International Journal of Botany Studies
www.botanyjournals.com
ISSN: 2455-541X
Received: 11-09-2021, Accepted: 27-09-2021, Published: 12-10-2021
Volume 6, Issue 5, 2021, Page No. 1184-1193

Characterisation of garhwal Himalayan honeys by their botanical origin and mineral contents

Preeti Naithani[1], Sarita Gupta[2], Eza Gloch[3], P Tiwari[4]

[1] Assistant Professor, Department of Botany, Doon College of Agriculture Science and Technology, Dehradun, Uttarakhand, India

[2] Senior Technical Officer, ICAR, IISWC, Dehradun, Uttarakhand, India

[3] Research Scholar, Department of Botany and Microbiology, HNB Garhwal University, Srinagar Garhwal, Uttarakhand, India

[4] Associate Professor, Department of Botany and Microbiology, HNB Garhwal University, Srinagar Garhwal, Uttarakhand, India

Abstract
In this work, different types of honey produced in the different regions of Garhwal Himalaya were characterized on the basis of their botanical origin and mineral contents. Thirty honey samples were collected for palynological study and mineral analysis from different localities of Garhwal Himalaya. The mineral contents in studied honey samples ranged 432–6151 mg/kg (K), 128–2176 mg/kg (Mg), 120–680 mg/kg (Ca), 129.9–613.9 mg/kg (Na) and 14.57–63.69 mg/kg (P). Within the mineral content, potassium was quantitatively the most important mineral followed by Mg, Ca, Na and P. The presence of different and large number of pollen grains indicated that the honey samples were of different botanical origins while the mineral analysis of the samples concluded that the multifloral honey samples are good source of minerals than the unifloral ones. The forests and agricultural fields in the sub-montane zone can be utilized for production of unifloral honeys from *Eucalyptus* spp., *Brassica* spp. *Pogostemon benghalense*, *Shorea robusta*, and *Litchi chinensis.* Different botanical origin also seemed to affect the mineral content of the honey.

Keywords: multifloral honey, unifloral honey, garhwal Himalaya, pollen, minerals

Introduction

Honey is a natural and nutritious food consumed by many people all over the world since ancient times. Assyrians, Chinese, Greeks and Romans employed honey for wounds and diseases of the gut [1]. Medicinally, honey is used in treatment of wounds [2-3], gastric ulcers [4] and diarrhoea [5-6] in humans. It is used as an ointment for rashes, burns and extensively in sore throat [7]. In India honey has been used by peoples as food, as medicine in treatment of cold, cough, eye ailments and in the healing of wounds.

Honey has different physical and chemical properties which are important indicators for accessing the quality of honey. Minerals are the naturally occurring inorganic substances required as essential nutrients by living organisms to perform functions important for life. These essential elements can be obtained directly from the diet. Calcium, phosphorus, potassium, sodium and magnesium are major minerals. Iron, chlorine, copper, zinc, manganese, sulphur and iodine are the trace elements, necessary for biochemical functions in human body. Potassium is the most abundant metal found in honey followed by calcium, magnesium, sodium, and phosphorus. Potassium helps to control the amount of water in body and maintain a blood pH level. Calcium plays a key role in bone formation. Magnesium plays an important role in regulating blood sugar level and also involved in contraction and relaxation of muscles. Sodium in honey is deeply associated with maintaining blood pressure. Phosphorus is an essential mineral involved in protein formation necessary for growth and repair of body tissues and cells.

The honey bees are best known for the production of honey, wax, propolis, royal jelly, etc. [8]. Bees and plants are mutually dependent. Honeybees visit flowers of different crops, vegetables, medicinal and fruit plants to collect pollen and nectar [9]. Nectar is raw material for honey while pollen provides major food to the developing brood [8]. Honey can be unifloral or multifloral which depends on the availability of different pollen and nectar sources of that area from which it is produced.

Garhwal Himalaya is the part of 'Himalayan Biodiversity Hotspot' situated in the Western part of Central Himalaya. There is a great diversity in the floristic pattern due to altitudinal variation and rainfall [10].The unusually wide altitudinal range, rapid change in altitudinal gradient even at small distances make it interesting for studies [11-12].

Keeping in view the importance of honey, availability of bee forage plants and lack of sufficient melissopalynological work and mineral analysis from the area the present work was envisaged. The objectives of the study are; (a) Identification of unifloral and multifloral honeys and mapping of different floristic zones within the study area, and (b) To analyse mineral content of different collected honey samples.

Materials and Methods

Garhwal Himalaya is situated between the latitudes 29° 31'9" N and 31° 26'5" N and longitudes 77° 33'5" E and 80° 6' E with a total area of 29,089 km^2 is the most frequented and best known part of the Himalaya. Plant and honey samples were collected from different localities with relative

information like place of collection, date, elevation, season of honey extraction and type of honey (*Apis cerana-indica/A. mellifera)*. Thirty honey samples were collected from inhabitants and beekeepers from different localities of of Garhwal Himalaya *viz*., Dehradun, Haridwar, Tehri, Rudraprayag and Chamoli. All samples were raw and unprocessed and were obtained from *Apis cerana-indica* and *A. mellifera* colonies. Honey was filtered through muslin cloth to remove suspended particles.

The laboratory work consists of preparation of honey pollen slides, identification of pollen grains in honey, microphotography and minerals contents in honey. Reference pollen slides were prepared using method suggested by Erdtman [13]. Pollen grains were described by following the terminology of Erdtman [14] and Nair [15]. Quantitative analysis of pollen in honey samples were observed through light microscopy. For mineral content, 5 g honey was dissolved in conical flask and 25 ml HNO_3 and 10 ml per chloric acid were added in to it and mixed properly and put a funnel over it. The entire flask was kept in digestion chamber until the clear solution was obtained. After this digested samples were dissolved in distilled water and then made up to 50 ml with distilled water [16]. Potassium, sodium, phosphorus, calcium and magnesium were analysed by following Jackson [16].

Results

The pollen analysis of the honey samples collected from different localities of Garhwal Himalaya provides significant information related to their botanical origin (bee flora) and type (whether unifloral or multifloral). In this section, analysed honey samples have been indicated as H1 to H30, followed by the name of locality, month of collection, type of honey (*Apis mellifera* or *Apis cerana-indica*), nature of honey (unifloral or multifloral) and absolute pollen count (APC, group I-IV) and number of pollen types with their quantitative presence (Table 1). Based on the number of pollen species and the share of each species in the total pollen count, 8 out of 30 analysed samples were identified as unifloral and 22 were multifloral. The pollen spectra of all the thirty samples are presented in the Table 2 while photographs of some important bee forage plants of the study area are shown in Plate 1–5.

Table 1 shows the concentration of 5 major mineral elements in the studied samples (30 samples). The present study indicated that the potassium is the most abundant mineral in all honey samples, followed by magnesium, calcium, sodium and phosphorus as second, third, fourth and fifth major minerals, respectively.

Among all the samples, potassium was the most abundant mineral ranging from 432–6151 mg/kg. Sample H13 (multifloral) has maximum (6151 mg/kg) potassium content and sample H1 (unifloral) has minimum (432 mg/kg) potassium content. Magnesium was the second most abundant mineral element in Garhwal Himalayan honey that ranges 128–2176 mg/kg. The highest value of magnesium (2176 mg/kg) was found in sample H13 (multifloral) collected from Tyuri village and lowest (128 mg/kg) in H2 (unifloral, Sal honey) from Thano forest.

Calcium was found as third most abundant element in honey samples and was ranging from 120–680 mg/kg. The highest value (680 mg/kg) was recorded in H25 (multifloral), H17 (multifloral) & H15 (multifloral) collected from different villages of Rudraprayag district and lowest value (120 mg/kg) in H16 and H29. Sodium was the fourth most abundant element in all the samples ranging from 129.9–613.9 mg/kg. The highest value (613.9 mg/kg) was observed in H25 (multifloral) collected from Guptkashi and lowest value (129.9 mg/kg) in H18 (multifloral) from chaumasi village. Phosphorus ranged from 14.57–63.69 mg/kg in studied samples. The highest value (63.69 mg/kg) was recorded in H17 (multifloral honey) collected from Chaumasi village and lowest value (14.57 mg/kg) in H29 (Kurchoi village) of multifloral origin.

Table 1: Details and mineral contents (mg/kg) of honey samples collected from different localities of Garhwal Himalaya.

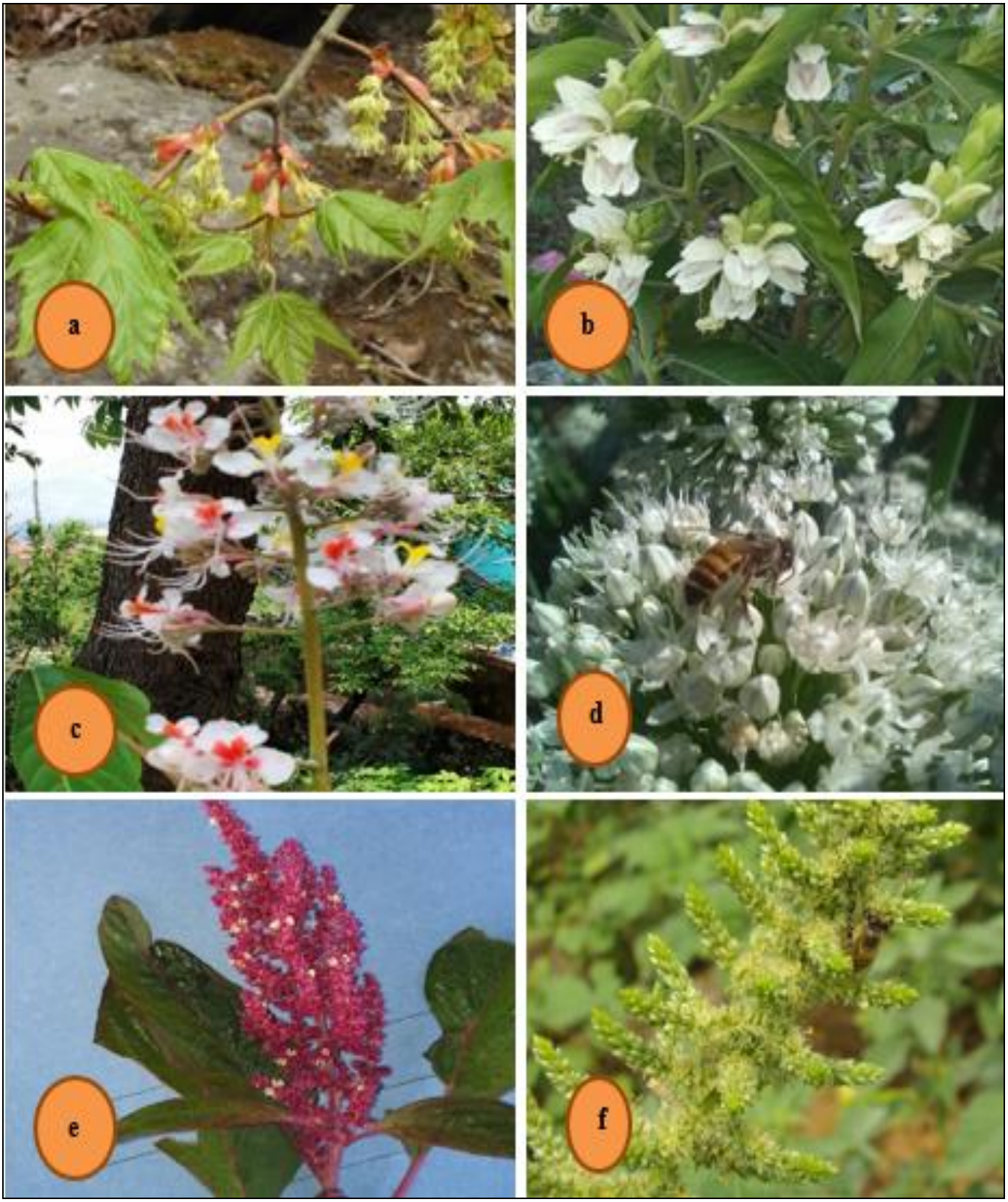
Sample code	Locality	Altitude (m asl)	Extraction season	Absolute pollen count (Group type)	K	Mg	Ca	Na	P
Dehradun									
H1*	Thano^{Un}	746	April	20226 (Group III)	432±.009	768±.005	520±.012	151.2±.021	25.62±.205
H2*	Thano^{Un}	746	May	10,752 (Group III)	503±.006	128±.040	320±.006	145.2±.021	22.56±.159
H3*	Balawala^{Mu}	612	April	20,418 (Group III)	567±.008	864±.003	320±.013	158.2±.040	25.85±.198
H4*	Katapatthar^{Un}	549	May	10,050 (Group III)	817±.006	576±.009	160±.047	177±.029	15.28±.324
H5*	Vikasnagar Ambari^{Mu}	505	May	31,716 (Group III)	1025±.004	704±.006	280±.018	281.7±.029	19.7±.261
Haridwar									
H6*	Bhagwanpur^{Un}	279	October	19,339 (Group III)	2840±.001	704±.006	400±.008	449.9±.009	24.21±.141
H7*	Bhagwanpur^{Un}	279	May	16743 (Group III)	1875±.001	640±.009	280±.018	409.4±.023	23.97±.186
H8*	Imli khera^{Mu}	278	May	19,416 (Group III)	3699±.001	832±.001	480±.004	473.2±.005	21.15±.064
H9*	Sultanpur village^{Un}	241	May	17,218 (Group III)	2196±.001	640±.005	160±.045	417.1±.008	22.8±.135
H10$^{=}$	Sultanpur village^{Un}	241	May	16,349 (Group III)	4605±.000	352±.006	420±.002	473.9±.005	23.97.120
H11*	Sultanpur village^{Un}	241	October	13,122 (Group III)	2557±.001	384±.011	200±.041	459.2±.012	23.74±.176
Tehri									
H12$^{=}$	Akhori village^{Mu}	1979	May	89,912 (Group IV)	2999±.001	950±.007	280±.015	175.6±.009	16.45±.317
Rudraprayag									
H13$^{=}$	Tyuri village^{Mu}	1700	May	78,165 (Group IV)	6151±.000	2176±.002	240±.034	402.5±.014	24.21±.102
H14$^{=}$	Ushara village^{Mu}	2299	May	78,088 (Group IV)	2680±.001	832±.002	520±.010	144.7±.026	22.8±.136
H15$^{=}$	Gadgu village^{Mu}	1600	May	82,578 (Group IV)	2741±.001	512±.004	680±.009	205.9±.009	21.39±.095
H16$^{=}$	Kirora Malla^{Mu}	2048	May	86,113 (Group IV)	1236±.003	448±.013	120±.017	408.5±.014	29.38±.225
H17$^{=}$	Chaumasi village^{Mu}	1899	May	86,641 (Group IV)	5461±.000	1472±.002	680±.007	181.4±.008	63.69±.054
H18$^{=}$	Chaumasi village^{Mu}	1899	October	92,328 (Group IV)	2361±.000	576±.005	440±.018	129.9±.037	27.5±.227
H19$^{=}$	Badeth village^{Mu}	1326	May	73,258 (Group IV)	5927±.000	704±.006	600±.007	265.9±.017	16.22±.230
H20$^{=}$	Khunnu village^{Mu}	1582	May	75,319 (Group IV)	3453±.000	800±.008	500±.006	335±.009	25.15±.135
H21$^{=}$	Bhunalvillage^{Mu}	1811	May	68,862 (Group IV)	5489±.001	1344±.001	360±.009	472.5±.005	46.77±.096
H22$^{=}$	Jaltalla village^{Mu}	1712	May	69,589 (Group IV)	5053±.000	1344±.004	320±.013	323.3±.010	22.33±.139
H23$^{=}$	Bermadi village^{Mu}	1700	May	86,418 (Group IV)	6063±.000	1472±.001	280±.007	429.3±.017	41.13±.029

H24[=]	Guptkashi[Mu]	1475	May	90,529 (Group IV)	5999±.001	320±.013	440±.007	328.6±.014	38.78±.134
H25[=]	Guptkashi[Mu]	1475	October	76,681 (Group IV)	5551±.000	1216±.005	680±.003	613.9±.002	35.25±.125
Chamoli									
H26[=]	Joshimath[Mu]	2037	May	84,138 (Group IV)	1774±.001	192±.026	360±.011	185.6±.019	15.04±.245
H27[=]	Karchi village[Mu]	2206	May	69,686 (Group IV)	956±.004	256±.016	200±.015	135.9±.022	21.86±.127
H28[=]	Karchi village[Mu]	2206	October	82,549 (Group IV)	926±.004	384±.005	320±.016	200.7±.023	23.5±.064
H29[=]	Kurchoi village[Mu]	1995	May	72,523 (Group IV)	1459±.006	256±.016	120±.017	198.7±.013	14.57±.134
H30[=]	Raigari Village[Mu]	3266	May	81,158 (Group IV)	1267±.003	512±.004	440±.005	225.9±.015	35.49±.064

*Apis mellifera honey, [=]Apis cerana-indica honey, [Un]Unifloral honey, [Mn]Multifloral honey

Table 2: Pollen spectra of honey samples.

Sample	Floral origin and Pollen spectra
H1	*Pogostemon benghalense* (76%)[1], *Adhatoda zeylanica* (20%)[2], *Brassica campestris* (4%)[2]
H2	*Shorea robusta* (92%)[1], *Pogostemon benghalense* (9%)[2], *Murraya koenigii* (1%)[2]
H3	*Brassica campestris* (41%)[2], *Eucalyptus* spp., (42%)[2], *Pogostemon benghalense* (17%)[2]
H4	*Litchi chinensis* (85%)1, *Eucalyptus* spp., (15%)[2]
H5	*Callistemon citrinus* (40%)[2], *Litchi chinensis* (25%)2, *Ageratum conyzoides* (17%)[2], *Dalbergia sissoo* (13%)[2], *Murraya koenigii* (5%)[2],
H6	*Brassica campestris* (75%)[1], *Ageratum conyzoides* (16%)[2], *Eucalyptus* spp. (7%)[2], *Coriandrum sativum* (2%)[2]
H7	*Eucalyptus* spp. (80%)[1], *Dalbergia* type (15%)[2], *Murraya koenigii* (5%)[2]
H8	*Eucalyptus* spp. (80%)[1], *Ageratum conyzoides* (16%)[2], *Murraya koenigii* (4%)[2]
H9	*Eucalyptus* spp. (90%)[1], Dalbergia sissoo (10%)[2]
H10	*Eucalyptus* spp. (88%)[1], *Dalbergia sissoo* (12%)[2]
H11	*Brassica campestris* (89%)[1], *Eucalyptus* spp. (11%)[2]
H12	*Citrus* spp. (33%)[2], *Pyrus-Prunus* spp. (25%)[2], *Brassica campestris* (15%)[2], *Rhododendron arboreum* (11%)[2], *Aesculus indica* (9%)[2], *Juglans regia* (4%)[2], *Coriandrum sativum* (2%)[2], *Grewia optiva* (1%)[2]
H13	*Pyrus-Prunus* spp. (34%)[2], *Aesculus indica* (16%)[2], *Citrus* spp. (12%)[2], *Brassica campestris* (10%)[2], *Rhododendron arboreum* (9%)[2], *Rubus* spp. (6%)[2], *Berberis* spp. (5%)[2], *Coriandrum sativum* (4%)[2], *Juglans regia* (3%)[2], *Lyonia ovalifolia* (1%)[2]
H14	*Pyrus-Prunus* spp. (23%)[2], *Citrus* spp. (20%)[2], *Aesculus indica* (15%)[2], *Brassica campestris* (13%)[2], *Rhododendron arboreum* (11%)[2], *Rubus* spp. (7%)[2], *Berberis* spp. (6%)[2], *Coriandrum sativum* (5%)[2]
H15	*Pyrus-Prunus* spp. (24%)[2], *Aesculus indica* (22%)[2], *Brassica campestris* (20%)[2], *Rhododendron arboreum* (12%)[2], *Citrus* spp. (9%)[2], *Woodfordia fructicosa* (7%)[2], *Coriandrum sativum* (5%)[2], *Juglans regia* (1%)[2]
H16	*Pyrus-Prunus* spp. (28%)[2], *Aesculus indica* (20%)[2], *Citrus* spp. (14%)[2], *Brassica campestris* (12%)[2], *Rhododendron arboreum* (11%)[2], *Coriandrum sativum* (5%)[2], *Woodfordia fructicosa* (4%)[2], *Juglans regia* (2%)[2]
H17	*Pyrus-Prunus* spp. (27%)[2], *Aesculus indica* (22%)[2], *Brassica campestris* (16%)[2], *Rhododendron arboreum* (13%)[2], *Citrus* spp. (8%)[2], *Rubus* spp. (5%)[2], *Coriandrum sativum* (4%)[2], *Berberis* spp. (3%)[2], *Juglans regia* (2%)[2]
H18	*Zea mays* (34%)[2], *Luffa acutangula* (18%)[2], *Cucurbita maxima* (15%)[2], *Abelmoschus esculentus* (5%)[2], *Myrica esculenta* (4%)[2], *Medicago sativa* (2%)[2]
H19	*Pyrus-Prunus* spp. (30%)[2], *Brassica campestris* (23%)[2], *Rhododendron arboreum* (15)[2], *Citrus* spp. (11%)[2], *Caesalpinia decapetala* (6%)[2], *Coriandrum sativum* (5%)[2], *Woodfordia fructicosa* (4%)[2], *Ricinus communis* (3%)[2], *Berberis* spp. (2%)[2], *Medicago sativa* (1%)[2]
H20	*Pyrus-Prunus* spp. (32%)[2], *Citrus* spp. (13%)[2], *Rhododendron arboreum* (11%)[2], *Sapindus* spp. (9%)[2], *Zanthoxylum* spp. (8%)[2], *Toona* spp. (7%)[2], *Rubus* spp. (6%)[2], *Coriandrum sativum* (5%)[2], *Colebrookia oppositifolia* (4%)[2], *Melia azedarach* (3%)[2], *Berberis* spp. *Grewia* spp. *Juglans* spp., *Rumex* spp. (2%)[2]
H21	*Pyrus-Prunus* spp. (31%)[2], *Citrus* spp. (24%)[2], *Aesculus indica* (14%)[2], *Rhododendron arboreum* (12%)[2], *Brassica campestris* (9%)[2], *Rubus* spp. (5%)[2], *Coriandrum sativum* (3%)[2], *Juglans regia* (2%)[2]
H22	*Pyrus-Prunus* spp. (25%)[2], *Citrus* spp. (18%)[2], *Rhododendron arboreum* (12%)[2], *Rubus* spp. (9%)[2], *Zanthoxylum* spp. (8%)[2], *Toona* spp. (7%)[2], *Colebrookia oppositifolia* (6%)[2], *Sapindus mukorossi* (5%)[2], *Melia azedarach* (4%)[2], *Juglans regia* (3%)[2], *Grewia optiva* (2%)[2], *Rumex* spp. (1%)[2]
H23	*Pyrus-Prunus* spp. (30%)[2], *Citrus* spp. (27%)[2], *Brassica campestris* (13%)[2], *Rhododendron arboreum* (9%)[2], *Caesalpinia decapetala* (6%)[2], *Coriandrum sativum* (5%)[2], *Ricinus communis* (4%)[2], *Juglans regia* (3%)[2], *Woodfordia fructicosa* (2%)[2], *Berberis asiatica* (1%)[2]
H24	*Pyrus-Prunus* spp. (38%)[2], *Zea mays* (24%)[2], *Melia azedarach* (19%)[2], *Brassica campestris* (8%)[2], *Coriandrum sativum* (5%)[2], *Juglans regia* (3%)[2], *Grewia optiva* (2%)[2], *Lyonia ovalifolia* (1%)[2]
H25	*Zea mays* (33%)[2], *Luffa acutangula* (28%)[2], *Rosa* type (20%)[2], *Brassica campestris* (13%)[2], *Amaranthus* spp. (3%)[2], *Myrica esculenta* (2%)[2], *Medicago sativa* (1%)[2]
H26	*Prunus-Pyrus* spp. (42%)[2], *Citrus* spp. (23%)[2], *Brassica campestris* (14%)[2], *Rhododendron arboreum* (11%)[2], *Coriandrum sativum* (5%)[2], *Juglans regia* (3%)[2], *Grewia optiva* (2%)[2]
H27	*Prunus-Pyrus* spp. (37%)[2], *Aesculus indica* (20%)[2], *Rubus* spp. (17%)[2], *Brassica campestris* (9%)[2], *Prinsepia* spp. (7%)[2], *Pyracantha* spp. (5%)[2], *Viburnum* spp. (3%)[2], *Juglans regia* (2%)[2]
H28	*Zea mays* (32%)[2], *Luffa acutangula* (24%)[2], *Rosa macrophylla* (19%)[2], *Brassica campestris* (12%)[2], *Impatiens* spp., (6%)[2], *Fagopyrum* spp., (5%)[2], *Amaranthus* spp. (2%)[2]
H29	*Pyrus-Prunus* spp. (38%)[2], *Rubus* spp. (15%)[2], *Aesculus indica* (14%)[2], *Brassica campestris* (12%)[2], *Prinsepia utilis* (8%)[2], *Pyracantha* spp. (6%)[2], *Viburnum* spp. (4%)[2], *Juglans regia* (3%)[2]
H30	*Pyrus-Prunus* spp. (38%)[2], *Aesculus indica* (20%)[2], *Brassica campestris* (13%)[2], *Rubus* spp. (9%)[2], *Prinsepia utilis* (8%)[2], *Pyracantha* spp. (5%)[2], *Viburnum* spp. (4%)[2], *Juglans regia* (3%)[2]



a. *Acer acuminatum*
b. *Adhatoda zeylanica*
c. *Aesculus indica*
d. *Allium cepa*
e. *Amaranthus tricolor*
f. *Amaranthus viridis*

Plate 1: Bee forage plants

a. *Berberis asiatica*
b. *Bombax ceiba*
c. *Brassica campestris*
d. *Citrus* sp.
e. *Colebrookia oppositifolia*
f. *Coriandrum sativum*

Plate 2: Bee forage plants

a. *Litchi chinesis*
b. *Lyonia ovalifolia*
c. *Mallotus philippensis*
d. *Mimosa himalayana*
e. *Murraya koeingii*
f. *Ougeinia oogeinensis*

Plate 3: Bee forage plants

a. *Pogostemon benghalense*
b. *Prinsepia utilis*
c. *Prunus ceresoides*
d. *Prunus persica*
e. *Psidium guajava*
f. *Pyracantha cranulata*

Plate 4: Bee forage plants

a. *Pyrus malus*
b. *Pyrus pashia*
c. *Raphanus sativus*
d. *Rhododendron arboreum*
e. *Rubus ellipticus*
f. *Rubus niveus*

Plate 5: Bee forage plants

Discussion

It has been observed that the *Brassica campestris* is the dominant pollen and nectar source for honey production in Dehradun and Haridwar as is evidences by the predominant presence in samples collected from Balawala, Bhagwanpur and Sultanpur village. *Eucalyptus* spp. were found as predominant pollen sources in honey samples collected from Bhagwanpur, Imlikhera and Sultanpur. *Pogostemon benghalense*, a naturally growing Lamiaceae plant was found as major pollen source with the occurrence of 76% in one sample collected from Thano forest. *Shorea robusta* was found as major pollen source in one sample collected from Thano forest with the occurrence of 92%. Similarly, *Litchi chinensis* was found as predominant source in sample collected from Thano forest. These all plant species emerged as most important pollen and nectar sources for unifloral honeys.

Brassica campestris emerged as secondary pollen source in several villages of district Tehri, Rudraprayag and Chamoli as against to the Dehradun and Haridwar districts where the plant species was mainly a predominant source of nectar and pollen. *Aesculus indica* was found as secondary pollen source in samples collected from villages of Tehri, Rudraprayag and Chamoli. *Citrus* spp. and *Zea mays* were

present as secondary pollen sources in villages of Rudraprayag. *Rhododendron arboreum* was one of the most important secondary pollen and nectar sources in honey samples collected from some villages of Tehri, Rudraprayag, and Chamoli. Several members of family Rosaceae such as *Rosa macrophylla*, *Principia utilis*, *Pyracantha crenulata*, *Prunus* spp., *Pyrus* spp., *Rubus* spp., etc. were emerged as secondary pollen and nectar sources in samples of districts Tehri, Rudraprayag and Chamoli.

Among the minerals, potassium is an essential mineral element for basic cell function, water balance, metabolism and nervous system. Potassium benefits relevant to organic anions related to K as it arises in foods such as honey [17]. The concentration of potassium in investigated honey samples (432–6151 mg/kg) was considerably higher than the previously reported values 489.52–932.56 mg/kg by Nanda *et al*. [18], 261–1380 mg/kg by Terrab *et al*. [19], 434.1–1935 mg/kg by Fernandez-Torres *et al*. [20]. Potassium has also been reported to be the most abundant element in honeys from New Zealand, Spain, Poland, Slovenia, Portugal and Italy [21-25]. Magnesium is an essential element as energy booster, in regulating blood pressure and nervous system. The magnesium concentration recorded (128–2176 mg/kg) was higher than the previously reported value 3.79–230.05 mg/kg by Terrab *et al*. [26], 7.25–165 mg/kg by Hernandez *et al*. [27] and 4.59–37.98 mg/kg by Conti *et al*. [28]. Calcium is an essential nutrient for bone health to ensure the calcification of the bone [29]. In this study, calcium concentration (120–680 mg/kg) was analysed higher than the previous reported values 2.50–13.74 by Conti *et al*. [28], 32.60–84.63 mg/kg by Nanda *et al*. [18], 110–248 mg/kg by Terrab *et al*. [19], 42.59–341 mg/kg by Fernandez-Torres *et al*. [20], 18–193 mg/kg by Hernandez *et al*. [27], 172–356 mg/kg by Pisani *et al*. [30]. Sodium is an essential element for normal cell function, continuation of plasma volume, acid-base balance and transmission of nerve impulses. The sodium level in honey samples (129.9–613.9 mg/kg) was similar to earlier reported value 256–501 mg/kg by Terrab *et al*. [19] and higher than 97.87–247.15 by Nanda *et al*. [18] and 7.21–62 mg/kg by Conti *et al*. [28]. Phosphorus is nutrient essential for digestion, DNA formation, teeth and bones. In this study, the phosphorus concentration in all the honey samples (14.57–63.59 mg/kg) was within the range of previously reported values 26–96 mg/kg by Terrab *et al*. [19], lower than the 51.17–154.3 mg/kg by Fernandez-Torres *et al*. [20]. It was also noticed that the different methods of sample solubilization (i.e., microwave-digestion, wet-digestion, dryashing) and analytical techniques often affects the results [30].

Conclusions

The presence of essential elements in honey is of certain nutritional relevance and dietary value connected with the people's health. It can be concluded from the results that the available bee flora at regional scale play an important role in determining the honey properties especially physico-chemical properties. The mineral content and pollen spectra of Garhwal Himalayan honeys vary with variations in the geographical conditions and vegetation. The multifloral honeys of Garhwal Himalayan are good source of minerals than those of the unifloral ones. Hence, the botanical origins of the Garhwal Himalayan honeys have a significant effect on their mineral content. Different regions of Garhwal Himalaya are rich in trees, medicinal plants, fruits and vegetables which make them suitable sites for multifloral honey production with remarkable amount of essential minerals.

Acknowledgements

We thank Prof. J.K. Tiwari (Department of Botany & Microbiology, HNB Garhwal University, Uttarakhand) for his moral support, motivation and guidance throughout the study. We also thank Mr. Rakesh Dhirwan (Department of Beekeeping, ATI, Guptkashi) for help during the field work.

Conflict of interest statement

The authors declare that they have no conflicts of interest.

References

1. Al-Jabri AA. Honey, milk and antibiotics. African Journal of Biotechnology,2005:4(13):1580-1587.
2. Adesunkanmi K, Oyelami OA. The pattern and outcome of burn injuries at Wesley Guild Hospital, Ilesha, Nigeria: a review of 156 cases. The Journal of Tropical Medicine and Hygiene,1994:97(2):108-112.
3. Aysan E, Ayar E, Aren A, Cifter C. The role of intra-peritoneal honey administration in preventing post-operative peritoneal adhesions. European Journal of Obstetrics & Gynecology and Reproductive Biology,2002:104(2):152–155.
4. Kandil A, El-Banby M, Abdel-Wahed K, Abou-Sehly G, Ezzat N. Healing effect of true floral and false nonfloral honey on medical wounds. Journal of Drug Research of Egypt,1987:17(1-2):71-75.
5. Salem SN. Honey regimen in gastrointestinal disorders. Bulletin of Islamic Medicine,1981:1:358-362.
6. Haffejee IE, Moosa A. Honey in the treatment of infantile gastroenteritis. British Medical Journal,1985:290:1866-1867.
7. Ige OE, Obasanmi OO. A palynological assessment of honey samples from Delta State, Nigeria. American International Journal of Biology,2014:2(2):47-59.
8. Gaur RD, Tiwari P, Tiwari JK, Rawat DS, Ballabha R. Bee forage potential of Garhwal Himalaya, India. Indian Journal of Fundamental and Applied Life Sciences,2014:4:196-204.
9. Tiwari P, Naithani P, Saklani S, Rawat DS. Phenolic content, antioxidant activity and palynological analysis of some multifloral honeys from Garhwal Himalaya. International Journal of Pharmacy and Biological Sciences,2017:7(3):84-92.
10. Arora RK. Himalayan resources: diversity and conservation. In: Dhar U (ed.), Himalayan Biodiversity. Gyanodaya Prakashan, Nainital, Uttarakhand,1995:2:39-55.
11. Singh SP, Singh RP, Rawat YS. Patterns of soil and vegetation and factors determining their forms and hydrologic cycle in Nanda Devi Biosphere Reserve. Final Technical Report (FTR) submitted to Department of Environment and Forests, Govt. of India, New Delhi, 1992, 176.
12. Zobel DB, Singh SP. Himalayan forests and ecological generalizations. BioScience,1997:47(11):735-745.
13. Erdtman G. The acetolysis method. A revised description. *Svensk Botany Tidskr*,1960:51:561-567.
14. Erdtman G. *Pollen morphology and plant taxonomy Angiosperm (An introduction to palynology, vol. 1).* Almqvist and Wiksell. Stockholm, 1952, 1.

15. Nair PKK. Pollen analytical study of Indian honeys. *J Ind Bot Soc*,1964:53:179-191.
16. Jackson ML. Soil Chemical Analysis. Constable and Company Ltd., London, 1962.
17. Altun SK, Dinç H, Paksoy N, Temamoğulları FK, Savrunlu M. Analyses of mineral content and heavy metal of honey samples from south and east region of Turkey by using ICP-MS. International Journal of Analytical Chemistry,2017:2017:6391454.
18. Nanda V, Sarkar BC, Sharma HK, Bawa AS. Physico-chemical properties and estimation of mineral content in honey produced from different plants in Northern India. Journal of Food Composition and Analysis,2003:16(5):613-619.
19. Terrab A, Recamales AF, Hernanz D, Heredia FJ. Characterisation of Spanish thyme honeys by their physicochemical characteristics and mineral contents. Food Chemistry,2004:88(4):537-542.
20. Fernández-Torres R, Perez-Bernal JL, Bello-Lopez MA, Callejon-Mochon M, Jimenez-Sanchez JC, Guiraúm-Pérez A. Mineral content and botanical origin of Spanish honeys. Talanta,2005:65(3):686-691.
21. Conti ME. Lazio region (Central Italy) honeys: A survey of mineral content and typical quality parameters. Food Chemistry,2000:11(6):459-463.
22. Golob T, Doberšek U, Kump P, Nečemer M. Determination of trace and minor elements in Slovenian honey by total reflection X-ray fluorescence spectroscopy. Food Chemistry,2005:91(4):593-600.
23. Madejczyk M, Baralkiewicz D. Characterization of Polish rape and honeydew honey according to their mineral contents using ICP-MS and F-AAS/AES. Analytica Chimica Acta,2008:617(1-2):11-17.
24. Silva LR, Videira R, Monteiro AP, Valentão P, Andrade PB. Honey from Luso region (Portugal): Physicochemical characteristics and mineral contents. Microchemical Journal,2009:93(1):73-77.
25. Terrab A, Recamales AF, Gonzalez-Miret ML, Heredia FJ. Contribution to the study of avocado honeys by their mineral contents using inductively coupled plasma optical emission spectrometry. Food chemistry,2005:2(2):305-309.
26. Terrab A, Gonzalez AG, Díez MJ, Heredia FJ. Mineral content and electrical conductivity of the honeys produced in Northwest Morocco and their contribution to the characterisation of unifloral honeys. Journal of the Science of Food and Agriculture,2003:83(7):637-643.
27. Hernández OM, Fraga JMG, Jiménez AI, Jimenez F, Arias JJ. Characterization of honey from the Canary Islands: determination of the mineral content by atomic absorption spectrophotometry. Food Chemistry,2005:93(3):449-458.
28. Conti ME, Finoia MG, Fontana L, Mele G, Botrè F, Iavicoli I. Characterization of Argentine honeys on the basis of their mineral content and some typical quality parameters. Chemistry Central Journal,2014:8:44.
29. Tuyen LD, Hien VTT, Binh PT, Yamamoto S. Calcium and vitamin D deficiency in Vietnamese: recommendations for an intervention strategy. Journal of Nutritional Science and Vitaminology,2016:62(1):1-5.
30. Pisani A, Protano G, Riccobono F. Minor and trace elements in different honey types produced in Siena County (Italy). Food Chemistry,2008:107(4):1553-1560.