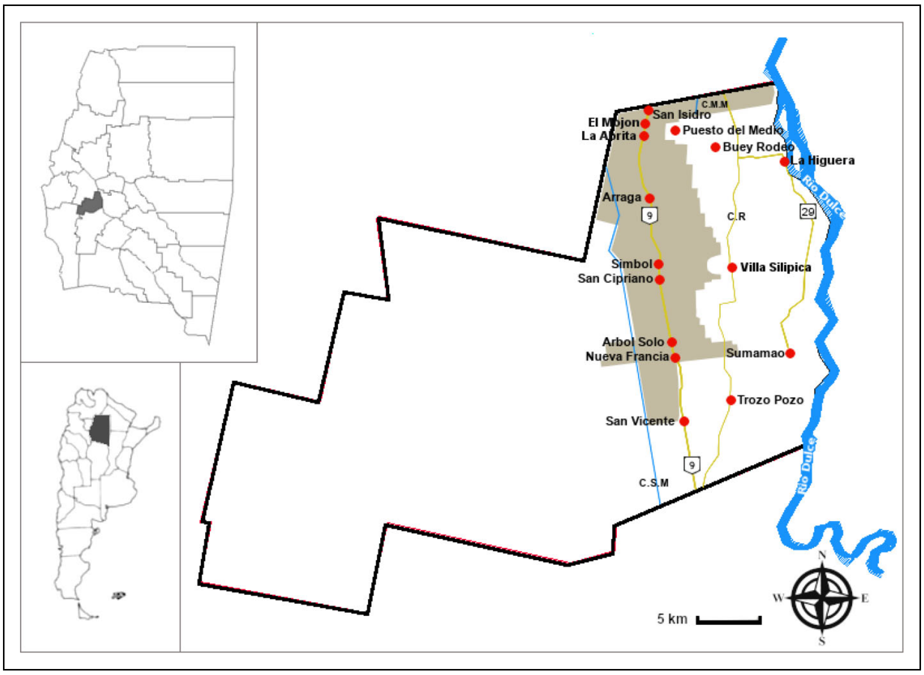

Figure 1. The Silípica department (Santiago del Estero, Argentina) and its rainfed and irrigated areas. Location of the apiaries: the area under irrigation is indicated in grey (C.S.M: San Martín irrigation channel, C.M.M: Maco-Manogasta irrigation channel, C.R: royal road), the area with no color corresponds to the rainfed area.

of xeric secondary forests alternating with the xeric forests of the alluvial plains which they came from. It is also composed of high open savannahs that do not flood, broken by patches of cultivated land and relatively isolated patches of forests in well-drained soils.

According to the Thornthwaite (1948) classification, the climate is type DB′4 da′, semiarid, with little or no excess water, high mesothermal. Annual average precipitation is 552 mm, with rainfall from the second half of spring to the end of summer; the hydric balance has a higher deficit from June to August, reaching negative values (Angueira and Zamora, 2007).

The Silípica department is the smallest district of the province of Santiago del Estero, covering 0.7% of its total surface area (Basualdo, 1981), and has the smallest population (7,700 inhabitants), representing 0.8% of the total population of the province (Instituto Nacional de Estadísticas y Censos, 2010) (**Figure 1**). The population is mainly concentrated toward the east, close to the Dulce river, where there is a history of settlement dating back to colonial times, when the Royal Road to Upper Peru and the Royal Road of the Incas passed through the area (Di Lullo, 1946). Silípica is one of the 14 bilingual departments where Quechua is spoken alongside Spanish, constituting the demographic base and the historic territorial nucleus of the province of Santiago del Estero (Tasso and Zurita, 2013).

The population profile is that of low-income rural sectors characterized by structural poverty and precarious employment (Ledesma et al., 2011). The region of Silípica is inhabited by families of rural smallholders who own or lease the land, seasonal workers, wage earners with no land, and many people who work in subsistence rural agricultural or non-agricultural activities. The agricultural productive structure reflects the economic context of small, precarious production, partly explaining the seasonal migration from the homes as locals look for work elsewhere, which in some cases generates the only income they can count on (Alberti and Martínez, 2011).

Throughout its history, the department of Silípica has undergone continuous transformation of its landscapes, from disturbed areas to zones where a large part of the forest was eliminated through human intervention (Basualdo, 1981). This can be verified in irrigated areas where the clearance for agricultural lands, followed by intense irrigation, caused salinization and/or alkalinization of sectors of natural forest (Angueira and Zamora, 2007). On the other hand, in the rainfed areas there is strong pressure on the environment both from tree felling and from animal grazing, mainly by goats (Paz, 2018; Schefer, 2019).

This study involved beekeeping families with apiaries installed at fixed sites in the proximity of 15 towns, 9 of which were situated in the rainfed area (La Abrita, Simbol, San Cipriano, Puesto del Medio, Buey Rodeo, La Higuera, Sumamao, and Trozo Pozo), and 6 in the irrigation area (San Isidro, El Mojón, Arraga, Árbol solo, Nueva Francia, San Vicente); 2 apiaries were situated in both types of area (Villa Silípica) (**Figure 1**). Although La Abrita, Simbol, San Cipriano, and Villa Silípica are areas with an irrigation system, the apiaries were installed in areas with no irrigation, on abandoned plots or in patches of relictual native forest (**Figure 1**).

Beekeeping in Silípica is carried out by beekeepers with an average age of 50 years and an average experience of 15 years; they are mainly male (76%). Their level of general and technical education varies, as do their reasons for taking up beekeeping; however, it is mostly a complementary activity and honey is the main product of the hives. Whereas in the rainfed area, the primary activities were livestock breeding (goats, pigs, and poultry) and horticulture (family-run) promoted by state programs; in the irrigation area, the main activities were public employment, agriculture, and commerce. This complementarity is common among apiarists in Argentina (Estrada, 2014). They are all small beekeepers with family production units of up to 5 hectares. The beekeepers have access to floral resources only through their properties. These family units usually contain patches of native vegetation of "Monte" that are key to the activity. Both irrigated and rainfed farmers depend exclusively on their land to develop their beekeeping activity.

Methods

Field work was performed according to the guidelines established by International Society of Ethnobiology (2006) and the Nagoya Protocol (Argentinian National Law N° 27,246) based on the protection of traditional knowledge. We worked with 85% of the apiarists present in the rainfed and irrigation areas of Silípica department. Beekeepers were selected using the "snowball" technique (Albuquerque et al., 2014), in which the selected beekeepers identified new participants among their acquaintances. Informed free consent was obtained from participants before the investigation began, and the objectives of the study were explained.

We visited 17 apiarists between July 2017 and May 2018; 13 men and 4 women participated in the study. In open and semi-structured interviews, we registered general aspects of participants, such as their schooling, type of apiculture training, membership of an apiculture cooperative or group, and other economic activities carried out. The number of apiaries and beehives used per producer was also registered as an indication of productive capacity, considering as apiary each site where a group of beehives was located. Beehives were considered as each of the boxes that housed a swarm of honeybees. The location of the apiaries (the production unit) may or may not coincide with the residence of the producer (domestic unit).

With regard to LEKHA, we registered aspects of knowledge of the honeybee flora (local names, blooming seasons, and resources provided), the cultural importance of apiculture, methods of acquisition and transmission of knowledge, apiary management practices (feeding, giving incentives and supplements to the hives, pest control, harvesting, cleaning of the hive, and hive materials). Each mention was registered according to the site the apiary was installed in (rainfed or irrigation). The interviews were audio-recorded and note-booked. The interviews were conducted in Spanish (the native language of the interviewees). Between two and three visits were made to each interviewee; the duration of each visit varied between 50 minutes and 1 h. Audio recordings and notes were transcribed, and the ethnographic records were then examined and interpreted by the authors.

Data analysis

Information obtained from the interviews was analyzed and interpreted qualitatively and quantitatively. The qualitative approach focused on discourse analysis (Albuquerque et al., 2021). In the discourse analysis, we linked relationships between topics, interviewees, and our field notes obtained by participant observation. The analysis of interviews was based on identifying key testimony to understand the group's central ideas (Guber, 2004). Discourse analysis is based on the fact that individuals who are part of an area or community share beliefs, values, and social representations, so that the analysis of the individual discourse reflects the construction of the collective thinking of the group. Through triangulation of the information, we interpreted the different meanings of what the informants said and did in their own words (emic categories; Guber, 2004).

The emic dimension refers to the way members of a society perceive, structure, classify, and organize their universe, while the etic dimension refers to how the researcher sees a culture different to their own (Posey, 1983). Fragments of participants' comments were selected to visibilize local opinions; the fragments are presented here using the letter P (producer) and a number, which corresponds to the sequence in which the interviews were carried out, from 1 to 13.

To describe LEKHA related to honeybee flora, we considered the variables described below, which were analyzed and classified into distinct categories. We understood honeybee flora to be plant species that produce substances or elements that honeybees collect and use, such as nectar, pollen, and resins (Silva and Restrepo, 2012; Grimaldi et al., 2020). The variables are the following:

a) Honeybee flora richness: The richness of honeybee flora species and botanical families, considering the number of honeybee flora mentioned for each study site (rainfed/irrigation) and the overall total. In order to characterize the botanical composition in etic terms, we classified the honeybee flora by biogeographic origin (native or exotic) and by growth habit (tree, shrub, subshrub, liana, creeper, or herb), according to Zuloaga et al. (2008). Taxonomic identification of the honeybee flora was made by ethnobotanical walking tours (Hersch-Martínez and González Chévez, 1996) and collection of herbarium material for later determination in the laboratory. The samples were placed in the herbarium of the Department of Agricultural Botany of the *Facultad de Agronomía y Agroindustrias, Universidad Nacional de Santiago del Estero.*
b) Floral rewards: Considering the honeybee flora mentioned by participants, the floral resources were classified as nectariferous, which provide nectar; polliniferous, which provide pollen; and nectariferous–polliniferous for plants providing both resources.
c) Cultural importance of honeybee flora: The cultural importance of the honeybee flora for apiculture was estimated using two methodologies. We considered the approach of May and Rodríguez (2012a), named

"*Consensus apicultorum*"; this takes into account the direct perception of beekeepers, who should define which plants are very important, important or of little importance to apiculture. In addition, the frequency of mentions was calculated for each item of honeybee flora, considering the number of times each one was cited in relation to the total number of interviewees (Ladio and Lozada, 2004) for rainfed, irrigation, and the overall total.

d) Flowering curve: Interviewees reported the blooming period of the honeybee flora, describing the flowers available to honeybees through the flowering curve for each site. The accumulated sum of honeybee flora in bloom was registered every two weeks at each site at the same time and classified by biogeographical status and growth habit.
e) Local apiculture calendar: It was constructed qualitatively, taking into account the saturation of reports related to seasons and the activities carried out (Albuquerque et al., 2021). Interviewees' testimonies were used to schematize the annual cycle for each area. This tool registered collective information, enabling us to understand how the domestic units organized their activities and their lives over a certain time period (Califano, 2019). The calendar was divided into seasons of the year and the beginning/end of the apiculture season (recess), indicating the blooming period of honeybee flora of high cultural importance and the main management practices.
f) Acquisition and social transmission of knowledge: Methods of acquisition and social transmission of knowledge were categorized as personal experience or idiosyncratic knowledge (Benz et al., 1994; Benz et al., 2000; Lozada et al., 2004), and as vertical, horizontal, or oblique (Cavalli-Sforza et al., 1982) according to interviewees' comments. Local categories that differentiated between methods of learning about apiculture were also distinguished.

The quantitative data were analyzed with the SPSS 25.0. program (IBM Corp. Released, 2017). We used descriptive statistics for general aspects (characterization) such as those related to LEKHA. As the data did not present a normal distribution, the results were analyzed using non-parametric statistics. The binomial test was used to test the null hypothesis that in the two areas the proportions of the components are equally distributed, such as the total richness of species and botanical families cited, the proportion of native and exotic plants, and the different modes of knowledge acquisition and transmission. With the Chi square test we compared how the proportion varied between categories, considering the biogeographic origin and growth habit of the honeybee flora species, and types of social transmission of knowledge. The Mann Whitney U test ($P < 0.05$) was applied to evaluate whether the distribution of honeybee flora mentions and their frequencies were equal in each area. The Spearman rank correlation coefficient was used to analyze the association of honeybee flora knowledge with age and years of experience of beekeeping ($P < 0.05$). In addition, honeybee flora species similarity was compared between "rainfed" and "irrigation" using the Jaccard coefficient (Höft et al., 1999), considering the absence/presence of the honeybee flora according to the formula IJ: $c/(a + b + c) \times 100$, where a is the number of species present only in rainfed, b the number of species present only in irrigation, and c the number of species rainfed and irrigation have in common.

Results and discussion

What does the beekeepers' LEKHA consist of? Is the same honeybee flora cited by beekeepers in the rainfed and irrigation areas?

LEKHA on honeybee flora richness

Total richness of the honeybee flora species identified by the beekeepers was similar in rainfed (71) and irrigation (63) areas (binomial test: $P = 0.546$, $n = 134$). In both areas, however, only 40% of the species were shared, mainly natives. The apiarists identified 96 honeybee flora species in total (Table S1), approximately 10% of the flora of the province (Zuloaga et al., 2008). The landscape differences between the two areas are shown in **Figures 2** and **3**.

The honeybee flora species belong to 36 botanical families, the most represented being Asteraceae (15%), Fabaceae (15%), Cactaceae (11%), and Cucurbitaceae (7%); the importance of Asteraceae and Fabaceae coincides with reports of honeybee flora in other countries of the Chaco region (Tejera et al., 2013; Insuasty-Santacruz et al., 2016; Lopes et al., 2016; Araujo-Mondragón and Redonda-Martínez, 2019). The richness of botanical families was similar in rainfed (25) and irrigation (29) areas (binomial test: $P = 0.638$, $n = 54$), with a similarity value of 59%.

The honeybee flora cited by beekeepers comprised mainly herbs (28%), trees (27%), and shrubs (25%), followed by creepers (8%), subshrubs (7%), and lianas (4%) ($\chi^2 = 38.394$, $P = 0.001$). However, the two areas differed in composition: The rainfed area had mainly shrubs (23%) and trees (22%) ($\chi^2 = 33.366$, $P = 0.001$), while the irrigation area had mostly herbs (22%) and trees (19%) ($\chi^2 = 28.714$, $P = 0.001$) (**Figure 4**). This difference coincides with reports on honeybee flora from other rainfed (Carrizo et al., 2015; Palacio et al., 2018) and irrigation areas in the province (Cilla et al., 2018; Cilla et al., 2019) and also other irrigated areas in the country (Tellería, 1995; Forcone, 2003; Forcone and Kutschker, 2006; Fagúndez et al., 2016).

The honeybee flora cited by beekeepers mainly consisted of native species (74%). In both areas, native species were more frequent (89% rainfed and 65% irrigation) than exotic species (**Figure 5**).

From a LEKHA viewpoint, the study of native and exotic plant knowledge offers an opportunity to appreciate how beekeepers have interacted with the diversity of their plant surroundings. As shown by ethnobiological studies (Pirondo and Keller, 2014; Aigo and Ladio, 2016; Ladio, 2020; Chamorro and Ladio, 2021), native species have had a long period of interaction with local dwellers, enabling them to generate emotional and material attachment and detailed recognition of the functions of the species in the landscape. The greater richness of native

Figure 2. Environment and vegetation around the apiaries installed in irrigated areas of the Silípica department. (a) Field cultivated with fruit trees and alfalfa (*Medicago sativa*), (b) apiaries, and (c) field with irrigated lot. Photos taken by Fernando N. Céspedes.

than exotic species recognized by the beekeepers of Silípica department reflects the differential environmental change in the case of the irrigated area, also evidencing aspects of its adaptive flexibility (Berkes et al., 2000; Davidson-Hunt and Berkes, 2010; Ladio, 2017). In other words, the beekeepers' previous knowledge of the

Figure 3. Environment and vegetation around the apiaries installed in rainfed areas of the Silípica department. (a) Secondary forest and (b) and (c) apiaries. Photos taken by Fernando N. Céspedes.

honeybee flora allows them to identify the potential of new species appearing due to the greater anthropization of the farmland (Cilia, 2020).

Apiarists mentioned 19 honeybee flora species per person (19 ± 10.26). The number was higher in the rainfed area (23 ± 10.88) than in the irrigated area (14 ± 6.87) (Mann Whitney $U = 20$, $N1 = 9$, $N2 = 11$, $P < 0.030$). This difference in species richness seems to be directly related to the transformation of the agricultural landscape in the irrigated area. According to some authors (Forcone, 2003; Fagúndez et al., 2016), it is possible to say that the abundance of cultivated plants in the irrigated area could favor

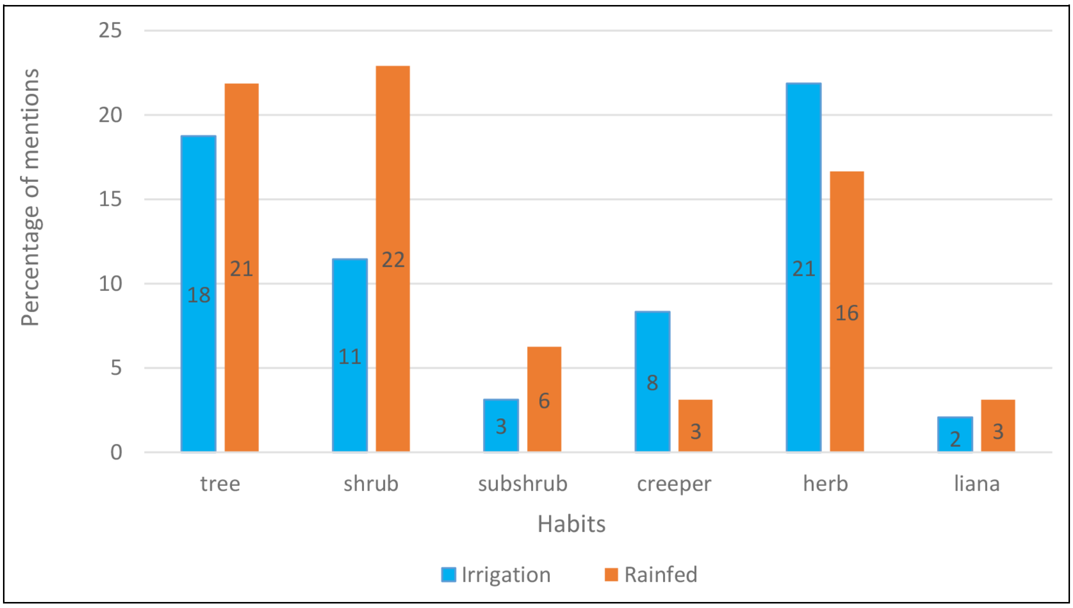

Figure 4. Percentage of mentions and richness of honeybee flora species according to growth habit and site in Silípica department. Inside each column, the corresponding species richness is detailed.

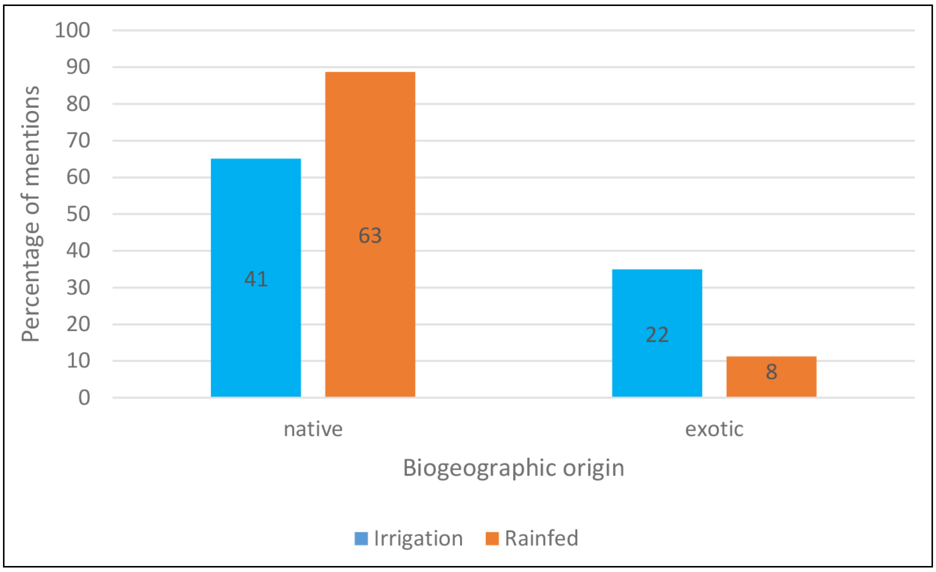

Figure 5. Percentage of mentions of honeybee flora species according to biogeographic origin and area (rainfed or irrigation) in the Silípica department. Inside each column, the corresponding species richness is detailed.

what happens with this activity there, while the raising of pigs and goats could affect differently the availability of flower resources in the rainfed area. However, future studies should analyze the species abundance in both sites, a key aspect to better understand the patterns found. The number of honeybee flora species per person was not correlated with age ($r = -0.006$; $P = 0.981$) or number of years in the activity ($r = 0.325$; $P = 0.178$).

LEKHA on floral rewards

In both areas, the nectariferous–polliniferous honeybee flora species were the most recognized (57% irrigation and 58% rainfed), followed in the rainfed area by the polliniferous (14%), and in the irrigation area by the nectariferous species (21%). In total, participants indicated that 51% of the honeybee flora was nectariferous–polliniferous, 18% nectariferous, and 11% polliniferous. These results are consistent with the general tendency that species that are important nectar sources for honeybees also provide pollen (Andrada, 2003). Although beekeepers could not determine the exact floral reward of 20% of the honeybee flora species, they were able to provide a detailed description of biological interactions and honeybee behavior: "*when the ucli* [*Cereus forbesii*] *blooms it attracts the honeybees a lot, it attracts it early, from before daylight . . . I don't know what the honeybees gets from it, but it's always flying around it*" (P1).

What is the cultural importance of honeybee flora for beekeepers? Does the cultural significance of honeybee species differ between areas?

Cultural consensus regarding honeybee flora

The cultural importance of the honeybee flora species, measured in terms of frequency of mentions, showed no difference between rainfed and irrigation areas (Mann Whitney $U = 2{,}142$, $N1 = 63$, $N2 = 71$, $P < 0.671$). Considering only those species with frequency of mentions ≥ 0.5, a total of 19 species were registered: 9 in irrigation and 14 in rainfed (**Figure 6a** and **b**). The principal honeybee flora species common to the two areas were *Geoffroea decorticans, Schinopsis lorentzii, Atamisquea emarginata,* and *Neltuma alba* documented as important sources of nectar and pollen (Carrizo et al., 2015; Palacio et al., 2018). These species are the most representative elements of the "Monte", which are an important part of the biocultural heritage of the area. Since ancient times, the species of the "Monte" have been used mainly for food, medicine, tinctures, fodder, construction, and fuel by different local societies, showing a strong link between knowledge and the environment (Carrizo et al., 2005; Riat and Pochettino, 2014; Riat, 2016; Grimaldi et al., 2019; Roger, 2020).

On the other hand, according to the *Consensus apicultorum* index, the most important honeybee flora species cited by the apiarists coincided in the two areas: *Schinus bumelioides*, *S. lorentzii*, *A. emarginata*, *N. alba,* and *Sarcomphalus mistol*. These five honeybee flora species were indicated as "very important" in both rainfed and irrigation areas. The remaining species were described as "important"; no species was labeled "unimportant": *"All the plants are important, the honeybees always get something from them, it always helps"* (P13), *"People don't understand that you shouldn't cut trees down, people cut plants to survive, but there must be another way. There's not much teaching for the children in school on how to look after the plants"* (P12–apiarist from the rainfed area). These ideas are in accordance with Bisi et al. (2010) and Sheremata (2018), who proposed that people who interact closely with the local environment are usually the first, and sometimes the only, people who experience the effects of environmental change and fight against the loss of biodiversity (Park and Youn, 2012; Uchiyama et al., 2017). In our study, even the honeybee flora species labeled generically as "yuyo" (local name for weeds or herbs) or "creepers" are considered as important in apiculture as the woody species. Following Yletyinen et al. (2022), the reason why no species is described by apiarists as "unimportant" is that all species have direct relevance to beekeepers' lives, and form part of environmental and communal experiences shared across generations.

Results from the frequencies of mention and *consensus apicultorum* show agreement on the most important honeybee flora species, but on further analysis differences can be found in the results. If we consider only the frequency of mention values, we can interpret that some honeybee flora species are culturally more important than others. In contrast, if we look only at the *consensus apicultorum,* it seems that all the honeybee flora species are valued by the apiarists as important. In complementing each other, these two methodologies highlight that analysis of the cultural importance of honeybee flora species involves complex cognitive processes. On the one hand, the *consensus apicultorum* showed that these beekeepers value plants in general—it is not easy for them to say that a particular plant is not important to their work, they are all considered important. On the other hand, the frequency of mentions measures popularity; that is, the number of people who know a given plant. This enables the identification of species that stand out for any particular reason (Caetano et al., 2020). In this case, it may be due to their abundance (Tellería, 1995; Montoya Pfeiffer, 2011; Méndez et al., 2021) or their significant contribution of resources as honeybee flora (Steffan-Dewenter and Kuhn, 2003; Wainselboim and Farina, 2003), among other reasons that should be studied further in the future.

What are the practices and how are the apiaries organized during the apicultural calendar in each area?

The apiculture calendar covers two well-defined periods: the "season" when most time and work is dedicated to the job, and the "winter break" when maintenance of the hives is carried out (**Figure 7**). The season begins midwinter when flowers start to bloom, with the consequent availability of nectar and pollen (July in rainfed and August in irrigation). **Figure 7** shows the species with the most frequent mentions. From the beekeepers' perspective, these species stand out because of their significant contribution of resources at certain moments of the year.

When flowering begins and the resources become available, the apiarists stop feeding the hives with diluted syrup (water and sugar) and begin to "incentivize" the honeybees with a more concentrated mixture. They seek to stimulate growth of the hive population so as to have a large, strong colony for the peak blooming period of the season (September–November), "*the supplement* [incentive] *is given at the end of July or August, it's done 40 days before the beginning of the flowering season"* (P2).

As the honeybee population increases in spring, the producers separate out "nucleus colonies" (September–October), which consists in splitting a colony and placing a young queen and some worker bees in a small hive (nuc box) before placing them in a permanent hive. The producers thus increase their number of hives and prevent the honeybees from swarming (when they divide alone) and leaving the hive.

As the flowering period progresses, apiarists begin to harvest honey from the large, strong colonies that are functioning well (December–February). At the same time, they extract the black wax from the harvested frames and replace it with virgin wax. The number of honey extractions, from 1 to 3, will depend on the work previously carried out by the apiarist (feeding, incentivizing, creating nuclei), the environment (blooming and meteorological conditions) and the state of the hives (large, strong, healthy colonies). Whereas in the rainfed area apiarists tend to harvest twice between November and February, in the irrigation area they may be able to harvest three times between December and March.

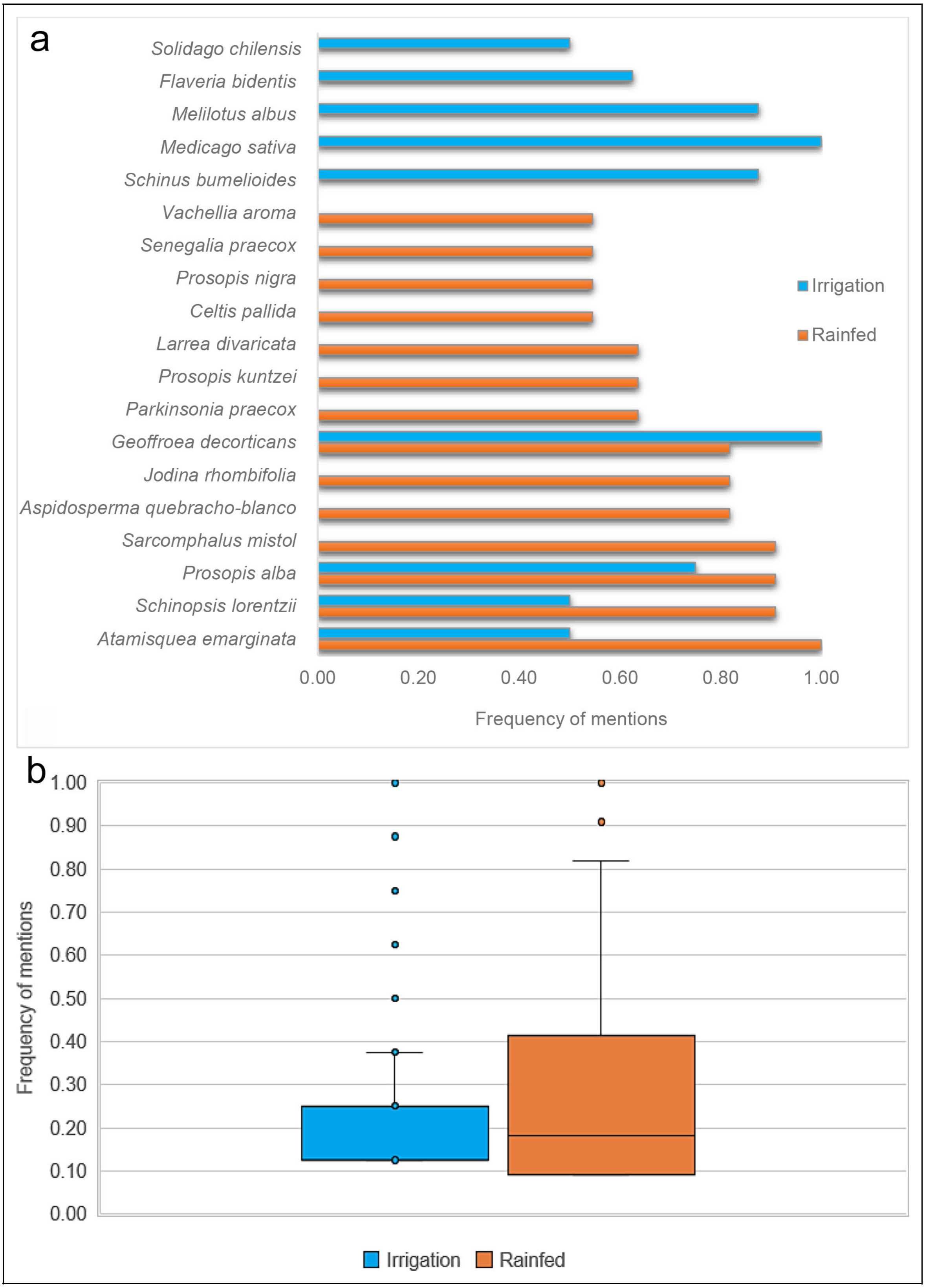

Figure 6. (a) Honeybee flora species with high cultural importance in irrigation and rainfed areas. Only those with a frequency of mention greater than or equal to 0.5 were considered. (b) Comparison of the frequencies of mention of honeybee flora species. The line dividing the box is the median. The upper and lower whiskers represent scores outside the middle 50%. Circles placed past the line edges to indicate outliers.

Following honey extraction, apiarists prepare the hives for the pollen harvest (February to March). This period is considered a time of low floral resources. When harvesting is complete, the apiarists let the colonies gather reserves for the winter, collecting what is left of the nectar and pollen. At this time, they treat the hives for varroa mites

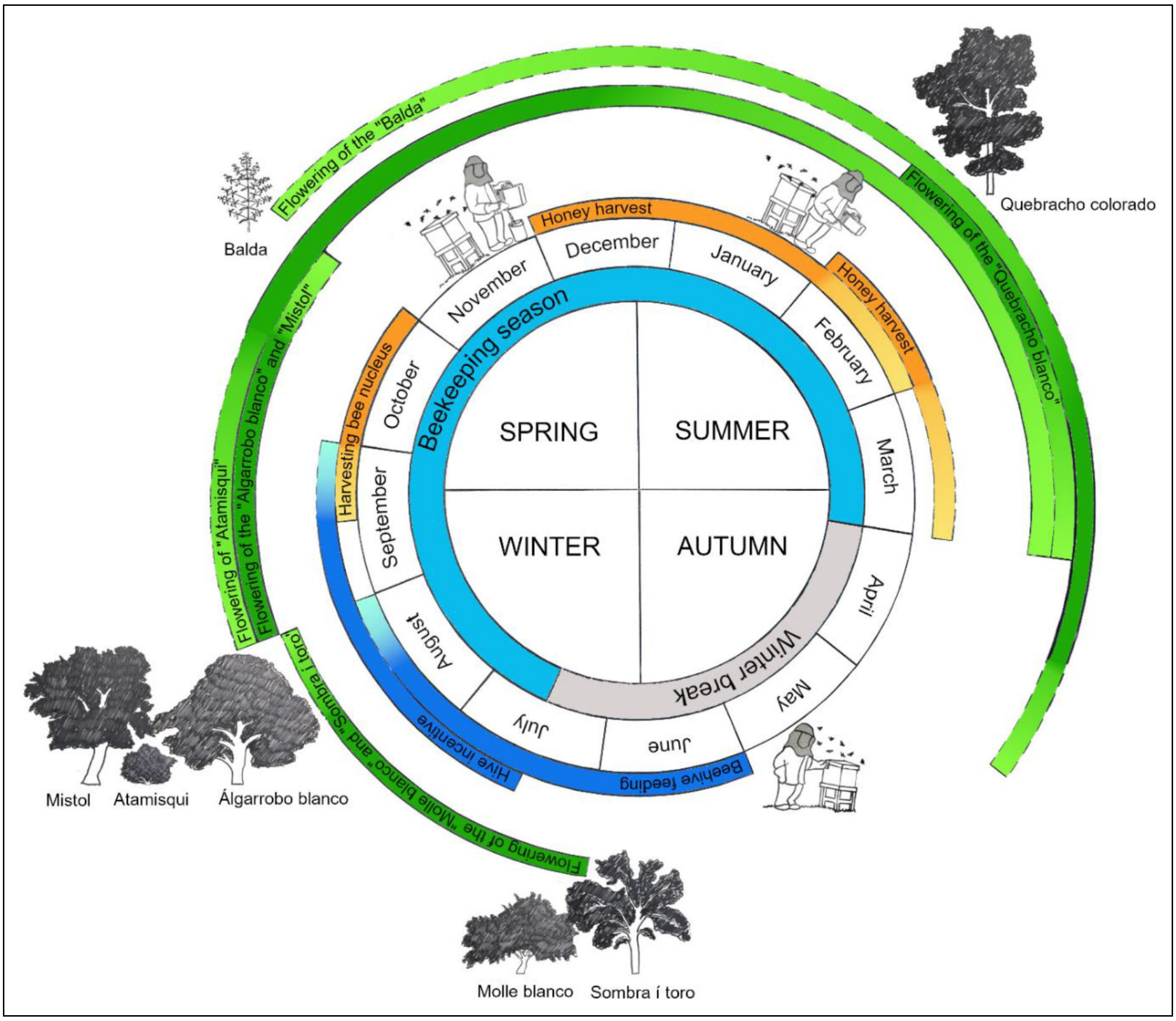

Figure 7. Local apiculture calendar of the Silípica department. The blooms of honeybee flora species of great cultural importance (green) and main management practices (light blue and orange), according to beekeepers, are indicated. The intensity of colors and line strokes indicates the probability of an event occurring: dark colors/solid lines, more likely; light colors/dotted lines, less likely.

(*Varroa destructor* Anderson & Trueman) which cause complications and losses in the apiaries; some participants said that "*when there are a lot of varroa they* [the honeybees] *abandon the hive*" (P5). The treatment is carried out in the rainfed area between March and April, and in the irrigation area in April.

When the winter break begins (end of March), activities focus on maintenance of the hive, protection against the cold, weeding (to prevent fire), renewal and cleaning of materials, monitoring of the health of the hive and the reserves (honey and pollen), and initiation of feeding. Feeding begins in the rainfed areas in June or July, since the honeybees have reserves of honey and pollen until then. In contrast, in the irrigation area feeding starts in May, due to the third harvest carried out. All the practices focus on getting the apiaries through the winter and preparing them for the new season.

LEKHA is a relational type of knowledge, based on everyday experience, which allows the association of different processes (Berkes et al., 2000). Beekeeping directly links beekeepers to their plant environment; beekeepers pay increasing attention to the flora visited by honeybees. This increased knowledge of the honeybee flora, including its flowering times and the rewards offered by the plants, in turn determines how and when beekeepers carry out apiary management practices. Therefore, our data allow us to propose that those who know more about the honeybee flora would know how to use and define better management practices. In future studies, we will investigate these aspects in more detail.

How is flowering temporally structured in each area according to the beekeepers' LEKHA?

This calendar, drawn up using interviewees' mentions of flowering dates, covers the months of July to April (**Figures 7** and **8**). The dates are similar for rainfed and irrigation areas, any differences lying in the richness and abundance of the vegetation strata (in rainfed, trees and shrubs are more abundant; in irrigation, herbs and trees).

In both areas, two periods of abundant floral resources were identified. The first was from September to November, with 20 honeybee flora species, of which 80% were

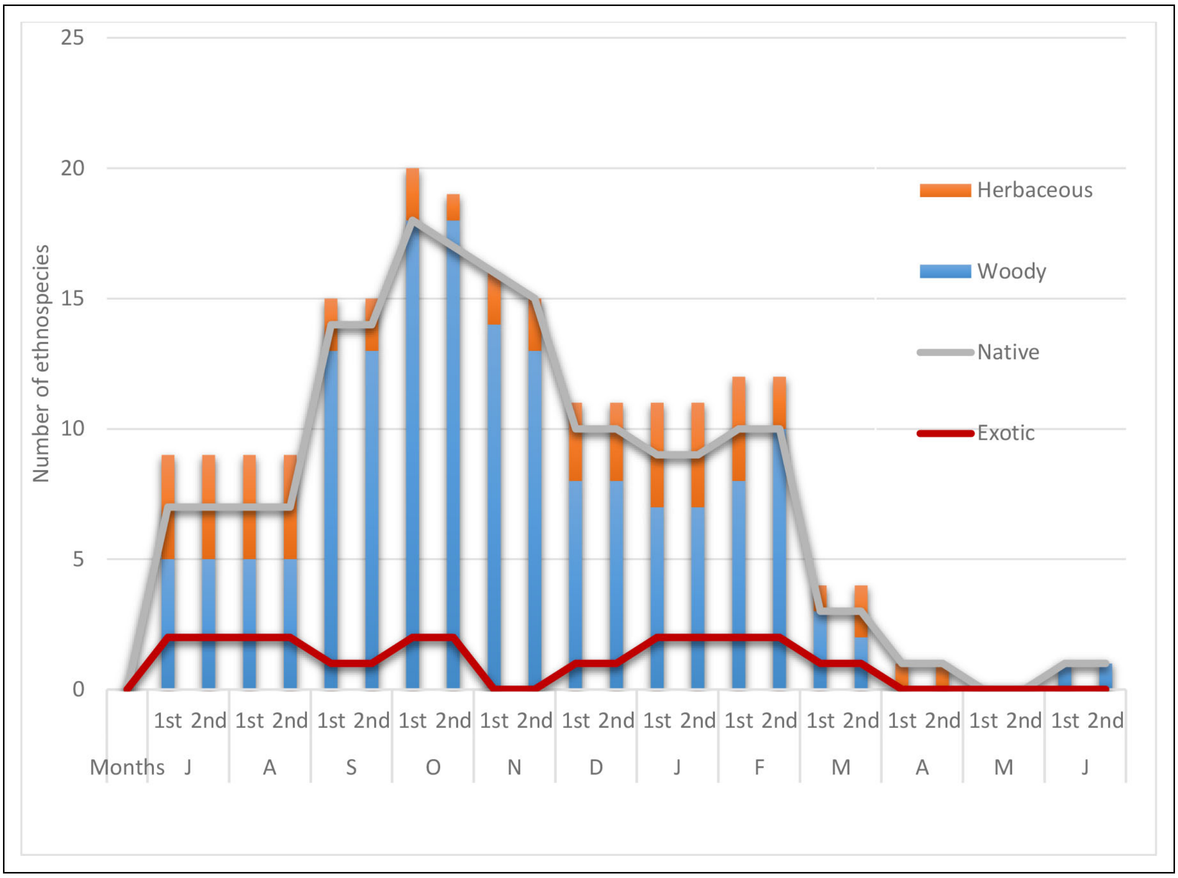

Figure 8. Flowering periods of honeybee flora species, according to habit and biogeographic origin of the species mentioned by beekeepers of Silípica department in both areas. Woody plants: trees, shrubs, subshrubs, and lianas. Herbaceous: herbs and creepers. Biogeographic origin: native and exotic. Months = begins in July, ends in June; 1st = first fortnight; 2nd = second fortnight.

woody plants. The second period occurred during February, with a smaller peak and 12 honeybee flora species, of which 75% were woody (**Figures 7** and **8**). This coincides with descriptions of the north of Argentina (Salgado, 2006; Dini and Bedascarrasbure, 2011; Cabrera et al., 2013), which highlights the apiarists' profound knowledge of the flowering patterns of the honeybee flora species.

On the other hand, the richness of woody species being concentrated in these two peaks leaves gaps in the resources, which are covered by herbs (July–August and December–April) (**Figure 8**). This is when the different vegetation strata become important, which is recognized by the apiarists, "*after the trees come the herbs*" (P8). The complementarity in habitat richness is favorable for the activity (May et al., 2008), reinforcing the consensus between apiarists that all the honeybee flora species are important.

The importance of LEKHA related to the floral calendar is directly linked to the contribution of nectar or pollen made by the species during the productive cycle (May and Rodríguez, 2012b; Cruz Zamudio, 2017; Palacio et al., 2017; Cilla et al., 2018). This valuable knowledge is fundamental for apiculture; together with management skills it determines the production levels (Park and Youn, 2012). In addition, LEKHA is a non-static knowledge; beekeepers perceive in great detail seasonal variations in species that are key to their work, as well as disturbances or changes between years due to environmental factors: "*now the flowering seasons have changed—before they were staggered, first came the algarrobo* [*N. alba*], *then the mistol* [*S. mistol*] *and then the atamisqui* [*A. emarginata*]; *we got a harvest from each one of them. Now it's all disorganised, they overlap*" (P3). "*. . . sometimes some plants are in bloom and others of the same species are not, maybe that depends on the age of the plant*" (P6). "*After the molle* [*S. bumelioides*] *comes the chañar* [*G. decorticans*], *it's sensitive to the wind and rain* [both affect the availability of nectar and pollen, drying it and washing it away], *they make the flowers fall more quickly*" (P10).

At the time when flowering begins (mid-winter), *S. bumelioides* "molle blanco" stands out, principally in the irrigation area (**Figure 7**), due to its contribution to the nutrition and reproduction of the hive (great contribution of nectar and pollen): "*it saves everything, it's the first to bloom*" (P7); "*the molle* [molle blanco] *gives life to the hive after the break, because the queen starts to lay eggs below* [in the brood chamber] *and above* [in the honey super]" (P11); "*I know that when the molle comes out* [begins to bloom] *I'll start to give an incentive with sugar* [to the colony] *. . .*" (P2). In the irrigation area, therefore, at the beginning of the flowering period the "molle blanco" is the outstanding honeybee flora species; in the rainfed area, in addition, *Jodina rhombifolia* "sombra i' toro" and *Schinus* spp. "molle pispita" also stand out (**Figure 7**).

At the time of the first honey harvest, the key honeybee flora species in both areas are *N. alba*, *S. mistol*, and *A. emarginata* (**Figure 7**). Their importance is due to their contribution of nectar, which determines the quantity and quality of the first harvest of the year. Among interviewees' comments, the following stand out: "*the honey is spectacular"* (P7), *"a big harvest, a lot of nectar"* (P2), referring to *S. mistol; "important because it defines the October–November harvest*," "*when it flowers a lot there's a big harvest"* (P2) referring to *N. alba*; "*very good honey, it's one that contributes most*" (P6), "*it flowers several times a year . . . it's the best honey," "people ask for this honey a lot, it's reddish, the flavour is very good"* (P4) referring to *A. emarginata*.

During the pollen harvest, *S. lorentzii* "quebracho colorado" was recognized in both areas for its enormous contribution of pollen, a determining factor for the apiarists (**Figure 7**): "*the quebracho colorado is one of the last to flower, the honeybees visit it a lot, it's important because of its pollen . . . the honey is dark and thick"* (P13). This pollen and honey, sold as "monofloral," are greatly appreciated and in high demand on the market (Hervías and Mogni, 2004; Barberis et al., 2012; Rodas, 2020).

Finally, *Flaveria bidentis* "balda" deserves a special mention among the species of the herb stratum. In both areas, it reaches its flowering peak at the end of the season (April–May), providing nectar and pollen to enable the colonies to survive the winter break (**Figure 7**). This honeybee flora species marks the end of the flowering season: "*after the quebracho colorado harvest the honeybees are left to work with the balda, and we don't harvest anymore, so that they can block the queen and have food for the autumn, the honey is bitter"* (P4).

Considering the biogeographical origin of the honeybee flora, it is clear that native species are prevalent (**Figure 8**) throughout the year; in line with numerous studies on honeybee flora richness (Andrada, 2003; Tamane, 2011; Cabrera et al., 2013; Méndez et al., 2021). Exotic species complement the native flora during the year, particularly in sites with a higher level of anthropization, where cultivated or naturalized species replace native vegetation as the principal source of pollen and nectar (May et al., 2008); observed in apiaries of the irrigation zone.

How is knowledge of LEKHA acquired and transmitted between beekeepers?

No significant differences were found in social transmission processes related to honeybee flora between the two areas studied (χ^2 = 6.757, P = 0.344) (**Figure 9**).

Idiosyncratic learning was similar in the rainfed (50%) and irrigation (55%) areas (binomial test: P = 0.696, n = 105). Interviewees commented that this mechanism worked in three different ways: through "observation" (62% rainfed and 68% irrigation); "*you get to know things when you look at the plants, you see where the honeybees go"* (P6); "walking all around" the area (19% rainfed and 16% irrigation); "*I learned by walking all over the Monte* (local toponym of the area) *looking . . . the best thing to do is walk around to get to know the plants"* (P3); and "reading" (19% rainfed and 16% irrigation); "*I learned by reading the booklets and leaflets they give us in the INTA* [Instituto Nacional de Tecnología Agropecuaria] *talks"* (P13).

Oblique transmission of knowledge was also similar in rainfed (41%) and irrigation (32%) areas (binomial test:

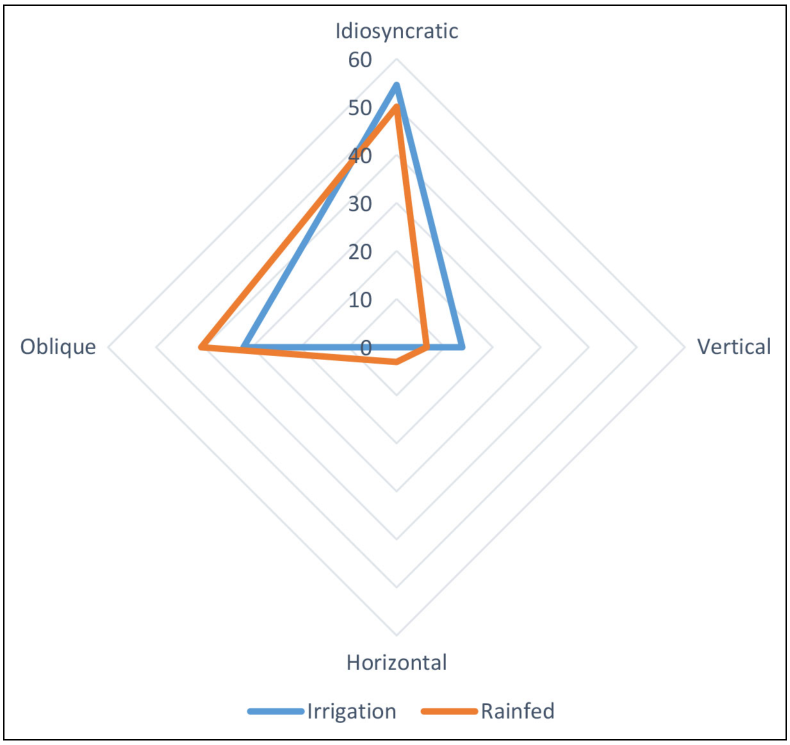

Figure 9. Spider chart showing forms of social transmission of LEKHA according to area.

P = 0.349, n = 73). Two sources of this transmission were identified from the interviews: through other apiarists, "*I learned by asking my fellow workers* [apiarists] *about the plants"* (P9); "*Being from Córdoba I didn't know the plants, so I learned by asking the neighbours and Mr Beltrán* [an apiarist]; *where we're from there was no atamisqui, el piquillín* [*Condalia microphylla*], *la talilla* [*Celtis pallida*] *—I didn't know them"* (P8); and through technicians: "*In the courses I learned a lot, like the flowering for example"* (P6); "*the first year, we all worked with the SAF* [Secretaría de Agricultura Familiar] *technicians—they trained us and helped us with everything, harvesting and setting everything up"* (P5).

Vertical transmission (father and uncles) was registered to a lesser extent and was also similar in rainfed (6%) and irrigation (14%) areas (binomial test: P = 0.115, n = 20), with certain reports worthy of note: "*my father was an apiarist—what I know is thanks to him. He dedicated himself from a young age but gave it up when he was older because the stings were affecting him"* (P1); "*It's in the family—I have two uncles who are apiculture technicians. One uncle offered to teach me, and I bought the hives, and he also paid for me to study to be an apiculture technician"* (P11). Also noteworthy is that horizontal transmission (brother) was registered only in the rainfed area (3%).

The results found here relating to acquisition and transmission of knowledge by apiarists differ from those found in other ethnobiological studies in Argentina, which recorded a high proportion of vertical transmission (familiar) from an early age (Ladio and Lozada, 2004; Lozada et al., 2006; Eyssartier et al., 2008, 2011). Apiculture has been promoted strongly by government institutions, which could explain the transmission methods found in this study. Oblique transmission and idiosyncratic learning are methods with a strong adaptive element, enabling societies to learn new things in order to develop more resilient responses to environmental change (Lozada et al., 2006; Reyes-García et al., 2009; Blanco and Carriére, 2016; Ladio, 2017).

For the apiarist, the apiary signifies the place where they can "observe," "walk around the 'Monte'," and interact with peers, where they have opportunities to learn and teach by "doing" (Lozada et al., 2006) in a process of dialogue and feedback (Eyssartier et al., 2008). The apiary is the context where "ethnobotanical ability" (sensu Reyes-García et al., 2009) develops and grows, given that, as Andrews (2019) also stated, the apiarists not only spend long periods of time observing the behavior of honeybees and plants in detail, but they also systematically repeat this throughout the season, affirming their knowledge and amplifying it with new elements.

Conclusion

This work shows that the rainfed and irrigation areas, which in terms of landscape show differential characteristics, do not seem to show significant differences in the apiculture carried out there. This could be mainly related to the strong cultural attachment of the inhabitants to some remaining elements of the native "Monte" landscape, which, despite the anthropic modifications undergone in both areas, remain functional for beekeeping. LEKHA also seems to be particularly flexible, generated mainly by idiosyncratic knowledge and oblique relationships, possibly in a relatively short period of time.

Everyday life revolves around the "Monte," as the place of work, transmission of knowledge, and mainly individual learning. The strong bond established with honeybees in daily practices seems to develop a sensitivity in beekeepers that makes them concerned about degradation of the native habitat. In addition, the public policy of promoting apiculture and the technical training programs are modes of oblique transmission that are key to stimulating the LEKHA of the beekeepers. This study also illustrates how a novel activity associated with care of the environment recreates and stimulates environmental knowledge, where flowers, honeybees, and people form an association of mutual care.

We believe that this type of study can serve as an example for other studies since it focuses on the importance of considering the LEKHA of small beekeepers for local development. This type of knowledge must dialogue horizontally with technical–scientific knowledge to find environmentally sustainable solutions.

Data accessibility statement

The data used to support the findings of this study are available from the corresponding author upon reasonable request.

Supplemental files

The supplemental file for this article can be found as follows:

Table S1. Ethnospecies mentioned by beekeepers as being of beekeeping interest in irrigated and rainfed areas of the Silípica department.docx

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Competing interests

The authors have no conflicts of interest to declare.

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Author contributions

Contributed to conception and design: FNC, PAG.

Contributed to acquisition of data: FNC, PAG.

Contributed to analysis and interpretation of data: FNC, PAG, AHL.

Drafted and/or revised the article: FNC, PAG, AHL.

Approved the submitted version for publication: AHL.

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