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A melissopalynological appraisal of apiculture in the upper Himalayan and Shivalik hills of Himachal Pradesh, India

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ABSTRACT

Melissopalynological payoff of 36 honey samples (18 summer and the same number of autumn honey samples) directly collected from feral colonies of European bee, *Apis mellifera* L., Rock bee, *Apis dorsata* F. and Indian hive bee, *A. cerana* F. during 2011-2015 from Solan district's Shivalik Hills of Himachal Pradesh (HP), India has been voiced in the present study. The majority of the 18 (9 summer and 9 autumn) honey samples were from *Apis mellifera* L. beehives, 13 (6 summer and 7 autumn) honey samples were from *A. cerana* F. beehives and 5 (3 summer and 2 autumn) honey samples were from *Apis dorsata* F. 67% of honey samples were unifloral during summers, however in winters the proportion dwindled to mere 22%. *Apis mellifera* and *Apis cerana* contribution to unifloral honey during summer was 58% and 42% respectively. 78% of winter honey samples were multifloral with more significant contribution owing to *Apis mellifera* (57%) followed by *A. cerana* (29%). None of the summer or winter honey samples which were obtained from *Apis dorsata* hives were unifloral. Melissopalynological analysis of honey samples from Solan hills collectively demonstrated the presence of pollens of 54 plant families. 12 summer honey samples were categorized as unifloral with 8 palynotaxa as predominant. 4 autumn honey samples were recorded as unifloral with 3 palynotaxa as predominant. Predominant bee plant taxa of summer season were: *Citrus* sp. *Pyrus communis*, *Pyrus domestica*, *Grewia optiva*, *Mangifera indica*, *Eucalyptus camaldulensis*, *Syzygium cumini* and *Prunus* sp. *Impatiens balsamina*, *Helianthus annuus* and *Sesamum indicum* were predominant bee plant taxa in winters.

Key words: *Unifloral, Multifloral, Melissopalynology, Bee flora*

Introduction

Agriculture provides direct employment to 71% of the population in Himachal Pradesh (Niti Aayog). The rich miscellany of agro-climatic circumstances, geographical distinctions and altitudinal variances coupled with fruitful, profound and well drained soils favour the cultivation of temperate to subtropical fruit crops, flowers, vegetables tea, medicinal and aromatic plants in Himachal Pradesh (Kaushal *et al.,* 2017). Honey bees are crucial crop pollinators. Beekeeping can help farmers in enhanc-

ing pollination and increase crop productivity. Besides this, honey production and other by-products for consumption and sale can boost the stability of a farmer's market (Gurung *et al.*). Beekeeping provides supplementary income to the agriculturists and horticulturists (Sain and Nain, 2017). The raw materials used in the beekeeping industry are nectar and pollen (Gary, 1992). Factors determining the success of beekeeping in an area are profusion and affluence of nectar and pollen possessions round, along with interval of time for which bee forage is accessible (Crane, 1975; Free, 1993; Mattu, 2008 a and b; Adeonipekun, 2012). Himachal Pradesh has nearly 3950 plant species under 112 families which is almost 23% of Indian Angiospermic flora (Kumar *et al.,* 2018). Rich floristic diversity can hold beekeeping easily. Melissopalynology is the microscopial study of pollen grains present in honey (Deodikar, 1965; Louveaux *et al*., 1978; Nair, 1985; Sharma, 1989; Caccavari and Fagundez, 2010; Feas *et al.,* 2010).

Melissopalynology classifies honey botanically as well geographically (Louveaux *et al.* 1978; Von *et al.,* 2004; Barth, 2004). Melissopalynology is consequently vastly beneficial for the management of hives. It additionally permits the corroboration of various hypothesized stages involved in unifloral honey production, which has high viable value (Costa *et al.,* 2013; Oliveira *et al.,* 2010). Habitually, the beekeepers are unable to access all the vital data related to nectar plants which are crucial to honey production, and so in-depth pollen investigations are deemed of high assistance towards beekeeping in a region (Song *et al.,* 2012). Microscopic pollen analysis of honeys could be a useful guide for beekeepers to identify important nectar plants in a region. Unifloral honey derived from one particular plant source may be more valuable (Zetsche, 1932; Ebenezer and Olugbenga, 2010). It has been observed by earlier workers that bees flying free are not able to produce entirely unifloral honey this can only be achieved when the bees are reared in apiaries which are exposed to a particular plant species pollinated by the bee (Ramnath and Venkataramegowda, 2012). Solan district is situated between longitude 76.42" and 77.20" East and latitude 30.05" and 31.15" North. This district is located at an elevation is between 300 and 3000 metres above sea level which comprises of Shivalik and upper Himalayan regions of Himachal. Major bee plant taxa of the region during summer were: *Citrus* sp., *Prunus* sp., *Pyrus communis*, *Pyrus domestica*, *Pyrus pashia*, *Prunus amygdalus*, *Malus domestica*, *Grewia optiva*, *Mangifera indica*, *Eucalyptus camaldulensis*, *Syzygium cumini*, *Dahlia pinnata*, *Albizzia stipulata*, *Punica granatum*, *Cucurbita maxima*, *Callistemon citrinus*, *Jacaranda mimosifolia*, *Litchi chinensis*, *Cedrella toona*, *Dalbergia sissoo*, *Bombax ceiba*, *Citrus sinensis*, *Bauhinia variegata*, *Acacia catechu*, *Brassica campestris*, *Aesculus indica*, *Taraxacum officinale* and *Trifolium repens*. Major bee plant taxa of the region during autumn were: *Eriobotrya japonica*, *Salvia splendens*, *Impatiens balsamina*, *Cucumis sativus*, *Leucaena leucocephala*, *Hypericum cernuum*, *Sesamum indicum*, *Lagerstroemia indica*, *Rosa macrophylla*, *Myrtus communis*, *Zea mays*, *Cassia fistula*, *Trifolium repens*, *Prinsepia utilis*, *Indigofera* sp., *Duranta repens*, *Hydrangea* sp. and *Rubus ellipticus*.

Materials and Methods

36 honey samples were directly collected from the feral bee hives of *Apis mellifera* L. (18 honey samples)., *Apis cerana* F. (13 honey samples) and *Apis dorsata* F. (5 honey samples) from different area of Solan district of HP, during 2011-2015. The colour of the honey samples was determined by a simple colour grading method (Upadhyay and Bera, 2012). Summer (May to June) and autumn (September to October) honey samples were collected from Solan district's localities like Kandhar, Arki, Darlaghat, Kotla, Doli, Baddi, Bhumti, Koti, Kanswala, Nalagarh, Thana, Mamligh, Subathu, Kandaghat, Chambaghat, Chail, Parwanoo and Jabli.

Quantitative microscopic analysis of honey was done by preparing slides using method of Louveaux *et al.,* 1978. The identification of the pollen grains was carried out from reference slides which were prepared from collected local flora situated 5 km from the beehive. The pollens were also verified with the support of previous pollen slide assortment of Entomology and Biodiversity Laboratory, Department of Biosciences, Himachal Pradesh University, Shimla, and typical works of Erdtman (1960) and Nair (1964, 1985). Few pollens of wild plant taxa have been established by likening them with the locus pollen slides available in the pollen herbarium of the Palynology Laboratory, National Botanical Research Institute, Lucknow and published literature (Hari and Sharma, 1986; Nayar, 1990; Chaya and Jana *et al.,* 2002; Saha *et al.,* 2007). Identification of a large section of the pollen types was possible at their

species level. Absolute pollen count has been done with the assistance of haemocytometer (Louveaux *et al*., 1978; Seethalakshmi, 1980; Suryanarayana *et al*., 1981). The honey samples were categorized into rich, poor and very poor in pollen if entire numeral of pollen grains per 10 g (Absolute Pollen Count) of honey were >1,00,000; 20,000 to 1,00,000 and <20,000 respectively (Maurizio, 1975). Quantification of the kind of pollen grain present was estimated from an arbitrarily counted sample having 500 pollen grains. This was followed by calculation of percentage frequency. Frequency of classes were determined based on the recommended guidelines of the International Commission for Bee Botany (Louveaux *et al*., 1978). These frequencies were used to construct pollen spectra (Sharma and Nair, 1965). Predominant pollen (representing 45% of the pollen grains counted), secondary pollen (16–45%), important minor pollen (3–15%), and minor pollen (less than 3%), are the four pollen frequency classifications. (Louveaux *et al*., 1978). A sample of honey with one type of pollen in predominance was considered unifloral and multifloral otherwise (Iwama and Melhem, 1979).

The customary procedure for pollen analysis is used to separate pollen from honey samples: 20 ml of hot water was used to dilute 10 g of honey, after which it was centrifuged for three minutes at 3500 rpm. Decanting is followed by re-suspending the residue in 20 ml of water before centrifuging it once again. The majority of the residue that is left over after removing the supernatant fluid is made up of pollen grains. The pollen residue obtained is then made to deposit on an adhesive which has already been applied to the smooth metal surface of the microscope stage. The specimen is set in a vacuum evaporator and coated with carbon and then gold before being ready for inspection. (Laere *et al*., 1969). Subsequently, dehydration by drying on silica gel drier is followed by analysis of small quantities of pollen grains on scanning electron microscopy (SEM). The samples were mounted on SEM stubs and then coated with Au-Pt (Ion Sputter JFC-1100) and thereby studied at an accelerating voltage of 15 to 20 kV in a Scanning Electron Microscope (Ultraplus Zeiss) at Center for Advanced Biomaterials, Italian Institute of Technology, Naples, Italy.

Results

The melissopalynological investigations of 36 honey samples collected during two major honey flow seasons (i.e. May-June and September-October) from Solan hills, collectively demonstrated the presence of pollens of 127 plant species and of members of 8 families. Melissopalynological analysis categorized 12 summer samples as unifloral with pollens of 8 plant taxa as predominant and remaining 6 samples as multifloral. Pollens of 29, 39 and 32 plant taxa were recorded as secondary, important minor and as minor respectively (Table 1). Pollens of *Citrus* sp. and *Pyrus communis* were predominant in maximum number of unifloral summer honey samples of Solan hills. Summer honeys of Arki, Doli and Jabli confirmed *Citrus* sp. as predominant source of pollens in the areas. Baddi, Subathu and Chambaghat honeys confirmed *Pyrus communis* as predominant source of pollen in the areas. Darlaghat, Kotla, Bhumti, Koti, Mamligh and Chail summer honeys confirmed *Prunus domestica*, *Grewia optiva*, *Mangifera indica*, *Eucalyptus camaldulensis*, *Syzygium cumini* and *Prunus* sp. as predominant source of pollens in respective areas.

However, in autumn honey samples 4 honey samples were recorded as unifloral, with pollens of 3 plant taxa as predominant and remaining 14 samples were multifloral. Pollens of 24, 38 and 34 plant taxa were recorded as secondary, important minor and as minor respectively (Table 1). Mamligh and Parwanoo autumn honeys reported *Impatiens balsamina* as predominant source of pollens in the areas. Arki and Kanswala autumn honeys reported *Helianthus annuus* and *Sesamum indicum* pollens as predominant respectively.

Solan summer honey samples had 29 secondary pollen types. These were (in decreasing order of their frequency percentages): *Prunus persica* (Two localities), *Litchi chinensis* (Two localities), *Syzygium cumini* (Two localities), *Bombax ceiba* (One locality), *Pyrus pashia* (One locality), *Cedrella toona* (Two localities), *Dalbergia sissoo* (One locality), *Carica papaya* (One locality), *Prunus amygdalus* (One locality), *Ricinus communis* (One locality), *Punica granatum* (Three localities), *Eucalyptus camaldulensis* (One locality), *Malus domestica* (One locality), *Callistemon citrinus* (Two localities), *Aesculus indica* (One locality), *Prunus* sp. (One locality), *Trifolium repens* (Two localities), *Citrus sinensis* (One locality), *Bauhinia variegata* (One locality), *Eriobotrya japonica* (One locality), *Erythrina suberosa* (One locality), *Mangifera indica* (One locality), *Hibiscus rosa–sinensis* (One locality), *Jacaranda mimosifolia* (One locality), *Brassica*

Table 1. Pollen spectrum of the honey samples of *Apis* spp. collected from various areas of Solan 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%

Sl. No.	Locality	Season	Colour of Honey	Unifloral OR Multifloral	Predominant pollen type	Secondary pollen type	Important minor pollen type	Minor pollen type
1	Kandhar	Summer	Light Amber	Multifloral		*Pyrus pashia*, *Prunus amygdalus*	*Citrus aurantifolia*, *Amaranthu scaudatus*, *Opuntia* sp., *Brassica campestris*	*Lepidagathis* sp., *Allium cepa*
		Autumn	Amber	Multifloral		*Dahlia pinnata*, *Eriobotrya japonica*	*Malvaviscus arboreus*, *Ocimum sanctum*, *Chenopodium album*	*Ageratum conyzoides*, *Bidens pilosa*
2	Arki	Summer	Light Yellow	Unifloral	*Citrus* sp.	*Mangifera indica*, *Albizzia stipulata*	*Hypericum cernuum*, *Woodfordia fruticosa*, *Berberis aristata*, *Lilium* sp.	*Cannabis sativa*, *Campsis grandiflora*
		Autumn	Bright Yellow	Unifloral	*Helianthus annuus*	*Salvia splendens*	*Taraxacum* officinale, *cosmos* sp.	*Hypericum cernuum*, *Brassica* sp., Convolvulaceae
3	Darlaghat	Summer	Light Amber	Unifloral	*Prunus domestica*	*Punica granatum*	*Acacia catechu*, *Emblica officinalis*, *Albizzia lebbek*, *Trigonella* sp.	*Ipomoea pulchella*, *Euphorbia royleana*
		Autumn	Watery White	Multifloral		*Impatiens balsamina*, *Cucumis sativus*	*Lagerstroemia indica*, *Salvia officinalis*, *Geranium* sp.	*Adhatoda vasica*, *Chrysanthemum* sp.
4	Kotla	Summer	Light Yellow	Unifloral	*Grewia optiva*	*Syzygium cumini*, *Cucurbita maxima*	*Tropaeolum majus*, *Adhatoda vasica*	*Anagalis arvensis*, *Zeamays*
		Autumn	Light Brown	Multifloral		*Leucaena leucocephala*, *Hypericum cernuum*	*Tagetus erectus*, *Cassia fistula*, *Portulaca grandiflora*	*Sonchus* sp., *Rumex hastatus*
5	Doli	Summer	Light Amber	Unifloral	*Citrus* sp.	*Eucalyptus camaldulensis*, *Callistemon citrinus*	*Bauhinia variegata*, *Hypericum cernuum*, *Brassica* sp.	Asteraceae
		Autumn	Light Brown	Multifloral		*Sesamum indicum*, *Eriobotrya japonica*	*Abelmoschus esculentus*, *Zizyphus jujuba*, *Amaranthus caudatus*	*Lycopersicum esculentum*, *Ipomoea pulchella*, *Asparagus* sp.
6	Baddi	Summer	Amber	Unifloral	*Pyrus communis*	*Punica granatum*, *Jacaranda mimosifolia*	*Melia azadarch*, *Dalbergia sissoo*, *Cassia fistula*	*Tropaeolum majus*, *Vitex negundo*, *Lycopersicum esculentum*

Table 1. *Continued ...*

Sl. No.	Locality	Season	Colour of Honey	Unifloral OR Multifloral	Predominant pollen type	Secondary pollen type	Important minor pollen type	Minor pollen type
		Autumn	Brown	Multifloral		*Lagerstroemia indica*, *Impatiens balsamina*	*Eriobotrya japonica*, *Coriandrum sativum*, *Cucurbita maxima*	*Mirabilis jalapa*, *Cuscuta reflexa*, *Ageratum conyzoides*, *Verbascum thapsus*
7	Bhumti	Summer	Brown	Unifloral	*Mangifera indica*	*Litchi chinensis*, *Erythrina suberosa*	*Acacia catechu*, *Emblica officinalis*, *Bombax ceiba*	*Hippaestrum reginae*, *Asteraceae*, *Capsella bursa-pastoris*
		Autumn	Light Amber	Multifloral		*Rosa macrophylla*, *Myrtus communis*	*Hypericum cernuum*, *Impatiens balsamina*, *Alyogyne* sp.	*Aster* sp., *Ipomoea pennata*, *Lilium* sp.
8	Koti	Summer	Dark Amber	Unifloral	*Eucalyptus camaldulensis*	*Callistemon citrinus*, *Eriobotrya japonica*	*Psidium guajava*, *Trifolium repens*, *Murraya koenigii*	*Bidens pilosa*, *Aloe barbadensis*
		Autumn	Yellow	Multifloral		*Zea mays*, *Cassia fistula*	*Gaillardia pulchella*, *Jacaranda mimosifolia*, *Stellaria media*	*Rumex hastatus*, *Rosa indica*, *Canna indica*
9	Kanswala	Summer	Brown	Multifloral		*Syzygium cumini*, *Cedrella toona*, *Hibiscus rosa-sinensis*	*Helianthus annuus*, *Brassica campestris*	*Cucurbitaceae*, *Pisum sativum*
		Autumn	Amber	Unifloral	*Sesamumindicum*	*Callistemon citrinus*	*Ricinus communis*, *Salvia officinalis*	*Ageratum conyzoides*, *Rumex hastatus*
10	Nalagarh	Summer	Light Yellow	Multifloral		*Bombaxceiba*, *Ricinuscommunis*, *Citrus sinensis*	*Raphanus sativus*, *Terminalia bellerica*, *Curcuma* sp.	*Ipomoea pulchella*, *Euphorbia pulcherrima*
		Autumn	Light Amber	Multifloral		*Salvia* splendens, *Leucaena leucocephala*, *Tithonia rotundifolia*	*Malvaviscus arboreus*, *Foeniculum vulgare*	*Cajanus cajan*, *Geranium* sp., *Capsicum annuum*, *Bidens pilosa*
11	Thana	Summer	Yellow	Multifloral		*Litchi chinensis*, *Carica papaya*	*Lagerstroemia indica*, *Dalbergia sissoo*, *Morusalba*	*Cosmos sulphureus*, *Jatropha curcas*, *Bidens pilosa*
		Autumn	Amber	Multifloral		*Trifolium repens* *Prinsepia utilis*, *Rubus ellipticus*	*Brassica campestris*, *Cannabis sativa*, *Amaranthus caudatus*	*Aster* sp., *Sonchus* sp.
12	Mamligh	Summer	Brown	Unifloral	*Syzygium cumini*	*Bauhinia variegata*, *Acacia catechu*	*Indigofera* sp., *Benincasa* sp., *Emblica officinalis*, *Cajanus cajan*	*Lilium* sp., Asteraceae

Table 1. *Continued ...*

Sl. No.	Locality	Season	Colour of Honey	Unifloral OR Multifloral	Predominant pollen type	Secondary pollen type	Important minor pollen type	Minor pollen type
		Autumn	Light Amber	Unifloral	*Impatiens balsamina*	*Cucumis sativus*, *Brassica campestris*	*Lagerstroemia indica*, *Dahlia pinnata*, *Foeniculum vulgare*	*Ocimum sanctum*, Myrtaceae
13	Subathu	Summer	Light Amber	Unifloral	*Pyrus communis*	*Aesculus indica*, *Taraxacum officinale*	*Murraya koenigii*, *Dalbergia sissoo*, *Emblica officinalis*	*Vitex negundo*, Malvaceae, *Geranium* sp.
		Autumn	Brown	Multifloral		*Prinsepia utilis*, *Indigofera* sp.	*Cosmos sulphureus*, *Abelmoschus esculentus*, *Myrtus communis*	*Ipomoea pulchella*, *Cuscuta reflexa*
14	Kandaghat	Summer	Yellow	Multifloral		*Prunus persica*	*Woodfordiafruticosa*, *Citrus aurantifolia*, *Rosa moschata*, *Zinnia elegans*	*Jacaranda mimosifolia*, *Zephyranthes sativum*, *Convolvulaceae*
		Autumn	Light Brown	Multifloral		*Rosa macrophylla*, *Dahlia pinnata*, *Duranta repens*	*Hypericum cernuum*, *Tropaeolum majus*, *Geranium sp.*	*Ipomoea pulchella*, *Lepidagathis* sp., *Plumbago zeylanica*
15	Chamba-ghat	Summer	Light Yellow	Unifloral	*Pyrus communis*	*Punica granatum*, *Trifolium repens*	*Woodfordia fruticosa*, *Leucaena leucocephala*, *Lycopersicum esculentum*	*Viola odorata*, Cosmos sp., *Pisum sativum*
		Autumn	Light Amber	Multifloral		*Raphanus sativus*, *Indigofera sp.*, *Hydrangea* sp.	*Chrysanthemum* sp., *Campsis grandiflora*, *Argemone Mexicana*	*Ageratum conyzoides*, *Ipomoea carnea*, *Pinus sp.*
16	Chail	Summer	Amber	Unifloral	*Prunus* sp.	*Malus domestica* *Trifolium repens*	*Rhododendron arboreum*, *Indigofera* sp.	*Viola odorata*, Asteraceae
		Autumn	Light Yellow	Multifloral		*Impatiens balsamina*, *Brassica* sp.	*Prinsepia utilis*, Cucurbitaceae	*Carum bulbocastanum*, *Geranium wallichiana*, *Aster* sp.
17	Parwanoo	Summer	Dark Brown	Multifloral		*Prunus persica*, *Dalbergia sissoo*, *Cedrela toona*	*Indigofera* sp., *Emblica officinalis*, *Woodfordia fruticosa*	*Adhatoda vasica*, Apiaceae
		Autumn	Light Amber	Unifloral	*Impatiens balsamina*	*Brassica* sp., *Callistemon citrinus*	*Aster* sp.,*Foeniculum vulgare*	Myrtaceae, *Viola odorata*
18	Jabli	Summer	Amber	Unifloral	*Citrus* sp.	*Prunus* sp., *Brassica campestris*	*Berberis aristata*, *Ocimum sanctum*, *Rosaindica*	Rutaceae, Cucurbitaceae
		Autumn	Light Yellow	Multifloral		*Trifolium* repens, *Prinsepia utilis*, *Rubus ellipticus*	*Ocimum sanctum*, *Salvia splendens*, *Bidens pilosa*	*Chenopodium album*, *Zea mays*, *Pinus sp.*

campestris (One locality), *Cucurbita maxima* (One locality), *Albizzia stipulata* (One locality), *Acacia catechu* (One locality), *Taraxacum officinale* (One locality).

Solan autumn honey samples had 24 secondary pollen types. These were (in decreasing order of their frequency percentages): *Sesamum indicum* (One locality), *Leucaena leucocephala* (Two localities), *Impatiens balsamina* (Three localities), *Zea mays* (One locality), *Lagerstroemia indica* (One locality), *Dahlia pinnata* (Two localities), *Prinsepia utilis* (Three localities), *Rosa macrophylla* (Two localities; Plate), *Salvia splendens* (Two localities), *Trifolium repens* (Two localities), *Raphanus sativus* (One locality), *Brassica* sp. (Two localities), *Callistemon citrinus* (Two localities), *Eriobotrya japonica* (Two localities), *Cucumis sativus* (Two localities), *Indigofera* sp. (Two localities), *Hypericum cernuum* (One locality), *Myrtus communis* (One locality), *Rubus ellipticus* (Two localities), *Duranta repens* (One locality), *Cassia fistula* (One locality), *Hydrangea* sp. (One locality), *Tithonia rotundifolia* (One locality), *Brassica campestris* (One locality).

Absolute pollen count (APC) indicated 83% (15 samples) of summer honeys and 78% (14 samples) of autumn honeys were rich in pollen count i.e >1,00,000; 17% (3 samples) of summer honeys and 22% (4 samples) of autumn honeys were poor (20,000-1,00,000) in pollen count. None of the summer or autumn honeys were very poor (<20,000) in absolute pollen count. As a whole about 81% of 36 honey samples were rich in pollen count defending the relevance of the present study area for establishing large scale apicultural enterprises. Key wild bee flora of the study area demonstrated *Hypericum cernuum*, *Woodfordia fruticosa*, *Adhatoda vasica*, *Rubus ellipticus*, *Opuntia dillenii*, *Vitex negundo*, *Grewia optiva*, *Termialia bellerica*, *Termialia chebula*, *Berberis aristata*, *Prinsepia utilis*, *Cannabis sativa*, *Acacia catechu, Taraxacum officinale*, *Trifolium repens*, *Bidens pilosa*, *Leucaena leucocephala*, *Bombax ceiba*, *Murraya koenigii*, *Tropaeolum majus*, *Bauhinia variegata*, *Stellaria media* and *Lepidagathis* sp. Melissopalynological studies designated Arki, Doli and Jabli summer honeys as Citrus honey, Koti summer honey as Eucalyptus Honey and Arki autumn honey as Sunflower Honey. Anemophilous pollens were found in Chambaghat and Jabli autumn honeys. The colour assortment of the samples diverges from watery white (Darlaghat autumn honey) to dark amber (Koti summer honey). SEM micrographs of some predominant and secondary palynotaxa recovered from the honey samples have been presented in Fig 3a-g.

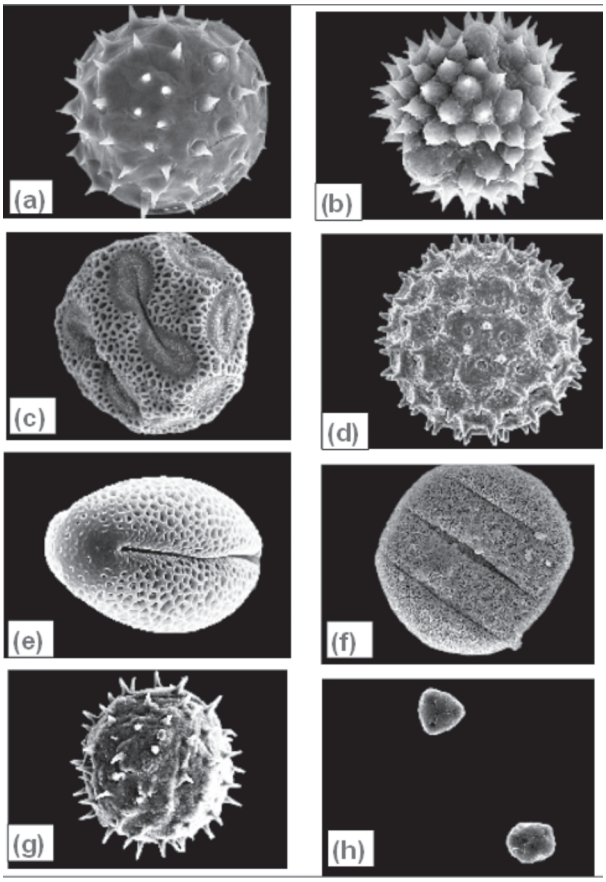

Fig. 3. SEM micrographs of pollens of a) *Dahila pinnata, b) Stevia* sp., c) *Opuntia* sp., d) *Ipomoea pennata, e) Trigonella* sp., f) *Salvia splendens, g) Abelmoschus esculentus, h) Malus domestica.*

Discussion

The Solan district is ranked as the number one district based on its district wise per capita income (The Tribune 21st July, 2022). It has approximately 1936 square km of total geographical area. Incidentally, for such a vast geographical area there are only 15 existing industrial areas with 106 registered large scale industrial units providing employment to 24048 individuals. Dominantly mountainous topography is observed with an elevation ranging from 300-3000 meters above sea level. 82% of the total population live in rural areas depending on agriculture/horticulture as the primary source of income (Brief industrial profile of district Solan, MSME, 2014-15). As per DOA, 54750 hectares of land in

Solan district is under foodgrain cultivation, 6341 hectares is under the cultivation of horticultural fruit crops (viz. apple, dry fruits, citrus fruis, other temperate and tropical fruits), 6982 hectares is under vegetable cultivation. Also, 42300 hectares of land is under aromatic and medicinal plant cultivation while 203000 hectares of land is under forest (DOA, 2009). Hence, significant land area in district Solan is under agricultural and horticultural practices of varied flora and it grants richness of pollen and nectiferous taxa for bee forage. So, commercial beekeeping in the study area is necessary to assure high production of better-quality crops successfully. It will also buffer the income of the rural population through honey and other bee products, hence uplifting the socioeconomic status of the inhabitants.

A reasonable area of Solan district is under cultivation of temperate and subtropical fruit crops and medicinal plants. Amongst all the pollinating insects, honeybees display the maximum degree of floral reliability and are, therefore, the most effectual pollinators (Deodikar and Suryanarayana, 1972; Butler, 1974; Verma, 1990). Verma (1970). Honey bees' impact on apple fruit set, fruit drop, and fruit quality was examined by Dulta and Verma (1987a) in the Shimla Hills. Honey bees appear to do more cross pollination than other natural insect pollinators, as evidenced by the higher fruit sets recorded in honey bee-pollinated flowers compared to other insect pollinators. In Himachal Pradesh, the majority of apple cultivars are self-unfruitful. To have a good fruit set, they need to cross pollinate with a suitable cultivar. Honey bees are essential for efficient pollination in orchards. By managing bee hive location quality of floral fidelity of honey bees can be exploited for the production of valuable unifloral honeys of medicinal uses. The demand for unifloral honey in the local as well as in the global market is high (Guemes-Ricalde *et al.,* 2006). Melissopalyological studies in Solan hills confirmed 4 summer honeys (Arki, Doli, Jabli and Koti honeys) and 1 autumn honey as medicinal uniforal honeys. Arki, Doli and Jabli summer honeys came out to be as Citrus Honey, Koti summer honey as Eucalyptus Honey and Arki autumn honey as Sunflower Honey. Many medicinal plants blooms in the summer season in the study area like *Emblica officinalis*, *Ocimum sanctum*, *Salvia officinalis*, *Helianthus annuus*, *Eucalyptus camaldulensis*, *Citrus* spp., *Brassica* spp. Moreover 22% of summer and only 5 % of autumn honeys came out to be medicinal, indicating summer season suitable for production of medicinal honeys. In the state's low to high hills, there are currently more than fifteen hundred beekeepers working with around one lakh bee colonies and producing nearly seventeen hundred metric tonnes of honey (Anonymous, 2013). Beekeepers maintain their colonies in Himachal Pradesh from April to October then relocate to arid regions of Haryana, Punjab, Rajasthan, and Uttar Pradesh for the remainder of the year in order to cope with the state's difficult climate. In the district of Solan specifically, there are two migration cycles: one from November to December in the direction of Punjab and Rajasthan for mustard, and another from January to February in the direction of Haryana for eucalyptus.

Conclusion

If more investments are made in bee colonies, India may potentially boost its honey export share from 7,000 tonnes to three lakh tonnes. In Himachal Pradesh, approximately 85,000 families raise bees, and 1600 tonnes of honey are produced there each year. Small business owners are assisted by the state government, which offers incentives and marketing resources. Rich diversity of flora in Solan hills provide prominent opportunity for the development of beekeeping industry in the study area.

If international quality requirements are satisfied, the nation's honey business has a good chance of becoming a significant source of foreign currency. India falls short in that regard. A focus on developing an export market and promoting high-quality products is necessary. Himalayan honey is considered as good quality honey. Acquaintance of pollen and nectar plants in beekeeping latent extents is vital and this may be attained only via melissopalynological and bee botany studies. Eventually the same will pave the way to fine honey manufacture and enhanced pollination services. With the knowledge of key bee plants of any given place and time, the migrant beekeeping may be methodically instituted. Without the widespread expansion of scientific beekeeping, a massive viticultural company currently operating in Himachal Pradesh may not prosper in the long run. Very little has been done to identify and evaluate the important honey plants of Himachal Pradesh, which has great potential for beekeeping (Sharma, 1989; Sharma, 1996; Verma, 2006; Rana, 2008; Kaur, 2009; Attri, 2010). The present study will be of great

benefit for beekeepers and provide a valuable insight for additional sectors like horticulture, forestry and agriculture. This will not only enhance honey production, but also improve the qualities of fruits, thereby economically uplifting the country. We can also launch plant-based industries without damaging ecological balance.

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Conflict of interest

No potential conflict of interest was reported by the authors.

References

Adeonipekun, P. A. 2012. Palynology of honeycomb and a honey sample from an apiary in Lagos, Southwest Nigeria. *Asian J. Plant Sci. Res.* 2 (3) : 274-283.

Anonymous, 2013. All India Coordinated Project on Honey Bees and Pollinators. Annual Progress Report, Department of Entomology, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan. 10-11.

Barth, O.M. 2004. Melissopalynology in Brazil: A review of pollen analysis of honeys, propolis and pollen loads of bees. *Scientia Agricola*. 61(3): 342–350.

Brief Industrial Profile of Solan District (2014-15). Micro, Small & Medium Enterprises Development Institute Govt. of India.

Butler, C.G. 1974. The world of Honeybee. *Collins, London*.

Caccavari, M. and Fagundez, G. 2010. Pollen spectra of honeys from Middle Delta of the Parana River (Argentina) and their environmental relationship. *Spanish J. Apic. Res.* 8(1): 42-52.

Chaya, P.K. and Varma, Y.N.R. 2004. Pollen diversity in the honey samples from Medak district of Andhra Pradesh. *Geophytology.* 34 : 95–100.

Costa, M.C., Vergara-Roig, V.A. and Kivatinitz, S.C. 2013. A melissopalynological study of artisanal honey produced in Catamarca (Argentina). *Grana.* 52: (3): 229-237. doi:10.1080/00173134.2013.819525.

Crane, E. 1975. *Honey – A Comprehensive Survey* (ed. Eva Crane). Heinemann, London.

Deodikar, G.B. 1965. Melittopalynology. *Indian Bee J.* 27: 59-72.

Deodikar, G.B. and Suryanarayana, M.C. 1972. Crops yield and bee pollination. *Indian Bee J.* 34: 53-63.

DOA, 2009, District Agriculture Plan: Solan, H.P., Volume XI.

Dulta, P.C., Verma, L.R. 1987a. Role of insect pollinators on yield and quality of apple fruit. *Indian Journal of Horticulture*. 44 : 274-279.

Ebenezer, I.O. and Olugbenza, M.T. 2010. Pollen characterization of honey samples north central Nigeria. *Journal of Biological Sciences*. 10 (1): 43-47.

Erdtman, G. 1960. *Handbook of Palynology.* Munksgaard, Copenhagen.

Feas, X., Pires J., Estevinho M. L., Iglesias A. and Pinto de Araujo, J. P. 2010. Palynological and physico-chemical data characterisation of honeys produced in the Entre-Douro e Minho region of Portugal. *International Journal of Food Science and Technology.* 45: 1255-1262.

Free, J.B. 1993. *Insect Pollination of Crops.* Academic Press, London.

Gary, N.E. 1992. Activities and behaviour of honeybees. In: J.M. Graham (ed.) *Honeybees in Mountain Agriculture.* Oxford and IBH Publishing Company, New Delhi.

Güemes-Ricalde, F.J., Villanueva, G.R., Echazarreta-González, C., Gómez-Alvarez, R. and Pat-Fernández, J.M. 2006. Production costs of conventional and organic honey in the Yucatan Peninsula of Mexico. *J. Apicult. Res.* 45: 106–111.

Gurung, M. B, Partap, U., Shrestha, N. C.T.D., Sharma, H. K., Islam, N. and Tamang, N. B. 2012. *Beekeeping Training for Farmers in the Himalaya: Resource Manual for Trainers.* ICIMOD publications.

Hari, P.G. and Sharma, C. 1986. Pollen flora of North-West Himalaya. Indian Association of Palynostratigraphers, Janki Bhawan, Narhi, Lucknow, India. https://naturalfarming.niti.gov.in/himachalpradesh/#:~:text=Agriculture%20provides%20direct%20employment%20to,area% 20is%2070%20lakh%20hectares.

Iwama, S. and Melhem T.S. 1979. The pollen spectrum of the honey of *Tetragonisca angustula angustula* L. *Apidologie.* 10 : 275–295.

Jana, D., Bandyopadhyay, A. and Bera, S. 2002. Pollen analysis of winter honey samples from Murshidabad district, West Bengal. *Geophytology.* 30: 91–97.

Kaushal, R., Thakur, D. S. and Kumar, A. 2017. Growth and contribution of horticulture of Himachal Pradesh: A case study of Kotgarh valley of Shimla district, Himachal Pradesh. *International Journal of Advanced Research.* 5(7): 393-400.

Kumar, A., Dogra, K. S., Srivastava, S. K., Kant, R. and Kharakwal, K. 2018. Vegetation types and floral composition of himachal Pradesh, Western Himalayas: An overview. *Phytotaxonomy.* 17:123-127.

Laere, O.V., Lagasse, A. and Mets, M.D. 1969. Use of the scanning electron microscope for investigating pol-

len grains isolated from honey samples. *J. Apic. Res.* 8: 139–145.

Louveaux, J., Maurizio, A. and Vorwohl, G. 1978. Methods of melissopalynology. *Bee World.* 59: 139-157.

Mattu, V.K. 2008 a. Melissopalynology and Bee Botanical Investigations on Honey Plant Resources of Himachal Pradesh. Institute of Integrated Himalayan Studies (UGC Centre of Excellence), HP Univ., Shimla. 45 pp.

Mattu, V.K. 2008 b. Strategies for the Development of Beekeeping in the Northwest Himalayan Region. In: Status of Biodiversiy among the Mountainous States of India (ed. Joshi *et al.*), Haridwar, 35 pp.

Maurizio, A. 1975. Microscopy of honey. In: Crane E. (Ed.) *Honey – A Comprehensive Survey*. Heinemann, London, pp. 240–247.

Nair, P.K.K. 1964. A pollen analytical study of Indian honeys. *J. Indian Bot. Soc.* 43: 179–191.

Nair, P.K.K. 1985. Melittopalynology. In: *Essentials of Palynology.* Today and Tomorrow's Publishers, New Delhi, pp. 59–64.

Nayar, T.S. 1990. *Pollen Flora of Maharashtra State, India.* Today and Tomorrow's Printers & Publishers New Delhi, India.

Oliveira, PP., van den Berg, C. and Santos, FDeARD. 2010. Pollen analysis of honeys from Caatinga vegetation of the state of Bahia, Brazil. *Grana.* 49(1): 66–75.

Ramnath, S. and Venkataramegowda, S. 2012. Physicochemical and pollen analysis of western ghats honey of Karnataka, South India. *Int. J. Sci. Nature.* 3(4): 831-835.

Saha, R., Bera, S., Datta, B.K. 2007. Melittopalynological iInvestigation of *Apis cerana indica* Fabr. honeys from West Tripura, India. *Adv. Plant Sci.* 20: 571–578.

Sain, V. and Nain, J. 2017. Economics and Importance of Beekeeping. *Journal of Science and Technical Research*. 1(7): 1833-1834.

Seethalakshmi, T.S. 1980. Melittopalynological investigations on some Indian honeys. *Proceedings of the 2nd International Conference on Apiculture in Tropical Climate*. New Delhi, pp. 609–621.

Sharma, M. and Nair, P.K.K. 1965. Pollen analysis of some honeys from Uttar Pradesh. *Indian J. Hortic.* 46–51.

Sharma, N. 1989. *Melissopalynology and survey of honey plants in Himachal Pradesh*. Ph.D. Thesis: Himachal Pradesh University, Shimla, India.

Song, XY., Yao, Y.F. and Yang, W.D. 2012. Pollen Analysis of Natural Honeys from the Central Region of Shanxi, North China. *PLoS ONE*. 7(11): e49545. doi:10.1371/journal.pone.0049545.

Suryanarayana, M.C., Seethalakshmi, T.S. and Phadke, R.P. 1981. Pollen analysis of Indian honeys. I. Honey from litchi (*Nephelium litchi*) and jamun (*Syzygium cumini*). *Proceedings of the IV International Palynology Conference, Lucknow*. 3: 491–498.

Upadhyay, D. and Bera, S. 2012. Pollen spectra of natural honey samples from a coastal district of Orissa, India. *J. Apicult. Res.* 51: 10–22.

Verma, L.R. 1970. A comparative study of temperature regulation in Apis mellifera L and *Apis cerana* indica F. *American Bee Journal.* 110(10):390-391.

Verma, L.R. 1990. Beekeepig in integrated mountain development: Economic and Scientific Perspective. Oxford and IBH Publ. Co. Ltd., New Delhi.

Von Der, O.W., Persano, O.L., Piana L., Morlot, M. and Martin, P. 2004. Harmonized methods of melissopalynology. *Apidologie.* 35: S18–S25.

Zetsche F.1932. *Handbuch der Pflanzenanalyse*. Wien Springer. 3(1): 215.