Environmental and Experimental Biology (2022) 20: 103–111
http://doi.org/10.22364/eeb.20.10

Original Paper

Wide diversity of pollens in honey samples from Indian Himalayan neighbourhoods: a melissopalynological study

ISSN 2255-9582

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Abstract

Melissopalynological analysis of 34 honey samples (17 summer and 17 autumn samples) collected from feral colonies of Indian hive bee (*Apis cerana*), European bee (*Apis mellifera*) and rock bee (*Apis dorsata*) during 2011 – 2015 from the Shimla Hills of Himachal Pradesh (India) was performed. Pollen from plant taxa belonging to 43 families was found in the honey samples. Of 34 honey samples from the Shimla Hills, 18 were unifloral with 12 pollen types as predominant and the remaining 16 samples were multifloral. The predominant pollen plant taxa of summer were *Pyrus* sp., *Malus domestica, Prunus amygdalus, Prunus* sp., *Eucalyptus camaldulensis, Citrus* sp. and *Rhododendron arboreum.* In autumn, the predominant pollen plant taxa were *Leucaena leucocephala, Salvia officinalis, Eriobotrya japonica, Impatiens balsamina* and *Prinsepia utilis*. Melissopalynological analysis of summer honey collected from Summer Hill and Sarahan tagged these as "mad honey", since *Rhododendron* pollen was predominant. The pollen spectrum indicated a diverse bee plant flora, which is promising indicator to augment the beekeeping industry in this region.

Key words: honey samples, multifloral, melissopalynology, pollen, unifloral.

Introduction

Production of honey in an area depends on the bee floral resources along with better strains of bees and their appropriate management. Success of beekeeping depends on basic factors such as bee forage, bee management and bee breed., and also the duration of time for which bee forage is available (Crane 1975; Free 1993; Mattu 2008a; Mattu 2008b; Adeonipekun 2012). While foraging on plants for nectar and pollen, honey bees incidentally reciprocate by performing valuable pollination services. Microscopic analysis of pollen in honey samples, melissopalynology, allows to gain evidence of the geographical location of honey samples due to the combination of pollen that is typical only to that particular location (Louveaux et al. 1978). Thus, melissopalynology is helpful in both quantitative and qualitative pollen analysis of honey samples (Louveaux et aI. 1978). Honey pollen analysis also enables identification of honey contaminated by poisonous plants (Chaubal, Deodikar 1965; Shubharani et al. 2012).

Himachal Pradesh is a hilly state situated in the heart of Western Himalayas. Himachal Pradesh is a fruit growing state and honeybees may boost crop productivity, thereby improving the socio-economic standing of the residents engaged in honey apiculture (Sharma et al. 2022). Along with apple, other temperate fruit trees (P*runus amygdalus, Prunus armenica, Prunus avium, Prunus domestica, Prunus persica* and *Pyrus communis*) are cultivated (Balokhra 2013). Incorporation of apiculture with horticulture augments the income by many times, improving the socioeconomic status of farmer (Tej et al. 2017). The beekeeping activity of the state has increased to about 90 000 colonies of *Apis mellifera* and the number of beekeepers increased to 1500 with production of 1700 million t honey in the low to high hills of Himachal Pradesh (Neha et al. 2020).

With a drastic increase in the area under fruit cultivation during recent years, a major problem related to bee forage has arisen. Once the bloom of a crop of interest is over, the bees are left with considerably reduced floral resources. This problem can be circumvented either by providing alternate bee forage or moving bees to locations where floral resources are plentiful. In both cases, knowledge of pollen and nectar plants in beekeeping potential areas is essential, and this can be achieved only through melissopalynological and bee botany studies. Therefore, this work presents pollen analysis of honey samples from different areas of the Shimla

hills of Himachal Pradesh, leading to the identification of major, medium and minor sources of pollen and nectar to honey bees in the Shimla District.

Materials and methods

Honey samples (17 each from summer and autumn) were collected from the feral colonies of *Apis cerana* F., *Apis dorsata* F. and *Apis mellifera* L. during 2011 – 2015 from different areas of the Shimla hills of Himachal Pradesh to determine the pollen flora of the region. Summer (May to June) and autumn (September to October) honey samples were collected from Suni, Kangal, Theog, Nankhari, Summer Hill, Shoghi, Kotkhai, Tikkar, Rohru, Chirgaon, Rampur, Sarahan, Junga, Chopal, Jubbal, Nerwa and Kupvi areas (Fig. 1). The colour of the honey samples was determined by a simple colour grading method (Upadhyay, Bera 2012).

The separation of pollen from honey samples followed the usual technique for pollen analysis: 10 g honey was diluted with 20 mL hot water and then centrifuged for 3 min at 3500 rpm. After decanting, the residue was once more brought into suspension with 20 mL water and again centrifuged. The pollen grains formed the major part of residue that remained after decanting the supernatant fluid.

Quantitative microscopic analysis of honey was done by preparing slides using the method of Louveaux et al. (1978). Pollen grains were identified with the help of reference slides (prepared from a collection of the local flora from an area about 5 km around the beehive). The pollen identification was also verified with the help of an earlier pollen slide collection of the Entomology and Biodiversity Laboratory, Department of Biosciences, Himachal Pradesh University, Shimla, and other publications (Erdtman, 1960; Nair 1964, 1985). A few pollen samples of wild plant taxa were confirmed by comparing them with reference pollen slides available in the pollen herbarium of the Palynology Laboratory, National Botanical Research Institute, Lucknow and published literature (Nayar 1990; Hari, Sharma, 1986; Jana et al. 2002; Chaya, Varma 2004; Saha et al. 2007). The majority of the pollen samples could be identified to the species level. An absolute pollen count was made using a haemocytometer (Louveaux et al. 1978; Seethalakshmi 1980; Suryanarayana et al. 1981).

The honey samples were considered rich, poor and very poor in pollen if the total number of pollen grains per 10 g (absolute pollen count) of honey was > 1 000 000, 20 000 to 1 00 000 and < 20 000 respectively (Maurizio 1975). For quantification of pollen grain types, 500 pollen grains were randomly counted from each sample. Percentage frequency of the pollen taxa in all the samples was calculated. Recommendations of the International Commission for Bee Botany (Louveaux et al. 1978) were followed for determination of the frequency classes. These frequencies were used to construct pollen spectra (Sharma, Nair 1965). Pollen frequency classes were determined as predominant pollen (represented by 45% of the pollen grains counted), secondary pollen (16 – 45%), important minor pollen (3 – 15%) and minor pollen (less than 3%) (Louveaux et al. 1978). A honey sample with one predominant pollen type was regarded as unifloral, and multifloral otherwise (Iwama, Melhem 1979).

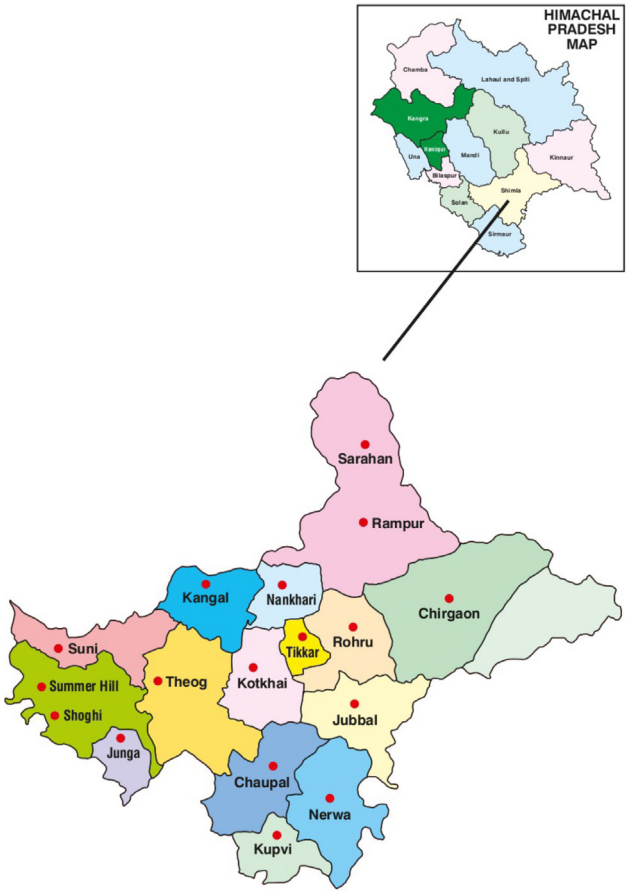

Fig. 1. Distribution of sites for honey sample collection within Shimla District of Himachal Pradesh, India.

Results

The melissopalynological investigations of 34 honey samples collected during two major honey flow seasons (i.e. May – June and September – October) from the Shimla hills, collectively demonstrated the presence of pollen of 86 plant species and nine families. Analysis categorized 12 summer samples as unifloral with seven pollen types as predominant and the remaining five samples as multifloral. Twenty two pollen types were recorded as secondary, 37 pollen types as important minor and 26 pollen types as minor (Table 1, Appendix 1). Pollen of *Malus domestica* was predominant in a maximum number of unifloral summer honey samples of the Shimla hills (Kotkhai, Rohru, Rampur and Chopal). Pollen of *Prunus* sp. was predominant in unifloral summer honey from Nankhari and Shoghi. *Prunus amygdalus* and

Pyrus sp. pollen was predominant in Theog and Tikkar summer honey, respectively. Similarly, *Rhododendron arboreum* pollen was predominant in Summer Hill and Sarahan summer honey. *Eucalyptus camaldulensis* and *Citrus* sp. pollens were predominant in Suni and Kangal summer honey, respectively.

However, in autumn honey samples, six were recorded as unifloral, with five pollen types as predominant and the remaining 11 samples were multifloral. Twenty one pollen types were recorded as secondary, 28 pollen types as important minor and 25 pollen types were present as minor (Table 1, Appendix 2). Of six unifloral autumn samples, two samples, from Rohru and Jubbal, had *Impatiens balsamina* as the predominant pollen source. The remaining four unifloral autumn honey samples from regions Suni, Kangal, Kotkhai and Kupvi had *Salvia officinalis, Leucaena leucocephala, Prinsepia utilis* and *Eriobotrya japonica* as predominant sporomorphs, respectively.

Significant secondary pollen taxa in the Shimla Hills were *Bauhinia perpurea, Psidium guajava, Emblica officinalis, Citrus* sp., *Brassica campestris, Raphanus sativus, Ocimum sanctum, Salvia splendens, Helianthus annuus, Woodfordia fruticosa, Aesculus indica, Rubus ellipticus, Impatiens balsamina, Dahlia pinnata, Tithonia rotundifolia, Tagetus erectus, Prinsepia utilis, Trifolium repens, Indigofera* sp., and *Hypericum cernuum*. The colour assortment of the samples diverged from watery white (in Theog honey) to dark amber (Shoghi, Nerwa and Kupvi honeys). *Malus domestica, Prunus* sp. and *Pyrus* sp. are the major cultivated economic fruit crops of the district and eight honey samples (about 67%) of all unifloral honey samples of summer possessed these three pollen taxa as predominant. The absolute pollen count indicated 65% (11 samples) of summer honey and only 18% (three samples) of autumn honey samples were rich in pollen (> 1 000 000), 29% (five samples) of summer honey and 70% (12 samples) of autumn honey samples were poor (20 000 –1 000 000) in pollen, and 6% (only one sample) of summer honey samples and 12% (two samples) of autumn honey samples were very poor (< 20 000) in pollen.

Discussion

Melissopalynological study confirmed 67% (eight of 12 honey samples) of unifloral summer honey samples with predominant pollen of cultivated temperate fruit crops i.e.: *Malus domestica, Prunus amygdalus, Prunus* sp. and *Pyrus* sp. Of 12 unifloral summer honey samples, four (Chopal, Rohru, Kotkhai, Rampur regions) had *Malus domestica* as the predominant pollen source. Recently, Attri (2010) also identified *Malus domestica* as an important source of pollen and nectar in various honey samples from Chamba district of Himachal Pradesh. Pollen from *Prunus* sp. was predominant in Theog, Nankhari and Shoghi honey samples, which was also found in an earlier study (Chaturvedi 1983), which reported *Prunus* sp. as an important minor pollen source. Sharma (1989) also reported it as a predominant pollen source in a Rohru honey sample. Kallesha et al. (1999) identified it as a predominant pollen source in Dharwad (Karnataka) honey, whereas Singh and Sharma (2007) reported *Prunus* spp. as an important source of pollen and nectar in Himachal Pradesh.

The study revealed that once the bloom of cultivated plants is over, honey bees forage on wild plants, as three unifloral summer honey samples had *Rhododendron arboreum* (two samples) and *Eucalyptus camaldulensis* (one sample) pollen as predominant. *Eucalyptus camaldulensis* as a predominant sporomorph is supported by study of Singh and Sharma (2007), which reported *Eucalyptus* sp. as an important source of pollen and nectar in low and mid hills of Himachal Pradesh. *Citrus* sp. was another predominant pollen source in Kangal region of the Shimla hills along with *Prunus amygdalus* from Theog and *Pyrus* sp. from Tikkar regions respectively. Sharma (1989) reported *Citrus* sp. as a predominant source of pollen from Bilaspur and Mandi in Himachal Pradesh. *Citrus* spp. was also identified as an important source of pollen and nectar in low hills of Himachal Pradesh (Singh, Sharma 2007).

In total, 83% (five samples) of unifloral autumn honeys had predominant pollen of wild flora i.e. *Salvia officinalis, Leucaena lucocephala, Impatiens balsamina* and *Prinsepia utilis*. It is also clear that the pollen spectra of multifloral summer and autumn honey is comprised of wide range of wild flora: *Prinsepia utilis, Leucaena leucocephala, Impatiens balsamina, Murraya koenigii, Woodfordia fruticosa, Trifolium repens, Taraxacum officinale, Adhatoda vasica, Acacia* sp., *Aesculus indica, Bauhinia variegata, Berberis aristata, Cassia fistula, Grewia optiva, Rosa moschata, Rubus ellipticus, Aster* sp., *Carum bubocastanum, Tropaeolum majus, Hypericuum cernuum, Indigofera* sp., *Vitex negundo, Viola odorata, Bidens pilosa, Opuntia* sp., *Cannabis sativa* and *Rumex hastatus*.

The bee flora of the hills of the study area is comprised of plentifull wild plants. This study yielded fresh insight into pollen composition of summer and autumn honey from different regions of the Shimla hills.

Six unifloral autumn samples reported in our study had *Impatiens balsamina* as a predominant pollen source in honey samples from regions Rohru and Jubbal. Earlier, Sharma (1989) reported *Impatiens* sp. as a predominant pollen source in Chail (45.27%) honey of autumn. Mattu et al. (2005) also found this species as a major source of nectar and pollen to honeybees during autumn. Similarly, Attri (2010) reported it as an important honey pollen source in autumn honey collected from Chamba district of Himachal Pradesh. Recently, Tiwari et al. (2012) reported *Impatiens* spp. as an important pollen type in various honey samples from the Uttarakashi area of Garhwal Himalayas. Four unifloral honey samples from autumn samples from regions Suni, Kangal, Kotkhai and

Table 1. Pollen spectrum of the honey samples of *Apis* spp. collected from various areas of Shimla hills of Himachal Pradesh. Predominant pollen type, 45% and above; important minor pollen type, 3 to 15%; secondary pollen type, 16 to 45%; minor pollen type, < 3%

Locality	Season	Month/ year	Species of honey bee	Colour of honey	Floristic nature	Predominant pollen type	Secondary pollen type	Important minor pollen type	Minor pollen type
Suni	Summer	Jul/2012	*A. dorsata*	Amber	Unifloral	*Eucalyptus camaldulensis*	*Emblica officinalis, Grewia optiva*	Brassicaceae, Rutaceae, *Leucaena leucocephala*	*Adhatoda vasica, Zea mays*
	Autumn	Oct/2012	*A. mellifera*	Light yellow	Unifloral	*Salvia officinalis*	*Pyrus* sp.	*Taraxacum officinale, Cassia fistula, Chenopodium album*	*Brassica* sp., *Hypericum cernuum*
Kangal	Summer	May/2012	*A. dorsata*	Light yellow	Unifloral	*Citrus* sp.	*Prunus persica, Berberis aristata*	*Cucurbita maxima, Tropaeolum majus, Adhatoda vasica*	*Sonchus* sp., *Cannabis sativa, Rumex hastatus*
	Autumn	Oct/2012	*A. cerana*	Light brown	Unifloral	*Leucaena lucocephala*	*Hypericum cernuum*	*Tagetus erectus, Foeniculum vulgare*	*Adhatoda vasica, Chrysanthemum* sp.
Theog	Summer	Apr/2011	*A. mellifera*	Brown	Unifloral	*Prunus amygdalus*	*Malus domestica, Citrus* sp.	*Mangifera indica, Berberis aristata*	*Bidens pilosa, Pisum sativum*
	Autumn	Oct/2011	*A. mellifera*	Watery white	Multifloral	–	*Impatiens balsamina, Portulaca grandiflora*	*Taraxacum officinale, Prinsepia utilis*	*Chenopodium album, Vitex negundo*
Nankhari	Summer	Jun/2012	*A. mellifera*	Amber	Unifloral	*Prunus* sp.	*Malus domestica, Pyrus* sp.	*Berberis aristata, Ocimum sanctum, Rosa indica*	Cucurbitaceae
	Autumn	Oct/2012	*A. mellifera*	Light yellow	Multifloral	–	*Prinsepia utilis, Rubus ellipticus*	*Indigofera* sp., *Ocimum sanctum, Salvia splendens*	*Chenopodium album, Zea mays*
Summer Hill	Summer	May/2011	*A. mellifera*	Brown	Unifloral	*Rhododendron arboreum*	*Aesculus indica, Taraxacum officinale*	*Prinsepia utilis, Gaillardia pulchella, Brassica* sp., *Agapanthus* sp.	Asteraceae, Convolvulaceae
	Autumn	Sep/2011	*A. mellifera*	Light amber	Multifloral	–	*Trifolium repens, Indigofera* sp., *Rosa moschata*	*Dahlia pinnata, Hydrangea* sp.	*Aster* sp., *Geranium wallichiana*
Shoghi	Summer	Jun/2011	*A. mellifera*	Dark amber	Unifloral	*Prunus* sp.	*Pyrus* sp., *Bauhinia variegata*	*Emblica officinalis, Murraya koenigii, Grewia optiva*	*Ageratum conyzoides,* Rutaceae, Cucurbitaceae, Fabaceae
	Autumn	Sep/2011	*A. dorsata*	Brown	Multifloral	–	*Impatiens balsamina, Salvia splendens*	*Tagetus erectus, Callistemon citrinus, Trifolium repens*	*Chenopodium album, Amaranthus caudatus*
Kotkhai	Summer	May/2015	*A. mellifera.*	Amber	Unifloral	*Malus domestica*	*Prunus* sp., Myrtraceae	*Punica granatum,* Cucurbitaceae, Apiaceae	*Euphorbia* sp., *Bidens pilosa, Opuntia* sp.
	Autumn	Sep/2015	*A. mellifera.*	Brown	Unifloral	*Prinsepia utilis*	*Rubus ellipticus, Impatiens balsamina*	*Abelmoschus esculentus, Amaranthus caudatus*	*Salvia officinalis, Cannabis sativa*
Tikkar	Summer	May/2014	*A. mellifera.*	Amber	Unifloral	*Pyrus* sp.	*Brassica campestris*	*Psidium guajava, Woodfordia fruticosa*	Rutaceae, Cucurbitaceae, *Lilium* sp.
	Autumn	Sep/2014	*A. mellifera*	Light yellow	Multifloral	–	*Dahlia pinnata, Ocimum sanctum, Raphanus sativus*	*Rosa macrophylla, Rubus ellipticus*	Apiaceae, Asteraceae
Rohru	Summer	Jun/2011	*A. cerana*	Amber	Unifloral	*Malus domestica*	*Prunus* sp., *Brassica oleracea*	Asteraceae, Cucurbitaceae	*Capsicum annuum, Solanum melongena, Pinus* sp.
	Autumn	Oct/2011	*A. mellifera*	Light amber	Unifloral	*Impatiens balsamina*	*Cucumis sativus, Brassica* sp.	*Bidens pilosa, Ageratum conyzoides*	*Rumex hastatus,* Convolvulaceae

Table 1. *Continued*

Locality	Season	Month/ year	Species of honey bee	Colour of honey	Floristic nature	Predominant pollen type	Secondary pollen type	Important minor pollen type	Minor pollen type
Chirgaon	Summer	May/2013	*A. cerana*	Brown	Multifloral	–	*Rhododendron arboreum, Helianthus annuus, Brassica* sp.	*Malus domestica, Impatiens balsamina, Campsis grandiflora*	*Lilium* sp., *Delphinium roylei, Papaver rhoeas*
	Autumn	Sep/2013	*A. cerana*	Light brown	Multifloral	–	*Tithonia rotundifolia, Salvia splendens*	*Hydrangea* sp. *Trifolium repens,* Apiaceae	*Lycopersicum esculentum, Carum bubocastanum*
Rampur	Summer	May/2014	*A. dorsata*	Yellow	Unifloral	*Malus domestica*	*Pyrus* sp.	*Prunus* sp., *Eucalyptus camaldulensis*, Cucubitaceae, *Acacia* sp.	*Delphinium roylei, Bidens pilosa, Pinus* sp.
	Autumn	Oct/2014	*A. dorsata*	Light amber	Multifloral	–	*Tagetus erectus, Salvia splendens*	*Rosa indica, Indigofera* sp., *Taraxacum officinale, Abelmoschus esculentus*	*Zea mays, Geranium wallichiana, Cannabis sativa*
Sarahan	Summer	May/2014	*A. cerana*	Amber	Unifloral	*Rhododendron arboreum*	*Malus domestica, Impatiens balsamina*	*Eucalyptus camaldulensis, Berberis aristata, Agapanthus* sp., *Graptopetalum* sp.	*Adhatoda vasica, Ageratum conyzoides, Pinus* sp.
	Autumn	Sep/2014	*A. mellifera*	Light brown	Multifloral	–	*Dahlia pinnata, Hydrangea* sp.	Asteraceae, *Carum bulbocastanum*	*Bidens pilosa, Rumex hastatus*
Junga	Summer	May/2015	*A. dorsata*	Brown	Multifloral	–	*Pyrus* sp., *Woodfordia fruticosa, Bauhinia variegata*	*Prunus* sp., *Berberis aristata, Malus domestica*	*Bidens pilosa, Hypericum cernuum, Papaver rhoeas*
	Autumn	Sep/2015	*A. dorsata*	Light brown	Multifloral	–	*Aesculus indica, Impatiens balsamina, Brassica* sp.	*Rubus ellipticus, Emblica officinalis, Adhatoda vasica*	*Cucumis sativus, Viola odorata*
Chopal	Summer	June/2014	*A. mellifera*	Brown	Unifloral	*Malus domestica*	*Prunus* sp.	*Citrus* sp., Cucurbitaceae, *Indigofera* sp.	*Adhatoda vasica, Ageratum conyzoides*
	Autumn	Sep/2014	*A. mellifera*	Amber	Multifloral	–	*Trifolium repens, Brassica* sp.	Rosaceae, Asteraceae, *Ocimum sanctum, Vitex negundo*	*Salvia splendens, Cannabis sativa*
Jubbal	Summer	Jun/2012	*A. cerana*	Light yellow	Multifloral	–	*Citrus* sp., *Prunus* sp., *Punica granatum*	*Brassica* sp., *Berberis aristata, Zinnia elegans*	Cucurbitaceae, Apiaceae, *Ranunculus* sp.
	Autumn	Sep/2012	*A. cerana*	Amber	Unifloral	*Impatiens balsamina*	*Aesculus indica*	*Prinsepia utilis, Indigofera* sp.	*Lilium* sp., *Vitex negundo,* Myrtaceae
Nerwa	Summer	May/2012	*A. dorsata*	Dark amber	Multifloral	–	*Bauhinia purpurea, Emblica officinalis*	*Taraxacum officinale, Callistemon citrinus*	*Aloe barbadensis, Asparagus* sp.
	Autumn	Sep/2012	*A. dorsata*	Brown	Multifloral	–	*Rubus ellipticus, Impatiens balsamina, Sesamum indicum*	Asteraceae, *Foeniculum vulgare*	*Salvia officinalis, Cannabis sativa*
Kupvi	Summer	Jun/2014	*A. cerana*	Dark amber	Multifloral	–	*Prunus* sp., *Psidium guajava*	*Helianthus annuus, Hibiscus rosa-sinensis, Callistemon citrinus*	Asteraceae, Rutaceae
	Autumn	Sep/2014	*A. mellifera*	Light brown	Unifloral	*Eriobotrya japonica*	*Impatiens balsamina*	*Indigofera* sp., *Taraxacum officinale, Cucurbita maxima*	*Sesamum indicum, Aster* sp.

Kupvi contained *Salvia officinalis, Leucaena leucocephala, Prinsepia utilis* and *Eriobotrya japonica* as predominant sporomorphs respectively. Sharma (1989) reported *Salvia officinalis* as a predominant, secondary, important minor and minor pollen source from different parts of Himachal Pradesh. *Salvia* sp. was also observed as a predominant and secondary pollen source in various honey samples collected from Dharwad in Karnataka (Kallesha et al. 1999). Recently, Tiwari et al. (2012) found *Prinsepia utilis* as an important pollen type in various honey samples from the Uttarakashi area of Garhwal Himalaya. *Eriobotrya japonica* is an important bee forage plant visited by honeybees in the Himalayan region (Partap 1997). Moreover, *Eriobotrya* flowers from November to January provide a major source of nectar and pollen to honeybees in Europe (D'Albore, Intoppa 2000).

Our results revealed that about 70% of the summer honey samples were unifloral. The demand for unifloral honey in the local as well as in the global market is high (Guemes-Ricalde et al. 2006). It is the location of the apiary that plays an important role in content of the honey, as the location determines the vegetation found around it. Moreover, worker honey bees elicit a curious behaviour called floral fidelity, which confines their attention to a single species of resource on its foraging expeditions (Akratanakul 1987). Many of the predominant pollen types from some regions are also found as important minor and minor pollen types from samples of other regions. This is due to wide distribution of these floral resources and variation in utilities to bees, in different studied sites (Suryanarayana 1978). The same factor could be behind five multifloral samples from summer honey samples and 11 multifloral samples from autumn, but seasonal differences in the availability of flowers cannot be ignored.

Conclusions

Analysis of honey pollen allows identification of source plant communities, source environment, and likely source regions for evidentiary material. This investigation was carried out in order to determine important pollen and nectar resources for honeybees in Shimla district. The Shimla hills have varied topographical conditions, resulting in an eclectic range of pollen in diverse honey samples. Our study showed availability of useful floral resources in abundance, which further hints to a wide scope for the beekeeping industry in the Shimla hills due to multiplicity of bee flora available throughout the year.

Acknowledgements

The study was part of the PhD research work of Ms. Vandana Kumari. The authors would like to express their unending gratitude to the Department of Biosciences, Himachal Pradesh University, Shimla, India for the lab facilities and other timely supports.

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Appendix 1. Frequency distribution of pollen types in summer honey samples of *Apis* spp. collected from different areas of Shimla hills of Himachal Pradesh (expressed as percentage of total number of pollen grains)

Plant taxon	Sunni	Kangal	Theog	Nankhari	Summer Hill	Shoghi	Kotkhai	Tikkar	Rohru	Chirgaon	Rampur	Saharan	Junga	Chopal	Jubbal	Nerwa	Kupvi
Acacia sp.	–	–	–	–	–	–	–	–	–	–	4.11	–	–	–	–	–	–
Adhatoda sp.	2.04	3.80	–	–	–	–	–	–	–	–	–	2.23	–	2.45	–	–	–
Aesculus sp.	–	–	–	–	16.25	–	–	–	–	–	–	–	–	–	–	–	–
Agapanthus sp.	–	–	–	–	4.01	–	–	–	–	–	–	4.10	–	–	–	–	–
Ageratum sp.	–	–	–	–	–	2.11	–	–	–	–	–	1.65	–	2.01	–	–	–
Aloe sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.38	–
Apiaceae sp.	–	–	–	–	–	–	4.30	–	–	–	–	–	–	–	1.76	–	–
Asparagus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.67	–
Asteraceae sp.	–	–	–	–	1.90	–	–	–	7.85	–	–	–	–	–	–	–	2.47
Bauhinia sp.	–	–	–	–	–	16.85	–	–	–	–	–	–	16.13	–	–	43.59	–
Berberis sp.	–	16.15	6.15	7.15	–	–	–	–	–	–	–	4.35	14.67	–	11.09	–	–
Bidens sp.	–	–	2.45	–	–	–	1.98	–	–	–	1.98	–	2.35	–	–	–	–
Brassica sp.	–	–	–	–	4.35	–	–	22.80	17.15	18.01	–	–	–	–	13.86	–	–
Brassicaceae sp.	7.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Callistemon sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13.80	10.59
Campsis sp.	–	–	–	–	–	–	–	–	–	6.96	–	–	–	–	–	–	–
Cannabis sp.	–	1.80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Capsicum sp.	–	–	–	–	–	–	–		2.44	–	–	–	–	–	–	–	–
Citrus sp.	–	46.01	16.25	–	–	–	–	–	–	–	–	–	–	10.23	22.89	–	–
Convolvulaceae sp.	–	–	–	–	1.30	–	–	–	–	–	–	–	–	–	–	–	–
Cucurbita sp.	–	7.18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Cucurbitaceae sp.	–	–	–	1.00	–	1.25	4.85	2.10	5.60	–	6.01	–	–	8.80	2.48	–	–
Delphinium sp.	–	–	–	–	–	–	–	–	–	1.72	2.26	–	–	–	–	–	–
Emblica sp.	17.09	–	–	–	–	5.14	–	–	–	–	–	–	–	–	–	23.41	–
Eucalyptus sp.	46.15	–	–	–	–	–	–	–	–	–	8.57	4.60	–	–	–	–	–
Euphorbia sp.	–	–	–	–	–	–	2.31	–	–	–	–	–	–	–	–	–	–

Continued

Appendix 1. *Continued*

Plant taxon	Sunni	Kangal	Theog	Nankhari	Summer Hill	Shoghi	Kotkhai	Tikkar	Rohru	Chirgaon	Rampur	Saharan	Junga	Chopal	Jubbal	Nerwa	Kupvi
Fabaceae sp.	–	–	–	–	–	1.01	–	–	–	–	–	–	–	–	–	–	–
Gaillardia sp.	–	–	–	–	4.60	–	–	–	–	–	–	–	–	–	–	–	–
Graptopetalum sp.	–	–	–	–	–	–	–	–	–	–	–	4.02	–	–	–	–	–
Grewia sp.	16.36	–	–	–	–	4.12	–	–	–	–	–	–	–	–	–	–	–
Helianthus sp.	–	–	–	–	–	–	–	–	–	21.55	–	–	–	–	–	–	14.48
Hibiscus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12.89
Hypericum sp.	–	–	–	–	–	–	–	–	–	–	–	–	1.50	–	–	–	–
Impatiens sp.	–	–	–	–	–	–	–	–	–	10.71	–	16.30	–	–	–	–	–
Indigofera sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	6.80	–	–	–
Leucaena sp.	4.01	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lilium sp.	–	–	–	–	–	–	–	1.80		2.45	–	–	–	–	–	–	–
Malus sp.	–	–	18.58	18.50	–	–	46.05	–	45.65	14.40	46.05	16.35	13.38	48.55	–	–	–
Mangifera sp.	–	–	8.50	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Murraya sp.	–	–	–	–	–	4.35	–	–	–	–	–	–	–	–	–	–	–
Myrtaceae sp.	–	–	–	–	–	–	16.20	–	–	–	–	–	–	–	–	–	–
Ocimum sp.	–	–	–	6.11	–	–	–	–	–	–	–	–	–	–	–	–	–
Opuntia sp.	–	–	–	–	–	–	1.06	–	–	–	–	–	–	–	–	–	–
Papaver sp.	–	–	–	–	–	–	–	–	–	1.05	–	–	1.15	–	–	–	–
Pinus sp	–	–	–	–	–	–	–	–	–	–	1.10	1.00	–	–	–	–	–
Pisum sp.	–	–	1.20	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Prinsepia sp.	–	–	–	–	5.37	–	–	–	–	–	–	–	–	–	–	–	–
Prunus sp.	–	17.02	47.12	46.36	–	45.81	17.80	–	18.35	–	9.18	–	15.23	21.35	20.06	–	32.19
Psidium sp.	–	–	–	–	–	–	–	11.78	–	–	–	–	–	–	–	–	25.67
Punica sp.	–	–	–	–	–	–	5.50	–	–	–	–	–	–	–	19.77	–	–
Pyrus sp.	–	–	–	17.01	–	17.35	–	49.09	–	–	20.54	–	18.05	–	–	–	–
Ranunculus sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.14	–	–
Rhododendron sp.	–	–	–	–	45.70	–	–	–	–	23.01	–	45.50	–	–	–	–	–
Rosa sp.	–	–	–	4.20	–	–	–	–	–	–	–	–	–	–	–	–	–
Rumex sp.	–	1.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Rutaceae sp.	6.15	–	–	–	–	1.85	–	2.45	–	–	–	–	–	–	–	–	1.80
Solanum sp.	–	–	–	–	–	–	–	–	1.90	–	–	–	–	–	–	–	–
Sonchus sp.	–	2.16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Taraxacum sp.	–	–	–	–	16.03	–	–	–	–	–	–	–	–	–	–	15.45	–
Tropaeolum sp.	–	5.09	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Woodfordia sp.	–	–	–	–	–	–	–	10.09	–	–	–	–	17.11	–	–	–	–
Zea sp.	1.30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Zinnia sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6.87	–	–

Appendix 2. Frequency distribution of pollen types in autumn honey samples of *Apis* spp. collected from different areas of Shimla hills of Himachal Pradesh (expressed as percentage of total number of pollen grains)

Plant taxon	Sunni	Kangal	Theog	Nankhari	Summer Hill	Shoghi	Kotkhai	Tikkar	Rohru	Chirgaon	Rampur	Saharan	Junga	Chopal	Jubbal	Nerwa	Kupvi
Abelmoschus sp.	–	–	–	–	–	–	8.85	–	–	–	5.66	–	–	–	–	–	–
Adhatoda sp.	–	2.90	–	–	–	–	–	–	–	–	–	–	7.80	–	–	–	–
Aesculus sp.	–	–	–	–	–	–	–	–	–	–	–	–	25.09	–	25.46	–	–
Ageratum sp.	–	–	–	–	–	–	–	–	4.99	–	–	–	–	–	–	–	–
Amaranthus sp.	–	–	–	–	–	1.24	6.89	–	–	–	–	–	–	–	–	–	–
Apiaceae sp.	–	–	–	–	–	–	–	2.45	–	9.69	–	–	–	–	–	–	–
Aster sp.	–	–	–	–	2.47	–	–	–	–	–	–	–	––	–	–	–	2.20
Asteraceae sp.	–	–	–	–	–	–	–	1.80	–	–	–	17.37	–	10.11	–	11.44	–

Continued

Appendix 2. *Continued*

Plant taxon	Sunni	Kangal	Theog	Nankhari	Summer Hill	Shoghi	Kotkhai	Tikkar	Rohru	Chirgaon	Rampur	Saharan	Junga	Chopal	Jubbal	Nerwa	Kupvi
Bidens sp.	–	–	–	–	–	–	–	–	6.64	–	–	2.36	–	–	–	–	–
Brassica sp.	2.40	–	–	–	–	–	–	–	18.95	–	–	–	18.19	27.80	–	–	–
Callistemon sp.	–	–	–	–	–	14.80	–	–	–	–	–	–	–	–	–	–	–
Cannabis sp.	–	–	–	–	–	–	1.05	–	–	–	1.60	–	–	1.60	–	1.75	–
Carum sp.	–	–	–	–	–	–	–	–	–	1.90	–	11.80	–	–	–	–	–
Cassia sp.	8.90	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Chenopodium sp.	6.25	–	2.10	2.45	–	2.30	–	–	–	–	–	–	–	–	–	–	–
Chrysanthemum sp.	–	2.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Convolvulaceae sp.	–	–	–	–	–	–	–	–	1.09	–	–	–	–	–	–	–	–
Cucumis sp.	–	–	–	–	–	–	–	–	20.20	–	–	–	2.05	–	–	–	–
Cucurbita sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8.16
Dahlia sp.	–	–	–	–	14.83	–	–	32.41	–	–	–	35.85	–	–	–	–	–
Emblica sp.	–	–	–	–	–	–	–	–	–	–	–	–	10.75	–	–	–	–
Eriobotrya sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	46.49
Foeniculum sp.	–	8.50	–	–	–	–	–	–	–	–	–	–	–	–	–	8.56	–
Geranium sp.	–	–	–	–	1.16	–	–	–	–	–	2.10	–	–	–	–	–	–
Hydrangea sp.	–	–	–	–	10.88	–	–	–	–	14.80	–	30.45	–	–	–	–	–
Hypericum sp.	1.18	24.15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Impatiens sp.	–	–	35.88	–	–	34.88	17.31	–	46.00	–	–	–	20.46	–	45.60	20.37	18.01
Indigofera sp.	–	–	–	15.35	22.40	–	–	–	–	–	9.85	–	–	–	8.90	–	12.05
Leucaena sp.	–	50.44	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Lilium sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2.33	–	–
Lycopersicum sp.	–	–	–	–	–	–	–	–	–	2.45	–	–	–	–	–	–	–
Myrtaceae sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.13	–	–
Ocimum sp.	–	–	–	13.10	–	–	–	25.89	–	–	–	–	–	8.90	–	–	–
Portulaca sp.	–	–	32.66	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Prinsepia sp.	–	–	12.88	32.10	–	–	45.50	–	–	–	–	–	–	–	14.77	–	–
Pyrus sp.	22.00	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Raphanus sp.	–	–	–	–	–	–	–	18.85	–	–	–	–	–	–	–	–	–
Rosa sp.	–	–	–	–	20.33	–	–	10.22	–	–	11.22	–	–	–	–	–	–
Rosaceae sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	13.46	–	–	–
Rubus sp.	–	–	–	25.56	–	–	18.22	8.11	–	–	–	–	14.85	–	–	36.67	–
Rumex sp.	–	–	–	–	–	–	–	–	2.10	–	–	1.90	–	–	–	–	–
Salvia sp.	48.50	–	–	9.80	–	22.46	1.90	–	–	22.16	24.76	–	–	2.34	–	2.10	–
Sesamum sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18.96	2.40
Tagetus sp.	–	11.33	–	–	–	15.45	–	–	–	–	34.99	–	–	–	–	–	–
Taraxacum sp.	10.88	–	15.40	–	–	–	–	–	–	–	7.54	–	–	–	–	–	10.11
Tithonia sp.	–	–	–	–	–	–	–	–	–	35.01	–	–	–	–	–	–	–
Trifolium sp.	–	–	–	–	27.80	8.55	–	–	–	13.90	–	–	–	30.15	–	–	–
Viola sp.	–	–	–	–	–	–	–	–	–	–	–	–	1.10	–	–	–	–
Vitex sp.	–	–	1.05	–	–	–	–	–	–	–	–	–	–	5.60	1.86	–	–
Zea sp.	–	–	–	1.80	–	–	–	–	–	–	2.40	–	–	–	–	–	–

Received 19 May 2022; received in revised form 29 June 2022; accepted 5 July 2022