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A study on nectar and pollen sources for honeybee, *Apis mellifera* L. in Al-Ahsa Saudi Arabia

El-Kazafy Abdou Taha

Abstract
This study was conducted at the apiary of Agricultural and Veterinary Training and Research Station, King Faisal University, Al-Ahsa province, East of Saudi Arabia for two successive years 2012 and 2013 to make a map of nectar and pollen sources in Al-Ahsa province. Throughout the year, we recorded seventy nine sources of bee forage belonging to 24 plant families. Sixty six species were recorded as nectar sources, while the recorded pollen sources were 77 species. *Medicago sativa* L., *Ziziphus* spp. and *Citrus* spp. were the dominant sources of nectar. The yearly average amount of collected pollen was 2.23 kg/colony. The highest amount of trapped pollen loads was obtained during March. The most abundant pollen sources were found to be *Cucurbita pepo* Thunb (21.10%), followed by *Phoenix dactylifera* L. (20.25%), *Helianthus annuus* L. (18.15%), *M. sativa* L. (17.42%) and *Brassica napus* L. (17.05%). Beekeepers could trap pollen loads that were collected from these sources during January-May and September-October, February-March, March-August, May-June, and January-March, respectively. It was possible to map the major and minor sources of honeybee flora in Al-Ahsa province throughout the year.

Keywords: flora, honeybee, nectar, pollen, Saudi Arabia

1. Introduction
Pollen grains play an important role in the life of honeybee (*Apis mellifera* L.) colony. They require carbohydrates, proteins, fats, minerals, vitamins, and water to be able to rear brood for growth and development of the colony [1]. These elements are sourced mainly from pollen and nectar. However, in times of floral dearth, bee colonies gradually use up stored resources within the combs in their nests. During this period, the queen stops laying eggs and the colony population weakens. For beekeepers, this process is destructive for their business [2]. Bee colonies need to be strong and populous in order to store surplus nectar, which is then harvested [3, 4, 5].

Foraging for nectar and pollen is a continuous process throughout the year in tropical and sub-tropical areas, where bee flora is available. However, the foraging activities of honeybees for pollen are greatly influenced by the weather conditions and availability of pollen [6]. Al-Ahsa isn't in tropical or sub-tropical areas, but it is one of the world's largest oases with cultivated area exceeds 10000 hectares [7], so some months of the year is considered a period of scarcity of bee flora. Beekeepers usually feed their colonies with sugar syrup and pollen substitutes during dearth periods. However, no artificial foods have been found equivalent to nectar and pollen [8]. It is very useful for beekeepers to have a map of nectar and pollen sources in their areas, that's will help them to plan for managing their colonies, and they may be decided to move them to another area rich with nectar and pollen sources during certain periods [9].

Investigations on important nectar and/or pollen plant were made by several investigators in many countries such as: Barth [10] in Brazil, Mora *et al*. [11] in Costa Rica, Shawer [12]; Mohanna [8]; Hussein *et al*. [13]; Abo-Lila and Ghoniemy [14]; Taha [9]; Taha *et al*. [15]; Taha [16]; Taha and Bayoumi [17] in Egypt, Dimou *et al*. [18] in Greece, Garg [19]; Lakshmi *et al*. [20]; Abrol [21]; Singh [22]; Bhalchandra *et al*. [23] in India, Zoratti *et al*. [24]; Fortunato *et al*. [25] in Italy, Woo [26] in Korea, Payawal *et al*. [27] in Philippines, Kaya *et al*. [28] in Turkey, Kells [29]; Kirk [30, 31] in UK, and Widrlechner and Senechal [32] in USA.

Beekeeping in Saudi Arabia is a growing industry. The preliminary estimates indicate that the number of bee colonies up to one million colonies and beekeepers numbers exceed 5000, and they produce collectively about 9000 tons of honey per year, that represented about 50% of the required demand. So, approximately 9000 tons of honey is imported annually. Accordingly, researchers need to have paid special attention to various aspects of beekeeping in the region including critical investigations into honeybee, flora. The knowledge on major floral resources leads beekeepers to maintain colony strength and harvest high honey yield [33].

The present study is the first attempt to make a map of major and minor sources of nectar and pollen in Al-Ahsa province throughout the year. This map was made to work as a field guide for the beekeepers at Al-Ahsa and other regions in the same environmental conditions. Also, the study aimed to throw the light on the periods in which beekeepers can collect bee-pollen from the major pollen sources.

2. Materials and Methods

The present study was conducted at the apiary of Agricultural and Veterinary Training and Research Station, King Faisal University, Al-Ahsa, Saudi Arabia throughout two successive years, from January 2012 to December 2013. Five colonies (each of ten combs) of hybrid Carniolan honeybees, *Apis mellifera carnica* imported from Egypt were used in this experiment. All colonies were equalized to be in the same strength (brood combs, stored food, and population size).

Recording of all plant species which observed to be visited by honeybee workers in Al-Ahsa province was done. Unidentified wild plant species were collected, transferred to the lab, then were identified according to Mandaville [34] and recorded. Each source was identified by its scientific name and botanical family. Average date of the blooming period of each plant and the value for bees as a source of nectar and/or pollen was recorded.

Fresh flowers were collected monthly from the flora in the apiary area comprise both cultivated and wild plants. They were collected as buds before anthesis, and used after opening in the lab. The procedure of preparation of reference slides was described by Louveaux *et al*. [35] was used in this work. Anthers were washed out 3 times in a watch glass filled with ether. After drying, the pollen was transferred to a slide and spread out. A drop of fructose solution (20 g fructose + 0.5 g crystallized phenol in 100 ml of distilled water) was added to make transfer easier, and accelerate the swelling of the pollen grains. The preparation was dried on warming plate (40°C), and mounted with glycerine gelatine. This procedure was done for the pollen grains of each plant species. The preparation reference slides were stored in refrigerator.

To determine the monthly contribution of major pollen sources, pollen traps with efficiency of 25% were fitted to the entrances of the hives. The pollen loads were collected from pollen traps twice weekly from January to December. Pollen pellets were dried at room temperature in shady place for one hour to facilitate the separation and referred to its sources, and weighted. The pollen loads were hand-sorted according to their color and appearance. Microscopical examinations were conducted to identify the floral origin of pollen grains according to their shape and size by comparing with the previously prepared reference pollen slide.

2.1 Statistical analysis

Data of pollen collection were statistically analyzed by ANOVA using SAS® software computer program [36]. The means were compared by Duncan's Multiple Range Test [37].

3. Results

As shown in Table 1, seventy nine plant species belonging to 24 botanical families were recorded as nectar and/or pollen sources in Al-Ahsa province throughout 2012 and 2013. Sixty six species were recorded as nectar sources, and 77 as pollen sources around the year. The highest numbers (60 spp.) of blooming species were recorded during March, while the lowest numbers (6 spp.) were recorded during November and December. The taxa of botanical families which visited by honeybee workers were arranged according to their represented as follows: Asteraceae (12 spp.), Fabaceae (10 spp.), Brassicaceae (9 spp.), Cucurbitaceae (8 spp.), Rutaceae (7 spp.), Poaceae (4 spp.), Apiaceae, Labiatae, Malvaceae, Solanaceae and Zygophyllaceae (each 3 spp.), Caryophyllaceae (2 spp.) and other 12 families (Arecaceae, Boraginaceae, Capparaceae, Casuarinaceae, Chenopodiaceae, Convolvulaceae, Moraceae, Myrsinaceae, Myrtaceae, Portulacaceae, Rhamnaceae and Tamaricaceae) each represented by one species. The most important species for honeybee were *Medicago sativa* L., *Ziziphus* spp., *Citrus* spp., *Helianthus annuus* L., *Brassica napus* L., *Cucurbita pepo* Thunb, and *Phoenix dactylifera* L.

The yearly amount of trapped pollen loads was 2.02 and 2.43 kg/colony in 2012 and 2013, respectively. Significant ($P<0.01$) differences among pollen collection during the different months were observed. Three peaks of pollen collection were occurred during March, May and August (Fig. 1). The contributions of the most abundant pollen sources were found to be *C. pepo* (21.10%), followed by *Ph. dactylifera* (20.25%), *H. annuus* (18.15%), then *M. sativa* (17.42%), and *B. napus* (17.05%). The contribution of other minor sources was estimated as 6.03% (Fig. 2).

4. Discussion

A map of bee flora throughout the year in Al-Ahsa province was made. *M. sativa*, *Ziziphus* spp. and *Citrus* spp. were the main honey flora, due to the presence of a large cultivated areas of these crops, as well as an abundance of nectar secretion of flowers. *B. napus*, *C. pepo*, *H. annuus* and *Prosopis* spp. were considered secondary sources of nectar. *C. pepo, Ph. dactylifera, H. annuus, M. sativa and B. napus* were the major sources of pollen as they produced an abundk2ance of pollen grains, and cultivated in large areas. These results are in agreement with the findings of Al-Jabr and Nour [38] who reported that the main pollen sources of Saudi honeys were *Ziziphus* spp., *Acacia* spp., *Brassica* spp., *H. annuus* L., *Trifolium fragiferum* L. and *Ph. dactylifera* L. Also, in Egypt, the major honey plants for honeybee were *T. alexdrinum* L., *Gossypium* spp., *Citrus* spp., *Vacia faba* L., *Zea mays* L., *B. nigra* L., *Melilotus siculus* All, *C. pepo* Thunb and *Ph. dactylifera* [9].

Blooming of the plants is a continuous process throughout the year, while the major sources were bloomed during certain periods. The flowering periods of major sources were as follow: *M. sativa* (May-June), *Ziziphus* pp. (September-October), *Citrus*s pp. (March-April), *H. annuus* (March-August), *B. napus* (January-March), *C. pepo* (January-December) and *Ph. dactylifera* (February-March). Similar results were obtained by Taha [9] who recorded that the flowering periods of major bee plants in Karelshiekh, Egypt were *Citrus* spp. and *Ph. Dactylifera* (March and April), *C. pepo* (April-September), *T. alexdrinum* L. (April-June) and both of *H. annuus* and *Gossypium* sp. (July-August). Several species were recorded as a good source of nectar and pollen for honeybee such as: *Antignon leptopus* Hook. and Arn. from August to October [39] and *Acacia ataxacantha* (DC.) Kyal. and Boatwr. from June to October [21] in India; *Schinus terebinthifolius* Raddi during September and October [8], *Luffa aegyptiaca* Mill. from June to November [15], *Musa* sp. during August-September [16] and *Citrullus lanatus colothynthoides* L. during June and July [17] in Egypt.

Nine sources of bee forage were recorded during January. The most important sources were *C. pepo* and *B. napus*. Thirty two species bloomed during February. The dominant species were *C. pepo*, *B. napus* and *Ph. dactylifera*. During March, 60 pollen sources and 50 nectar plants were recorded.

Table 1: List of nectar and pollen flora for honeybee in Al-Ahsa province in 2012 and 2013.

No.	Scientific name	Family	Flowering period	Source	
				Nectar	Pollen
1	*Brassica napus* L.	Brassicaceae	January-March	++	++
2	*Diplotaxis acris* (Forssk.) Boiss.	Brassicaceae	January-March	+	+
3	*Sisumbrium irio* L.	Brassicaceae	January-March	+	+
4	*Raphanus sativus* L.	Brassicaceae	January-March	+	+
5	*Eruca sativa* Mill.	Brassicaceae	January-March	+	+
6	*Vicia faba* L.	Fabaceae	January-March	+	+
7	*Lavandula* spp.	Labiatae	January-March	+	+
8	*Cucurbita pepo* Thunb	Cucurbitaceae	January-December	++	++
9	*Phoenix dactylifera* L.	Areck2aceae	February-March	-	++
10	*Senecio glaucus* L.	Asteraceae	February-March	+	+
11	*Silybium marianum* L.	Asteraceae	February-March	+	+
12	*Anthemis* spp.	Asteraceae	February-March	+	+
13	*Erucaria hispanica* (L.) Druce	Brassicaceae	February-March	+	+
14	*Notoceras bicorne* (Ait) Amo	Brassicaceae	February-March	+	+
15	*Cakile arabica* Velen.	Brassicaceae	February-March	-	+
16	*Casuarina equisetifolia* L.	Casuarinaceae	February-March	-	+
17	*Melilotus siculus* All	Fabaceae	February-March	-	+
18	*Melilotus indicus* All	Fabaceae	February-March	-	+
19	*Medicago hispida* Gaertn.	Fabaceae	February-March	-	+
20	*Haplophyllum bucharicum* Litv.	Rutaceae	February-March	+	+
21	*Tamarix* spp.	Tamaricaceae	February-March	+	+
22	*Malva sylvestris* L.	Malvaceae	February-March	+	+
23	*Anagallis arvensis* L.	Myrsinaceae	February-March	-	+
24	*Zygophyllum* spp.	Zygohpyllaceae	February-April	+	+
25	*Anethum graveolens* L.	Apiaceae	February-May	+	+
26	*Coriandrum sativum* L.	Apiaceae	February-May	+	+
27	*Petroselenum crispum* Mill.	Apiaceae	February-May	+	+
28	*Sonchus oleraceas* L.	Asteraceae	February-May	+	+
29	*Senecio vulgaris* L.	Asteraceae	February-May	+	+
30	*Aaronsohnia factorovskyi* Warb and Eig.	Asterak2ceae	February-May	+	+
31	*Ocimum* spp.	Labiatae	February-December	+	+
32	*Onopordum acanthium* L.	Asteraceae	March-April	+	+
33	*Heliotropium digynum* (Forssk.) Asch.	Boraginaceae	March-April	-	+
34	*Zilla spinosa* (L.) Prantl	Brassicaceae	March-April	+	+
35	*Polycarpaea repens* (Forssk.) Asch. and Schw.	Caryophyllaceous	March-April	+	+
36	*Haloxylon salicornicum* (Moq.) Bunge	Chenopodiaceae	March-April	+	+
37	*Prosopis* spp.	Fabaceae	March-April	++	+
38	*Acacia* spp.	Fabaceae	March-April	+	+
39	*Senna italica* Mill.	Fabacek2ae	March-April	+	+
40	*Teucrium* spp.	Labiatae	March-April	+	+
41	*Citrus aurantifolia* Swingle	Rutaceae	March-April	+	+
42	*Citrus sinensis* Osbeck	Rutaceae	March-April	++	+
43	*Citrus reticulate* Blanco	Rutaceae	March-April	+	+
44	*Citrus aurantium* L.	Rutaceae	March-April	+	+
45	*Citrus medica* L.	Rutaceae	March-April	++	+
46	*Prunus dulcis* Mill	Rutaceae	March-April	+	+
47	*Tribulus pentandrus* Forssk.	Zygohpyllaceae	March-April	+	+
48	*Tribulus arabicus* Hosni	Zygohpyllaceae	March-April	+	+
49	*Chloris gayana* Kunth	Poaceae	March-May	-	+
50	*Chloris virgata Sw.*	Poaceae	March-May	-	+
51	*Morus spp.*	Moraceae	March-June	+	+
52	*Helianthus annuus L.*	Asteraceae	March-August	++	++
53	*Convolvulus arvensis L.*	Convolvulaceae	March-October	+	+
54	*Cucumis sativus L.*	Cucurbitaceae	March-October	+	+
55	*Cucumis prophetarum* Jusl.	Cucurbitaceae	March-October	+	+
56	*Portulaca oleraceas* L.	Portulacaceae	March-October	-	+
57	*Solanum lycopersicum* L.	Solanaceae	March-December	+	+
58	*Solanum melongena* L.	Solanaceae	March-December	+	+
59	*Capsicum annuum* L.	Solanaceae	March-December	+	+
60	*Trifolium alexandrinum* L.	Fabaceae	April-May	+	+

Table 1: Continued.

61	*Trifolium fragiferum* L.	Fabaceae	April-May	+	+
62	*Anvillea garcinii* Burm.	Asteraceae	April-May	+	+
63	*Pulicaria undulata* (L.) Kostel	Asteraceae	April-May	+	+
64	*Rhanterium epapposum* Oliv	Asteraceae	April-June	+	+
65	*Achillea fragrantissima* (Forssk.) Sch. Bip	Asteraceae	April-June	+	+
66	*Dipterygium glaucum* Decne.	Capparaceae	April-June	+	+
67	*Medicago sativa* L.	Fabaceae	May-June	++	++
68	*Abelmoschus esculentus* (L.) Moench	Malvaceae	May-October	+	-
69	*Citrullus colocynthis* L.	Cucurbitaceae	May-October	+	+
70	*Gossypium* sp.	Malvaceae	July-August	+	-
71	*Oryza sativa* L.	Poaceae	July-October	-	+
72	*Cucurbita maxima* Duchesne	Cucurbitaceae	July-October	+	+
73	*Cucurbita moschata* Duchesne	Cucurbitaceae	July-October	+	+
74	*Citrullus lanatus* (Thunb.) Matsum. and Nakai	Cucurbitaceae	July-October	+	+
75	*Ziziphus* spp.	Rhamnaceae	September-October	++	+
76	*Cucumis melo* L.	Cucurbitaceae	September-October	+	+
77	*Hammada salicornica*	Caryophyllaceous	September-October	+	+
78	*Zea mays* L.	Poaceae	September-October	-	+
79	*Eucalyptus globulus* Labill	Myrtaceae	September-March	+	+

+, ++ and – indicate source, major source and not source, respectively.

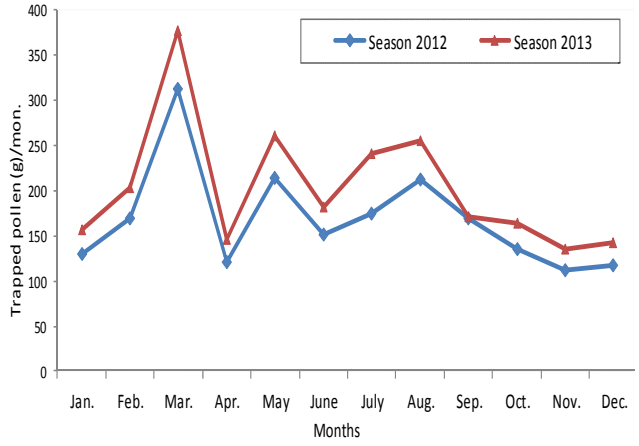

Fig 1: Mean amount of trapped pollen loads (g) on different months during 2012 and 2013 in Al-Ahsa province.

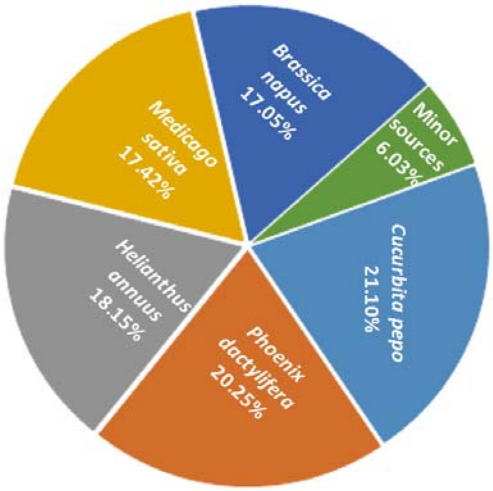

Fig 2: Average contributions of the major pollen sources in Al-Ahsa province in 2012 and 2013.

The predominant bee flora were *C. pepo*, *B. napus*, *Ph. dactylifera*, *H. annuus*, *Citrus* spp. and *Prosopis* spp. Forty four pollen and 40 nectar sources were recorded during April; unfortunately most of them were dried at the first week of April. *C. pepo*, *H. annuus* and *Citrus* spp. were the most benefit plants in this month. Twenty nine pollen and 27 nectar plant species were recorded on May. The most abundant were *M. sativa*, *C. pepo* and *H. annuus*. Seventeen sources of bee forage were recorded during June-August; *H. annuus* were the most importance. Twenty taxa were bloomed through September-October; *C. pepo* and *Ziziphus* spp. were the major sources. Although, six plant species bloomed on November and December, it considered dearth period. In Egypt, Hussein *et al*. [13] reported that the pollen sources through months during 1988-1990 in Assiut Governorate were: *V. faba* and *Sinapis arvensis* L. (January); *V. faba*, *H. annuus*, *S. arvensis* and *Coriandrum prunus* (February); *T. alexandrinum* L., *S. arvensis*, *Calendula* sp., *Citrus* sp., *Ph. dactylifera*, *C. prunus* and *Reseda odorata* L. (March); *T. alexandrinum*, *S. arvensis*, *Calendula* sp., *Citrus* sp., *Ph. dactylifera* and *R. odorata* (April); *T. alexandrinum*, *S. arvensis*, *Ph. dactylifera and Psidum* sp. (May); *T. alexandrinum*, Cucurbitaceae and *Zea mays* L. (June); *Z. mays*, *H. annuus*, *Casuraina equisetifolia* L. and Cucurbitaceae (July); *Z. mays*, *H. annuus* and *Sesamum* sp.(August); *Z. mays*, *H. annuus* and *Sesamum* sp. and *C. equisetifolia* (September); *Z. mays* and *C. equisetifolia* (October); *Z. mays* and *C. equisetifolia* (November) and *V. faba* and *C. equisetifolia* (December).

The most represented families were Asteraceae (12 spp.), Fabaceae (10 spp.), Brassicaceae (9 spp.), Cucurbitaceae (8 spp.), Rutaceae (7 spp.). They contributed by 58.23% of total bee flora, and more than 73.72% of total yearly pollen loads. These results are in harmony with those obtained by Zoratti *et al*. [24] who recorded great number of bee plant species in Italy, the most represented families were Asteraceae, Rosaceae, Labiatae, Fabaceae, Brassicaceae and Poaceae. Also, Adekanmbi and Ogundipe [40] reported that the most abundant taxa identified from honey samples of Nigeria were *Tridax procumbens* L. (Asteraceae) and *Elaeis guineensis* Jacq. (Arecaceae). In the present study, although family Arecaceae was represented by one species (*Ph. dactylifera*) only, it is the second most important source of pollen since it contribuk8ted by 20.25% of total trapped pollen.

The monthly weight of trapped pollen loads indicated that, the honeybee colonies started their activities in pollen collectk2ion during January, then significant ($P<0.01$) increasing was

occurred during February and reached the maximum amount during March formed the biggest peak. Sharp decrease in pollen collection was occurred during April, then increased significantly (P<0.01) and formed the second peak in May coincide with the blooming period of alfalfa, then significant (P<0.01) decrease occurred during June. Significant (P<0.01) increasing in pollen collection from *H. annuus* and *C. pepo*. occurred and formed the third peak in July and August, then gradually and significantly (P<0.01) decreasing was occurred from September to November. Our results are confirmed by the findings of Sattigi and Lingappa [41] who found the maximum area of stored pollen during March in India, while it was during May in Egypt [4, 9, 12,42] and Yemen [43]. On contrary, the maximum area of stored pollen was recorded during September in the Island of Hawaii [44]. The highest amount of collected pollen was occurred in March (the blooming period of *C. pepo*, *B. napus*, *Ph. dactylifera* and *H. annuus*). April considered dearth period in Al-Ahsa province due to shortage of pollen and nectar flora, as a result of dried of most flowering plants after short time of April. Besides, the presence of migratory bee-eater (*Merops* spp.) birds in the apiary area during April caused declined in workers flights.

The large amount of trapped pollen loads from *C. pepo* was due to the availability of the blooming plants throughout the year. Although the blooming period of *Ph. dactylifera* was occurred only during February and March, collected pollen from it ranked second, due to the large area of cultivated date palm trees which estimated by14140 hectares in eastern region [7]. Pollen from *H. annuus* was found in the third place, since it was grown and flowered more than once in the year. *M. sativa* and *B. napus* and were in a tight places. The major pollen sources might be differed from area to another within the same k2country. In Egypt, Shawer [12] found that the most abundant pollen sources in Kafrelsheikh were found to be *Z. mays* (42.00%) followed by *T. alexandrinum* (40.40%), *B. kaber* (7.60%), *Melilotus siculus* (4.00%) and *V. faba* (0.90%), the contribution of other unidentified minor sources was estimated as 5.10%. Besides, Abo-Lila and Ghoniemy [14] listed 22 plants belonging to 15 families from which bees collected pollen in Dokki region. Trees represented the most important pollen sources, offering more than 80.00% of the total amount of collected pollen. In India, Garg [19] analyzed the pollen loads collected by honeybees (*A. cerana*) in Uttar Pradesh in autumn. Taxa of the Asteraceae were dominant (34.70% of loads) followed by Poaceae, Labiatae and Fabaceae (each 10.00%) and eleven minor sources of bee forage.

5. Conclusion

The present study suggests that, the beekeepers in Al-Ahsa province could use this map as a field guide for moving their apiaries to obtain high honey yield, supporting their colonies and/or economizing the cost of artificial feeding. They could move their colonies during the blooming seasons of *Citrus* spp. (February-March), *M. sativa* (May-June) and *Ziziphus* spp. (September-October) to obtain good honey yield, and could trapping pollen loads collected by honeybees during the flowering periods of *C. pepo* (January-May and September-October), *Ph. dactylifera* (February-March), *H. annuus* (March-August), *M. sativa* (May-June) and *B. napus* (January-March).

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