Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(1): 234-237

Received: 01-11-2018
Accepted: 03-12-2018

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Altitudinal food preference of bumblebee species (Hymenoptera: Apidae) from Indian Himalaya

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Abstract
This paper describes the food preferences of bumblebee species available in the lower and upper reaches of North-east and North-western Indian Himalaya. These anthophilous insects are completely dependent on pollen and nectar on the high altitude flora and in turn help in their pollination. At higher reaches these insects are one of the most efficient pollinators and are responsible for the conservation of high altitude vegetation germplasm. Depending upon the altitude, different species have different host plants in the Himalayas. The overall picture reveals that there are some plants on which Bumblebees feed heavily such as *Cisium arvensis, Cirsium falconeri, Carduus* spp., *Nepeta* spp., *Prunella vulgaris, Impatiens balsamina, Saussurea* spp., *Trifolium repens* and *Trifolium pratense.* However, there are some other plants like, *Artemisia* spp., *Pedicularis pectinata, Swertia* spp. and *Indigofera* spp. which though occur in close proximity to the above mentioned plants but are seldom visited. The bumblebees are generally associated with different types of flowers (wild or cultivated) and are found foraging in various mountainous regions. The open sunny meadows are favoured by these insects in comparison to the closed deep and dense forests. The species confined to high altitudes are small in size, dull in colour and during flight produce a high buzzing sound. This small size of high altitude species is correlated with the fact that the vegetation present in these areas is in the form of small bushes having very small flowers preferring smaller insects which can easily feed and pollinate them. These species are so adapted to their specific habitats that many of species that are found here are not reported from low altitude areas and vice-versa.

Keywords: Altitudinal food preferences, bumblebees, India

1. Introduction
Bumblebees play a key role in the functioning of agricultural and natural ecosystems as pollinators of crops and wild flowers. These economically important insects are responsible for pollinating plants that provide much of our food. When honey bee pollination is usually limited by low temperature, bumblebees are the chief pollinators there. Bumblebees are ideal for studying the effects of urbanization because these species persist in urban habitats with minimum requirements of nest sites, nest building material and flowers from which they can collect pollen and nectar (Stelzer *et al.*) [22]. Most of these bees are polylectic foraging from a wide variety of flowers, and are better suited to survive in human dominated landscapes than olgolectic, or specialist bees (Westrich) [25]; Laverty & Plowright [12].
Most of the Bumblebees are generalists in their choice of food plants, visiting any remunerative flowers. Their foraging follows a scramble pattern without recruitment of nest mates to good food sources (Dornhaus & Chittka) [5]; Molet *et al.* [16]. These characteristics of bumblebees may account for their abundance in cool environments that have a predictable season of adverse conditions, where flowers are often fairly evenly dispersed. At rest, bumblebees generally have an internal temperature close to ambient temperature (Heinrich) [9]. However, to generate the power required for flight, bumblebees need raising the body temperature above 30 °C, which they do by shivering the flight muscles and through substrate cycling.
In India, Bumble bees are mostly confined to the high altitude regions. Different species are restricted to different altitudinal strata starting from 1000m and going up to 5500m amsl. These species are so adapted to their specific habitats that many of species that are found at highly elevated areas are not reported from low altitude areas and vice-versa. (Arnold *et al.*) [1]
These bees nests either in the ground, often in abandoned rodent burrows, or above ground, in tall grasses (Kearns & Thomson) [10]. Recent studies have shown that bumblebees routinely forage at considerable distances from their nests Dramstad [4]; Osborne *et al.* [20].

Regarding ecological and behavioral studies there is hardly any work on Indian bumble bees. Inspite of the fact that bumble bees diversity can be exploited for the purpose of pollination of various crops, green house farming, floriculture, fruit trees, various vegetables and medicinal plants, no body made any effort in this direction. Among the anthophilous insects, bumble bees exhibit special morphological and other adaptations for removing nectar and pollen from flower species they visit. These adaptations include; hairy bodies well adapted for pollen collection; the presence of pollen basket or corbiculae on Bees hind legs; mandibles and long tongue used to remove the pollen grains from anthers and moistening the pollen grains with regurgitated droplet of nectar.

The present study is designed to explore food preference and ecological distribution pattern of the bumblebees of the North-west and North-east Himalayan belt as the two region forms a natural unit of taxonomic coverage for the genus *Bombus*.

2. Materials and Methods

The study was conducted from 2007-2015 in different agro forestry and wild habitats in North- west and north-east Indian Himalayas covering the states of Jammu and Kashmir, Himachal Pradesh, Sikkim, Assam, West Bengal and Nagaland, in regions located at an altitude ranging from 1000m to 5500m above mean sea level. Areas with dense vegetation and rich floral diversity were selected for the collection of bumblebees and their host plants. These localities were systematically explored twice or thrice every year (May to July for queens and August to October for workers and males) for the collection of all the three castes of every species. Particular attention was paid to the areas above 2000m. Above mean sea level. During the present thorough investigations 37 species of bumblebees, belonging to 10 subgenera of the genus *Bombus* were found in the Indian Himalaya within an altitudinal range given above. These bees were mainly collected with sweeping hand nets and later killed with ethyl acetate/KCN vapors. Some collection was also made with the help of Malaise traps. Most of the collections were available from open areas rather than closed ones. The collection was based mainly on random sampling methods, covering different agro-ecosystem(s). During the study it was found that bumblebee collection with a sweeping hand net was found more effective than malaise trap, the latter does not work well at high altitude because of very high wind velocity accompanied with intermittent rains. During field surveys live photographs of bumblebees along with their host plants were taken with "Olympus" Zoom Digital camera (7.2 MP, C A Media C-7070). We also quantified the food preferences of various bumblebee species under study. All the food plants of these bees were collected side by side and altitude of each site was measured with a digital altimeter. Sampling was conducted at sites dominated by the most representative vegetation types of the region.

2.1 Identification

While dealing with bumblebee taxonomy in general, two major keys, i.e. (Bingham [2]; Williams) [27]. were used. The identification of plants visited by the bees was confirmed by Center of Plant Taxonomy, University of Kashmir; Department of Botany, Punjabi University Patiala (Punjab) and the Forest research Institute, Dehradun (Uttarakhand). All the identified bumblebee specimens have been deposited in the Department of Zoology and Environmental Sciences, Punjabi University, Patiala for future references.

3. Results and Discussion

Depending upon the altitude, different species have different host plants. At lower altitude ranging from 1500-2000m above mean sea level, Bumble bees in general have more preference towards *Allium* sp. (Amaryllidaceae), Duranta *plumieri* (Verbenaceae), *Citrus aurantianus* Linn. (Rutaceae), *Brassica campestris* Linn. (Cruciferae), *Helianthus annuus* Linn., *Dahlia variabilis* Linn., *Tagetes patula, Cynara scolymus* (Asteraceae), *Callistemene linearis* (Myrtaceae), *Lavatera cashmeriana* (Malvaceae,) *Digitalis lanata, Digitalis purpurea* (Scrophulariaceae), *Althaea rosea* Linn. (Rosaceae), *Trifolium pratense* Linn. *Trifolium rapense* Linn (Paplionaceae). The above mentioned flora is mainly visited by the bumble bee species which include *B. tunicatus, B. haemorrhoidalis, B. trifasciatus, B. eximus, B. rotundiceps* and *B. simillimus.*

For the north-western and north-eastern Himalayan hills ranging from 2000-3500m above mean sea level, the most preferred host plants for pollen and nectar are *Impatiens sulcata* Wall., *Impatiens scabrida* Linn. (Balsaminaceae), *Carduus nutans* Linn. *Echinops niveus* Wall. (Asteraceae), *Trifolium pratense* Linn. (Paplionaceae), *Dipsacus inermis* Wall. (Dipsacaceae) and *Buddleja paniculata* Wall. (Lamiaceae). The most common Bumble bees associated with these plants include *B. asiaticus, B. rufofasciatus, B. biroi, B. ferganicus, B. flavescens, B. himalayanus, B. eximus, B. tunicatus, B. melanurus, B. festivus, B. cornutus, B. lucorum, B. breviceps, B. pyrosoma, B. avinoviellus* and *B. kashmirensis.* In the upper Himalayas particularly the tree less alpine meadows situated mostly between 3500m to 5400m above mean sea level, the flora that is conserved particularly by the bumble bees include large variety of medicinal plants, herbs, shrubs and grasses having tiny flowers. Extremely harsh and inhospitable environment of these snow clad mountains, particularly the Apparwatt range, Leh-Ladakh, Lahaul-Spiti, Yamthang valley, Nathula Pass areas of Jammu and Kashmir, Himachal Pradesh and Sikkim where only some selected species of medicinal plants are maintaining their existence, bumble bees play a very positive and deciding role in conserving them This is because of the fact that at these altitudes, excepting bumblebees the insect actively is very rare, only some species of Diptera, Aphids and Coccinellid beetles occur which are labeled as the accidental pollinators because of very low temperature they are very sluggish. The common flora existing at these reaches and repeatedly visited by these bees include *Anaphalis busua* DC, *Circbita cineria* Linn., *Senecio chrysanthemoides* DC, *Taraxacum officinale, Saussurea jacea* (Klotz) Cl., *Saussurea lappa, Scorzonera virgata, Senecio chrysanthemoides, Saussurea costus, Lactuca orientalis, Saussurea albescens, Saussurea auriculata, Rudbeckia laciniata,Saussurea fastuosa Leontopodium alpinum, Tanacetum dolicophyllum* (Asteraceae) *Potentilla atrosanguinea* Lodd. (Rosaceae), *Thymus serpyllum* Linn., *Mentha longifolia* Linn., *Phlomis bracteosa* Royle, *Stachys serecia* Wall. ex Benth., *Nepeta discolor* Linn., *Hyssopus officinalis* Linn., *Dracocephalum heterophyllum* Benth., *Nepeta laevigata* (D. Don) Hand. - Mazz. (Lamiaceae), *Polygonum amplexicaule* D.Don. (Polygonaceae), *Pedicularis pectinata* Wall., *Euphrasia officinalis* (Scrophulariaceae), *Gypsophil cerastioides* D. Don (Caryophyllaceae), *Myosotis sylvatica* Ehrh. et Hoffm.

(Boraginaceae), *Melilotus officinalis* (L.) Pall (Leguminosae), *Cyanthus lobatus* Wall. (Campanulaceae), *Gypsophila cerastioides* (Caryophyllaceae), *Rhodiola crenulata* Linn., *Sedum ewersii* Ladeh (Crassulaceae) and *Hyoscyamus niger* Linn. (Solanaceae).

This long list of plants clearly show that the most of the high altitude flora is mainly and frequently visited by these bees. In addition to their soil binding nature and numerous other ecological roles, these plants have a lot of medicinal importance as well. The species of Bumble bees that are mainly found foraging on the above mentioned flora are: *B. asiaticus, B. keriensis, B. melanurus, B. personatus, B. semenovianus, B. waltoni, B. lepidus, B. biroi, B. oberti, B. lemniscatus, B. rufofasciatus, B. kashmirensis, B. hypnorum, B. himalayanus, B. ladakhensis, B. miniatus, B. eximus, B. pressus, B. festivus, B. flavescens,* and *B. subtypicus.*

When viewed in totality, the reason for the preference of host plants by Bumble bees cannot be attributed to a single factor, rather a group of factors are likely to contribute towards this predilection. Some of these factors include the shape, size and colour of flowers, pollen contents, pollen amount, season and site. The Bumble bees prefer those flowers which grow on the open slopes of mountains rather than closed deep and dense forests. They prefer sunshine and dry weather as compared to moist, cloudy and wet conditions. The shape of the flower is an important factor for preference by these insects. The flowers with funnel-shaped structure help guide the movement of and thus facilitates pollen and nectar collection. It has also been observed that bumble bees prefer symmetrical flowers rather than asymmetrical ones (Moler [17]; Moller & Sorci [18] and bilateral symmetry is preferred over radial symmetry (West &Laverty) [24]. Experimental observations further prove that morphologically complex flower designs took bees longer to learn than open tubed or cup shaped designs (Laverty) [11].

The field observations also show that the Bumble bees are more attracted towards bright coloured pink flowers of *Impatiens sulcata* Wall. (Balsaminaceae) rather than yellow coloured *Impatiens scabrida* Linn. (Balsaminaceae). When both these plant species are growing side by side, the number of bees attracted towards pink flowers/unit time is large in comparison to the yellow flowers. During a foraging flight bumble bees work on not more than two plant species at a time (one major and one minor) (Gegear &Laverty) [7].

The observation is largely in conformity with earlier studies Darwin [3]; Grant [8]; Free [6]; Levin & Anderson [13]; Henrich [9]; Waser [23]; Lewis [14, 15]. *B. asiaticus; B. rufofasciatus* and *B. melanures* were also observed to have a broad host spectrum while *B. kashmirensis; B. lucorum* and *B. simillimus* are more specific. However, when seen from the angle of preference, it has been observed that bumble bees mostly prefer members of family Asteraceae followed by Scrophulariaceae, Lamiaceae and Papilionaceae.

Regarding ecological and behavioral studies there is hardly any work on Indian bumble bees. Inspite of the fact that bumble bees diversity can be exploited for the purpose of pollination of various crops, green house farming, floriculture, fruit trees, various vegetables and medicinal plants, no body made any effort in this direction. From the last 9 years the authors have taken great pains to explore the different high altitude regions of Indian Himalaya to enlist some important food plants of bumblebee species and their association with the entomophilous flowering plants occurring up to the permanent snowline.

4. Conclusion

These anthophilous insects thrive well in this otherwise very harsh and inhospitable environment. At some of the secluded hill terrains, slopes and gorges these hard built insects are the only ones to maintain the vivid tapestry of vegetation. If some of the very important medicinal herbs and shrubs of high altitude regions are maintaining their existence that is all because of these insects. However, due to the massive induction of modern technology and variety of other environmental factors, the role of these insects as the preserver of vegetation diversity is being mercilessly brought under a tremendous ecological stress and strain in the entire Himalayan ecosystem. They are shrinking in number and kind and so is the fate of related plant diversity.

The overall picture reveals that there are some plants on which bumble bees feed heavily such as *Cisium arvensis, Cirsium falconeri, Carduus* spp., *Nepeta* spp., *Prunella vulgaris, Impatiens balsamina, Saussurea* spp., *Trifolium repens* and *Trifolium pratense.* However, there are some other plants like, *Artemisia* spp., *Pedicularis pectinata, Swertia* spp. and *Indigofera* spp. which even though occur in close proximity to the above mentioned plants, they are seldom visited. Data generated demands conservational strategy programmes to ensure the ultimate balance of this delicate but delightful interrelationship. All the above derivations are based on very precise experiments as well as general observations taken in the field. However, to authenticate any of the above points, detailed experimental studies with specific designs should be made under the natural environmental conditions. Though this study is mainly concerned with the bumblebees foraging on the medicinal and some other plants of north eastern and north western belt but it can be easily extended to other high altitude regions of Indian Himalaya on the same pattern.

5. Acknowledgements

The authors are grateful to ICAR/MoEF &CC, New Delhi (Govt. of India) and for providing financial assistance under different research projects. Thanks are due to Dr. Paul H. Williams Natural History Museum (London) for providing direly needed literature and confirmation of some important species identification of bumblebees. Thanks are also due to Head, BSI, Gangtok (India), Dr. Anzar Ahmad Khuroo Sr. Assistant Professor and Dr. Akhter H. Malik, Curator, Centre of Plant Taxonomy University of Kashmir (India) for identification of plant species.

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