forests

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A Comparative Study of Methods Recording Beekeeping Flora

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Abstract: The knowledge of beekeeping flora of an area and of each plant's provision is crucial for beekeepers to plan their hive transfers when practicing nomadic beekeeping. Thus, in the present study, we evaluated the use of pollen traps as a means of identifying beekeeping plants in target areas, assessing their pollen percentage contributions and estimating their flowering seasons. The results were compared with the classical field observation method, widely used for flora recording. In total, 98.8% of the plants were recognized by using pollen traps and 89.4% from observations in the field, while for 73% there was found an agreement between population size (Wittig Scale) and Pollen Contribution Scale (PCS). The results showed that pollen traps can be helpful tools not only for defining the presence or absence of a beekeeping plant, but also for providing important information regarding the population size of a taxon of major beekeeping importance in the area surrounding the apiary. Finally, the estimation of the flowering season and its maximum point can be accurately predicted by using pollen traps on plants of beekeeping interest.

Keywords: bee flora; population size; bee pollen traps; estimation of flowering season; field recording; pollen contribution scale

Citation: Liolios, V.; Kanelis, D.; Rodopoulou, M.-A.; Tananaki, C. A Comparative Study of Methods Recording Beekeeping Flora. *Forests* **2023**, *14*, 1677. https://doi.org/10.3390/f14081677

Academic Editor: Paloma Cariñanos

Received: 15 July 2023
Revised: 9 August 2023
Accepted: 16 August 2023
Published: 18 August 2023

1. Introduction

The use of natural resources (nectar for energy and pollen for growth) to feed honeybee colonies and produce honey is one of the main factors in successful beekeeping at a professional level [1,2]. For this reason, beekeepers schedule the growth of their colonies and seasonal management (e.g., transfers of hives, dividing colonies, production of hive products, etc.) based on the beekeeping flora of an area. Honeybees forage a large number of plants, but it still remains under discussion that there is a probable relation between bees' preferences for a pollen source and its availability linked to flower features, such as architecture, color and odor [3–5], with Liolios et al. [6] highlighting the population size of beekeeping plants surrounding an apiary as the major factor affecting this relation.

In addition, climate change and its impact on the flowering of beekeeping plants creates problems and leads to failures in the moving schedule of the hives. Especially in water-limited ecosystems, variation in precipitation may lead to divergence of flowering time over the season [7]. Rafferty et al. [8], studying the flowering observations of 590 species of plants in five communities, observed linkages between temperature and phenology in colder ecosystems, while in drier, water-limited ecosystems, the interactive effects of both temperature and rainfall on the phenological changes of beekeeping plants are less understood.

Greece, due to its Mediterranean climate, provides high floristic heterogeneity and diverse physiognomies, with some areas containing more trees, while others are home to a larger number of shrubs or herbs, offering a rich biodiversity for bee foraging. Nevertheless, there is little information on the peak blooms of beekeeping plants in the different areas, while the transfer of hives is mainly based on beekeepers' previous experiences or rumors, with the result that they are often incorrect. Also, the increase in the number of bee colonies and the limitation of the beekeeping flora due to a multitude of factors (extensive fires,

degradation of ecosystems, etc.) make the transfer of hives in different areas a necessary condition for satisfactory productivity. Indeed, currently, there are few areas blooming all seasons that can sustain stable apiaries and probably mainly at an amateur level.

Thus, the knowledge of bee flora of an area as well as the estimation of the flowering duration of target beekeeping plants seems to be vital for beekeepers to optimize production [9], contributing remarkably to the planning of hive transfers and consequently to the reduction of production costs. Pollen traps, as a flora-recording tool, have been used in the past with considerable success [10–13], given that the composition of pollen loads can vary according to the region or season, indicating patterns and variations of the local flora [14]. Dimou et al. [15] also noted that it is possible to capture the beekeeping flora of an area using pollen traps, harvesting samples of a three-day trapping duration collected at six- to nine-day intervals through one year.

Considering all the above, in the present study, we applied and compared two methods to record the beekeeping plants in two target areas, by determining their population size through field observations and their pollen percentage contributions using pollen traps. We also inserted a new index and scale in order to identify the pollen contribution in the area surrounding the apiary, and compared the results to those from field recording. We finally investigated the flowering season of selected beekeeping plants, using both methods, with the ultimate goal of developing a reliable tool for the future study of climate change effects on the alteration of flowering time in plants of major beekeeping importance.

2. Materials and Methods

2.1. Installation of Experimental Apiaries/Pollen Collection

Six bee colonies of equal population (10 frames in each colony of Langstroth pattern) were transferred to two semi-mountainous areas (three in each area) with native beekeeping plants in the prefecture of Thessaloniki, Greece (Area 1: 40.553059, 23.050231, Area 2: 40.520636, 23.153601). The straight distance between the two apiaries was 10 km, while there was a high mountain mass between them. The experiment took place from early March to middle November 2022 in order to cover the whole beekeeping period. These areas were selected as targets, as they are rich in beekeeping flora, mainly herbaceous and bushy vegetation, and thus attract many beekeepers of the region.

After the transfer, plastic pollen traps with a separation grid were fitted to the entrance of the hives, and bee pollen was collected every 5 days, with the removal of the collection drawer. The samples after their harvest were placed in the freezer until the time of their separation, to avoid any alteration in texture and color.

2.2. Identification and Estimation of Population Size of Surrounding Flora

For the estimation of the population size of the surrounding flora, we recorded the plant species in the target areas every second week, in a distance about 3 km from the experimental apiaries, as bees usually collect within this radius around the perimeter of their hive. Having drawn an imaginary circle with a radius of 3 km on the map and within this area, the sampling took place. We sampled the entire perimeter and the transects were demarcated from the experimental apiaries. In each field observation, there was a team of 4 people, recording from 8 to 12 in the morning. For the calculations, we used a semiquantitative scale with four classes, according to the Wittig scale [16], where Class I contained scarcely-located taxa and class IV contained the dominant taxa (taxa covering at least 30% of the collection site).

2.3. Pollen Separation and Identification

The pollen loads were separated mainly based on color, shape and size. For the identification of pollen grains, the method of Louveaux [17] was used, according to which a small amount of pollen was placed on a slide and the pellets were dissolved with 2–3 drops of diethyl ether. After the evaporation of the solvent, one drop of aqueous isoglucose solution (2:1) was added on the slide to hydrate the pollen grains and one drop of aqueous

fuchsine to color them. The slides were placed on a heating plate to remove the moisture and covered with coverglass containing a drop of Entellan. For the identification of the pollen grains, the database of the Laboratory of Apiculture-Sericulture, AUTH, was used. At the same time, slides were also prepared from flower stems collected from the fields around the bee colonies, followed by microscopic examination for their identification.

2.4. Estimation of Pollen Percentage Contribution of Polliniferous Plants

To evaluate the contribution of each plant taxon in the total amount of bee pollen collected from the traps, we analyzed a representative pollen sample in each sampling. Specifically, the total amount of collected pollen was weighed, recorded and then the quarter sampling method was repeatedly applied to ensure a random sample of 10% [13]. Visual separation and microscopic identification were followed, and the percentage of each taxon was calculated based on the formula:

$$P_i(\%) = \frac{\alpha_1 X_1 + \alpha_2 X_2 + \ldots \alpha_n X_n}{X_1 + X_2 + \ldots X_n}$$

where

$P_i(\%)$: The percentage of i plant taxon found in the pollen trap during its flowering period
$\alpha_{1\ldots n}$: The amount of pollen of i taxon in the total amount of pollen in each sampling
$X_{1\ldots n}$: Total amount of pollen collected from the traps in each sampling

In order to facilitate the visualization of the percentage contribution of each species on the total amount collected during flowering season, as well as to be able to compare the results to the Wittig scale used for the estimation of population size in field observations, we created a scale of 4 classes (Pollen Contribution Scale, PCS); class IV corresponded to percentage participation in traps > 20% (dominant species), class III to 10%–20% (important species), class II to 2%–10% (moderately important species) and class I in 0%–2% (species of minor importance).

2.5. Flowering Season Determination: Flowering Rate Calculation

For the determination of flowering season, we targeted 10 beekeeping plants of major importance. The beginning of flowering was signaled when the first pollen loads of a species appeared in the pollen traps and ended when no more pollen loads were found. At the same time, in order to cross-check the results, a visual recording in the field was carried out. For field observation, we marked the areas and counted every five days the number of blooming flowers of the target plants. In general, we considered the beginning of blooming when taxa had at least 10% of their flowers open, while full flowering corresponded to 80% of blooming. In plants with single flowers, we counted the number of them, while in the case of other plants (i.e., trees) we assessed inflorescences of individual marked branches.

The whole study approach is given in Figure 1.

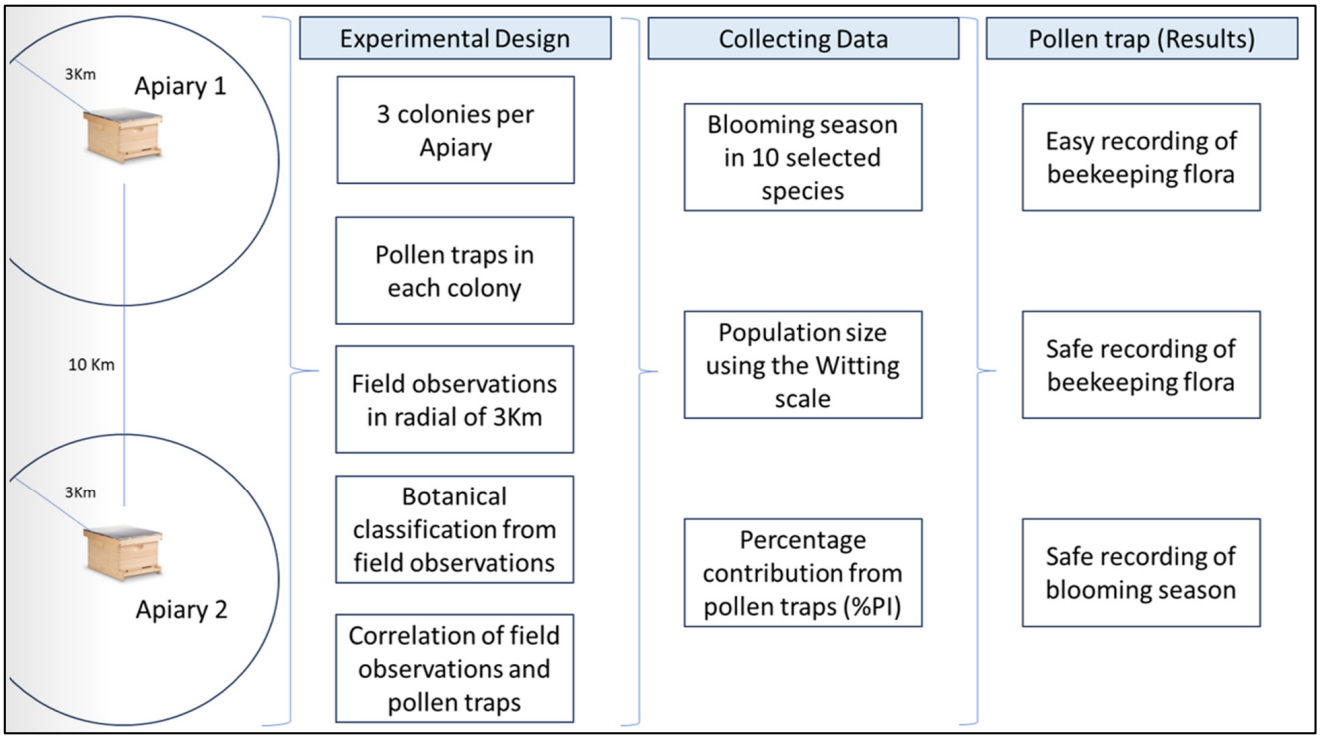

Figure 1. Study approach.

3. Results and Discussion

3.1. Identification of Surrounding Flora

In the present study, we recorded the surrounding flora in two target areas, comparing two methods, the field observation and the use of pollen traps. The scientific names of the taxon, the families, the flowering period in the target areas, and their presence in the field (population size) and in the pollen traps (Pollen Contribution Scale, percentage of plant taxon found in the trap) are given in Table 1. In total, 84 different polliniferous taxa belonging to 49 families were recorded in the pollen traps, giving a recognition capability of about 98.8%, while the recognition in field visits was lower (about 89.4%), as 76 taxa were spotted providing pollen and/or nectar. The flowering of most taxa occurred in mid-to-late spring, while some of them flowered in early autumn.

Table 1. Taxa recorded in two target areas (flowering period, presence in field, population size, presence in pollen traps, PCS, P_i%).

No.	Scientific Name	Family	Flowering Period in the Target Areas	Presence in Field	Population Size (Wittig Scale)	Presence in Pollen Traps	Pollen Contribution Scale (PCS)	Percentage of Plant Taxon Found in the Pollen Trap (P_i%)
1	*Acer* sp.	Spindaceae	March–April	√	II	√	I	1.2
2	*Asphodelus aestivus*	Asphodelaceae	March–July	√	II	√	I	1.9
3	*Brassica rapa*	Brassicaceae	April–June	√	III	√	III	17.8
4	*Calendula arvensis*	Asteraceae	March–April	√	I	√	I	0.8
5	*Carduus armatus*	Asteraceae	May–July	√	I	√	I	1.3
6	*Carduus marianus*	Asteraceae	April–June	√	II	√	II	2.5
7	*Carthamus lanatus*	Asteraceae	June–July	×	×	√	I	0.3
8	*Castanea sativa*	Fagaceae	April–June	×	×	√	I	0.9

Table 1. *Cont.*

No.	Scientific Name	Family	Flowering Period in the Target Areas	Presence in Field	Population Size (Wittig Scale)	Presence in Pollen Traps	Pollen Contribution Scale (PCS)	Percentage of Plant Taxon Found in the Pollen Trap (P_i%)
9	*Centauria solstitialis*	Asteraceae	May–June	√	I	√	I	1.4
10	*Centauria* sp.	Asteraceae	May–June	√	II	√	II	4.6
11	*Cephalaria* sp.	Caprifoliaceae	May–June	x	x	√	I	0.1
12	*Chenopodium album*	Chenopodiaceae	August–September	√	II	√	III	18.3
13	*Cichorium intubus*	Asteraceae	June–August	√	II	√	II	8.7
14	*Cirsium* sp.	Asteraceae	April–September	√	II	√	II	2.9
15	*Cistus creticus*	Cistaceae	May–July	√	IV	√	IV	25.8
16	*Cistus parviflorus*	Cistaceae	May–July	√	III	√	IV	22.0
17	*Convolvulus arvensis*	Convolvulaceae	May–November	√	I	√	II	2.3
18	*Crataegus monogyna*	Rosaceae	April–May	√	I	√	II	2.1
19	*Daucus carota*	Apiaceae	May–August	×	×	√	I	0.1
20	*Echinops ritro*	Asteraceae	May–July	×	×	√	I	0.2
21	*Echium plantagineum*	Boraginaceae	May–August	√	I	√	I	1.8
22	*Eleagnus angustifolia*	Eleagnaceae	May	√	I	√	I	0.2
23	*Epilobium parviflorum*	Onagraceae	April–June	√	I	√	I	0.2
24	*Erica arborea*	Ericaceae	February–April	√	II	√	I	1.4
25	*Erica manipuliflora*	Ericaceae	September–October	√	IV	√	IV	20.6
26	*Eriobotrya japonica*	Rosaceae	November	√	I	√	I	0.2
27	*Eucalyptus* sp.	Myrtaceae	June–August	×	×	√	I	0.3
28	*Ferula communis*	Apiaceae	June–July	×	×	√	I	1.2
29	*Genista acanthoclada*	Fabaceae	May–June	√	II	√	II	2.3
30	*Geranium macrostylum*	Geraniaceae	May–June	√	I	√	I	0.6
31	*Hedera helix*	Araliaceae	August–October	√	II	√	II	6.3
32	*Helianthus annuus*	Asteraceae	June–August	√	I	√	I	1.3
33	*Heliotropium europeum*	Heliotropiaceae	July–September	√	II	√	I	0.6
34	*Hypericum triquetrifolium*	Hypericaceae	June–July	√	III	√	III	12.3
35	*Inula viscosa*	Asteraceae	August–October	√	II	√	II	7.3
36	Iridaceae	Iridaceae	March–April	√	II	√	II	2.9
37	*Juglans nigra*	Juglandaceae	May–June	√	I	√	I	1.8
38	*Lamium* sp.	Lamiaceae	March–April	√	III	√	II	4.6
39	*Laurus nobilis*	Lauraceae	April	√	I	√	I	1.1
40	*Ligustrum japonicum*	Oleaceae	June–July	√	II	√	II	6.8
41	*Lonicera japonicus*	Caprifoliaceae	May–June	√	I	√	I	1.3
42	*Marticaria chamomilla*	Asteraceae	March–April	√	III	√	II	7.4
43	*Olea europaea*	Oleaceae	April–May	√	IV	√	II	13.3
44	Onagraceae	Onagraceae	April–May	√	I	√	I	1.5
45	*Onopordum acanthium*	Asteraceae	May–July	√	II	√	II	2.2
46	*Opuntia Ficus*	Cactaceae	May–June	×	×	√	I	0.3

Table 1. *Cont.*

No.	Scientific Name	Family	Flowering Period in the Target Areas	Presence in Field	Population Size (Wittig Scale)	Presence in Pollen Traps	Pollen Contribution Scale (PCS)	Percentage of Plant Taxon Found in the Pollen Trap (P_i%)
47	*Ornithogalum pannonicum*	Asparagaceae	June–July	√	II	√	II	2.7
48	*Paliurus spina-christi*	Rhamnaceae	May–June	√	III	√	III	19.2
49	*Papaver rhoeas*	Papaveraceae	March–June	√	IV	√	IV	21.4
50	*Parthenocissus quinquefolia*	Vitaceae	April–June	√	I	√	I	1.2
51	*Pastinaca sativa*	Apiaceae	April–May	√	I	√	I	1.3
52	*Pinus halepensis*	Pinaceae	April	√	III	√	I	0.4
53	*Pimpinella peregrina*	Apiaceae	May	√	I	√	I	0.1
54	*Pitosporum tobira*	Pitosporaceae	May–June	√	I	√	I	1.6
55	*Polygonum aviculare*	Polygonaceae	June–October	√	II	√	II	7.3
56	*Portulaca oleracea*	Portulacaceae	July–September	√	III	√	III	12.1
57	*Prunus amygdalus*	Rosaceae	March	√	II	√	II	7.6
58	*Pyracantha coccinea*	Rosaceae	April–May	√	I	√	I	0.4
59	*Pyrus pyraster*	Rosaceae	April	√	II	√	II	3.7
60	*Quercus* sp	Fagaceae	April–June	√	II	√	III	14.5
61	*Ranunculus* sp.	Ranunculaceae	April–May	×	×	√	II	4.6
62	*Robinia pseudoacacia*	Fabaceae	May	√	II	×	×	×
63	*Rubus fruticosus*	Rosaceae	May–September	√	II	√	II	2.6
64	*Rubus ulmifolius*	Rosaceae	June–August	√	III	√	III	10.1
65	*Rumex crispus*	Polygonaceae	April–June	√	II	√	II	6.5
66	*Salix* sp.	Salicaceae	April	√	I	√	I	1.6
67	*Silybum marianum*	Asteraceae	April–May	√	III	√	III	16.8
68	*Sinapis arvensis*	Brassicaceae	March–June, August–November	√	IV	√	IV	21.6
69	*Sisymbrium irio*	Brassicaceae	March–June, August–November	√	IV	√	IV	20.8
70	*Sonchus asper*	Asteraceae	March–June	√	III	√	III	10.1
71	*Sorghum halepensis*	Poaceae	June–August	√	III	√	I	0.2
72	*Syringa vulgaris*	Oleaceae	April–May	√	I	√	I	0.3
73	*Tamarix* sp.	Tamaricaceae	April–August	√	I	√	I	0.5
74	*Taraxacum officinale*	Asteraceae	March–June	√	III	√	III	17.3
75	*Thymus* sp.	Lamiaceae	March–June	√	I	√	I	0.6
76	*Tilia intermedia*	Malvaceae	June	√	I	√	III	12.2
77	*Tribulus terrestris*	Zygophyllaceae	June–October	√	III	√	III	11.6
78	*Trifolium pratense*	Fabaceae	May–June	√	III	√	III	11.5
79	*Trifolium* sp.	Fabaceae	April–July	√	III	√	III	19.2
80	*Urtica dioica*	Urticaceae	May–October	√	II	√	II	2.7
81	*Verbascum* sp.	Scrophulariaceae	May–July	√	II	√	II	2.3
82	*Vicia villosa*	Fabaceae	March–April	√	III	√	III	12.0
83	*Vitex-agnus castus*	Lamiaceae	June–September	√	II	√	II	3.3

Table 1. *Cont.*

No.	Scientific Name	Family	Flowering Period in the Target Areas	Presence in Field	Population Size (Wittig Scale)	Presence in Pollen Traps	Pollen Contribution Scale (PCS)	Percentage of Plant Taxon Found in the Pollen Trap (P_i%)
84	*Xanthium strumarium*	Asteraceae	July–October	√	II	√	II	9.8
85	*Zea mays*	Poaceae	July–September	√	I	√	I	0.8

The observations in the field were carried out at regular intervals (every second week) within a radius of 3 km from the colonies; however, some plants could not be found. Indeed, *Carthamus lanatus*, *Castanea sativa*, *Cephalaria* sp., *Daucus carota*, *Eucalyptus* sp., *Ferula communis*, *Opuntia ficus*, *Ranunculus* sp. and *Echinops ritro* were only detected in the pollen traps. The difficulty of accessing some points within the measurement field, mainly because of natural obstacles, combined with the difficulty of spotting some plants found in very small populations (e.g., herbs), is probably responsible for the deviation of the results between the two recording methods. In the cases of chestnut (*Castanea sativa*) and eucalyptus (*Eucalyptus* sp.), despite the fact that these trees are easily recognizable, it was not possible to record them in the field, as they were outside the range of the 3 km radius defined as the observation area in the field. Indeed, the flight of bees when foraging can in some cases reach 10 km [18–20]. On the contrary, acacia trees (*Robinia pseudoacacia*) were observed in the field observations, but the corresponding pollen pellets were not detected in the traps. Despite the high bee foraging of the acacia tree, the plant offers abundant nectar but no pollen [21].

According to the results of Table 1, it seems that the recording of beekeeping plants of an area is better performed by the bees themselves, avoiding laborious and time-consuming observations in the field, but requires knowledge of palynology, so as to identify the plants under the microscope. Additionally, in order to obtain more reliable results, it is recommended that the use of pollen traps are combined with recording in the field [22]. In the microscopic analyses carried out on bee pollen for species-level identification, in several cases, field observation and collection of flower samples is considered particularly important to create a database (photographs of pollen grains) to facilitate the microscopic identification of the collected pellets.

3.2. Population Size (Wittig Scale) and Percentage Contribution Scale (PCS) of Beekeeping Plants

The most dominant species according to the Wittig scale (class IV) were *Cistus criticus*, *Erica manipuliflora*, *Olea europaea*, *Papaver rhoeas*, *Sinapis arvensis* and *Sisymbrium irio*. These species were dominant in the PCS scale as well, with the addition of *Cistus parviflorus*, which in the Wittig scale was in level III. Between the population size of beekeeping plants in the field and their PCS, there was found an agreement of about 73% (62 taxa) and a deviation about 27% (Table 1). This discrepancy was mainly observed on the wind-pollinated species *Pinus halepensis*, *Acer* sp., *Olea europaea* and *Sorghum halepensis*, which were ranked as population size in the Wittig scale at levels III, II, IV and III, respectively, while their PCS were at levels I, I, II and I, respectively. These results could be attributed to the fact that bees prefer entomophilous species rather than anemophilous ones that usually provide pollen of poor nutritional value [6] (Liolios et al., 2016). Also, the species *Lamium* sp., *Marticaria chamomilla*, *Heliotropium europeum*, *Erica arborea* and *Asphodelus aestivus* were found in higher populations in the field than in the pollen traps. *Lamium* sp. and *Asphodelus aestivus* bloom very early in the spring, where adverse weather conditions probably inhibit bee flights and pollen collection. On the other hand, *Marticaria chamomilla*, *Heliotropium europeum* and *Erica arborea* bloom in spring at the same time with a variety of other plants, so bees are probably attracted to other plant sources, either with a stronger smell or better provisions. In the case of *Chenopodium album*, *Cistus parviflorus*, *Convolvulus arvensis*, *Crataegus monogyna* and *Tilia intermedia*, higher percentages were detected in the traps compared to the populations recorded in the field. The results highlight the use of pollen traps and the PCS as effective

tools to identify not only the presence or absence of a beekeeping plant in an area, but also its population size in the area surrounding the apiary, with greater accuracy compared to field recording. The use of pollen traps and the color separation of pellets that can capture in several cases the extent of the population of the species in the field is also referred to in literature [13,23,24].

3.3. Flowering Season Determination: Flowering Rate Calculation

The flowering season of 10 taxa is depicted in Figure 2 based on the recording of the flowering stages of the target plants in the field and the percentage contributions of their pellets in the pollen traps.

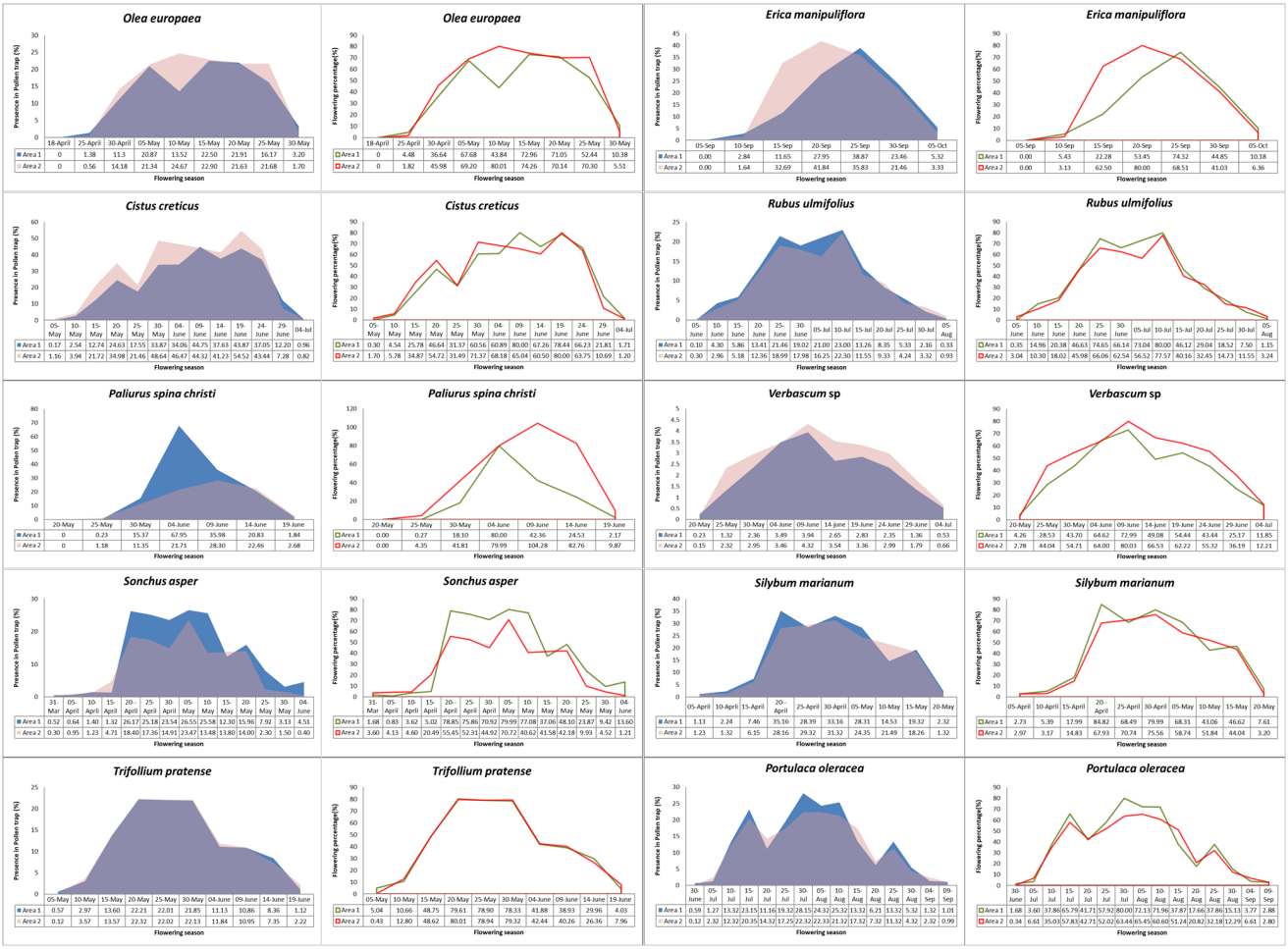

Figure 2. Flowering season of 10 taxa, based on field recording and their presence in pollen traps.

In all cases, there was agreement of the data recorded from the field observations with those obtained from the analyses of the pollen samples collected from the traps [P_i(%)]. Indeed, on the dates when the beginning of flowering (at least 10% open flowers) was observed in the examined taxa, their first pollen loads were detected in the traps as well. Correspondingly, full flowering (80%) coincided with the maximum presence/percentage of the respective pollen loads in the traps. Although bees' preferences for the amount of pollen collected is influenced by many parameters (e.g., plant abundance, plant supply, etc.), it seems that the estimation of the flowering period and its peak can be predicted accurately with the use of pollen traps on plants of beekeeping interest. A long-term study using pollen traps and P_i(%) could be further applied as an initial tool to record and better visualize the possible long-term alterations in the flowering of beekeeping plants in relation to climate change.

The results of the study confirm the strict linkage between honeybees, environment and biodiversity. The role of bees as bioindicators, as well as their importance in the conservation of biodiversity is also emphasized by other authors, highlighting the need for conservation measures to prevent the loss of honeybees and to preserve ecotypes and further world biodiversity [25–29].

The use of pollen traps to map beekeeping flora and estimate the suitable time for hive transfers in target areas is also suggested by other authors, such as Alves and dos Santos [24] for Sergipe (Brazil), Taha [30] for Al-Ahsa province (Saudi Arabia) and Taha et al. [31] for Kafrelsheikh province (Egypt), so that beekeepers move their apiaries to obtain high honey yield, supporting their colonies and/or economizing the cost of artificial feeding.

4. Conclusions

In the present study, we applied and compared two methods for beekeeping flora recording: the classical method of field observation and the use of pollen traps. Although the preference of bees in terms of the harvested quantity of pollen is influenced by many parameters (e.g., abundance of plants, plant supply, etc.), the estimation of the period and maximum flowering can be predicted with great accuracy with the use of pollen traps. Additionally, we created an index (P_i%) and a scale (PCS) to better visualise and compare the results from recording using pollen traps with the Wittig scale applied to determine the population size of plants in the field. The use of pollen traps for bee flora recording presents the advantage of ease of application, as bees travel long distances every day in order to collect pollen, while the removal of the collected pollen is easy, without additional beekeeping treatments. On the contrary, field recording requires time-consuming visits to the field, enabling the researcher to understand plant populations and their flowering stages, but does not provide access to information about bees' feeding habits. Finally, the graphs exported from P_i(%), regarding the flowering season of 10 plants of major beeekeeping importance, could be further applied to target beekeeping plants in consecutive years to evaluate long-term alterations in their flowering affected by climate change. The results may be further used to design specific algorithms to find the appropriate beekeeping areas to transfer bee hives, minimizing costs and increasing honey yield.

Author Contributions: Conceptualization, C.T., V.L. and D.K.; methodology, V.L., D.K. and C.T.; investigation, V.L., D.K. and M.-A.R.; writing—original draft preparation, V.L., D.K., M.-A.R. and C.T.; visualization, V.L., D.K. and M.-A.R.; supervision, C.T. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Single RTDI State Aid Action "Research-Create-Innovate", ESPA 2014-2020 (project code: 2076).

Data Availability Statement: Data supporting reported results are stored at the Laboratory of Apiculture-Sericulture, AUTH.

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

References

1. Nicolson, S.W. Bee food: The chemistry and nutritional value of nectar, pollen and mixtures of the two. *Afr. Zool.* **2011**, *46*, 197–204. [CrossRef]
2. Rutschmann, B.; Kohl, P.L.; Steffan-Dewenter, I. Foraging distances, habitat preferences and seasonal colony performance of honeybees in Central European forest landscapes. *J. Appl. Ecol.* **2023**, *60*, 1056–1066. [CrossRef]
3. Bragavan, S.; Smith, B.H. Olfactory conditioning in the honey bee, *Apis mellifera*: Effects of odor intensity overlay panel. *Physiol. Behav.* **1997**, *61*, 107–117. [CrossRef] [PubMed]
4. Çakmak, İ.; Wells, H.; Firatli, Ç. Response of *Apis mellifera syriaca* and *A. m. armeniaca* to nectar variations: Implications for agriculture. *Turk. J. Agric. For.* **1998**, *22*, 561–571.
5. Cakmak, I.; Song, D.S.; Mixson, T.A.; Serrano, E.; Clement, M.L.; Savitski, A.; Johnson, G.; Giray, T.; Abramson, C.I.; Barthell, J.F.; et al. Foraging Response of Turkish Honey Bee Subspecies to Flower Color Choices and Reward Consistency. *J. Insect. Behav.* **2010**, *23*, 100–116. [CrossRef]
6. Liolios, V.; Tananaki, C.; Dimou, M.; Kanelis, D.; Goras, G.; Karazafiris, E.; Thrasyvoulou, A. Ranking pollen from bee plants according to their protein contribution to honey bees. *J. Apic. Res.* **2016**, *54*, 582–592. [CrossRef]

7. Sherry, R.A.; Weng, E.; Arnone, J.A., III; Johnson, D.W.; Schimel, D.S.; Verburg, P.S.; Wallace, L.L.; Luo, Y. Lagged effects of experimental warming and doubled precipitation on annual and seasonal aboveground biomass production in a tallgrass prairie. *Glob. Chan. Biol.* **2008**, *14*, 2923–2936. [CrossRef]
8. Rafferty, N.E.; Diez, J.M.; Bertelsen, C.D. Changing Climate Drives Divergent and Nonlinear Shifts in Flowering Phenology across Elevations. *Curr. Biol.* **2020**, *30*, 432–441.e3. [CrossRef]
9. Bagella, S.; Satta, A.; Floris, I.; Caria, M.C.; Rossetti, I.; Podani, J. Effects of plant community composition and flowering phenology on honeybee foraging in Mediterranean sylvo-pastoral systems. *Appl. Veg. Sci.* **2013**, *16*, 689–697. [CrossRef]
10. Pearson, W.D.; Braiden, V. Seasonal Pollen Collection by Honeybees from Grass/Shrub Highlands in Canterbury, New Zealand. *J. Apic. Res.* **1990**, *29*, 206–213. [CrossRef]
11. Webby, R. Floral origin and seasonal variation of bee-collected pollens from individual colonies in New Zealand. *J. Apic. Res.* **2004**, *43*, 83–92. [CrossRef]
12. Andrada, A.C.; Tellería, M.C. Pollen collected by honey bees (*Apis mellifera* L.) from south of Caldén district (Argentina): Botanical origin and protein content. *Grana* **2005**, *44*, 115–122. [CrossRef]
13. Dimou, M.; Thrasyvoulou, A. Seasonal variation in vegetation and pollen collected by honeybees in Thessaloniki, Greece. *Grana* **2007**, *46*, 292–299. [CrossRef]
14. Barth, O.M.; Munhoz, M.C.; Luz, C.F.P. Botanical origin of *Apis* pollen loads using colour, weight and pollen morphology data. *Acta Aliment.* **2009**, *88*, 133–139. [CrossRef]
15. Dimou, M.; Thrasyvoulou, A.; Tsirakoglou, V. Efficient use of pollen traps to determine the pollen flora used by honey bees. *J. Apic. Res.* **2006**, *45*, 42–46. [CrossRef]
16. Witting, R. Flora and Vegetation. In *Stadtökologie*; Sukopp, H., Witting, R., Eds.; Gustav Frisher: Stutgard, Germany; Jena, Germany; New York, NY, USA, 1993; pp. 198–238.
17. Louveaux, J.; Maurizio, A.; Vorwohl, G. Methods of Melissopalynology. *Bee World* **1978**, *59*, 139–157. [CrossRef]
18. Beekman, M.; Ratnieks, F.L.W. Long-range foraging by the honey-bee, *Apis mellifera* L. *Funct. Ecol.* **2000**, *14*, 490–496. [CrossRef]
19. Garbuzov, M.; Couvillon, M.J.; Schürch, R.; Ratnieks, F.L.W. Honey bee dance decoding and pollen-load analysis show limited foraging on spring-flowering oilseed rape, a potential source of neonicotinoid contamination. *Agric. Ecosyst. Environ.* **2015**, *203*, 62–68. [CrossRef]
20. Danner, N.; Keller, A.; Härtel, S.; Steffan-Dewenter, I. Honey bee foraging ecology: Season but not landscape diversity shapes the amount and diversity of collected pollen. *PLoS ONE* **2017**, *12*, e0183716. [CrossRef]
21. Giovanetti, M.; Aronne, G. Honey bee handling behaviour on the papilionate flower of *Robinia pseudoacacia* L. *Arthropod Plant Interact.* **2013**, *7*, 119–124. [CrossRef]
22. Harter, B.; Leistikow, C.; Wilms, W.; Truylio, B.; Engels, W. Bees collecting pollen from flowers with poricidal anthers in a south Brazilian Araucaria forest: A community study. *J. Apic. Res.* **2002**, *41*, 9–16. [CrossRef]
23. de Novais, J.S.; Lima e Lima, L.C.; dos Santos, F.A.R. Bee pollen loads and their use in indicating flowering in the Caatinga region of Brazil. *J. Arid Environ.* **2010**, *74*, 1355–1358. [CrossRef]
24. Alves, R.F.; dos Santos, F.A.R. Plant sources for bee pollen load production in Sergipe, northeast Brazil. *Palynology* **2014**, *38*, 90–100. [CrossRef]
25. Odoux, J.F.; Feuillet, D.; Aupinel, P.; Loublier, Y.; Tasei, J.-N.; Mateescu, C. Territorial biodiversity and consequences on physico-chemical characteristics of pollen collected by honey bee colonies. *Apidologie* **2012**, *43*, 561–575. [CrossRef]
26. Kaluza, B.F.; Wallace, H.M.; Heard, T.A.; Minden, V.; Klein, A.; Leonhardt, S.D. Social bees are fitter in more biodiverse environments. *Sci. Rep.* **2018**, *8*, 12353. [CrossRef]
27. Brittain, C.; Kremen, C.; Klein, A.M. Biodiversity buffers pollination from changes in environmental conditions. *Glob. Chang. Biol.* **2012**, *19*, 540–547. [CrossRef] [PubMed]
28. Durazzo, A.; Lucarini, M.; Plutino, M.; Lucini, L.; Aromolo, R.; Martinelli, E.; Souto, E.B.; Santini, A.; Pignatti, G. Bee Products: A Representation of Biodiversity, Sustainability, and Health. *Life* **2021**, *11*, 970. [CrossRef] [PubMed]
29. Le Conte, Y.; Navajas, M. Climate change: Impact on honey bee populations and diseases. *Rev.-Off. Int. Epizoot.* **2008**, *27*, 499–510.
30. Taha, E.K.A. A study on nectar and pollen sources for honeybee, *Apis mellifera* L. in Al-Ahsa Saudi Arabia. *J. Entomol. Zool.* **2015**, *3*, 272–277.
31. Taha, E.K.A.; Taha, R.A.; AL-Kahtani, S.N. Nectar and pollen sources for honeybees in Kafrelsheikh province of northern Egypt. *Saudi J. Biol. Sci.* **2019**, *26*, 890–896. [CrossRef]