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Berberis aristata DC: An Important Winter Foraging Source for Anthophilous Insects in Western Himalaya

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Abstract

The article presents a first-hand study that provides information about the anthophilous insects of Berberis aristata in Nainital Western Himalaya. By using the direct sampling method, a total of 11 species of anthophilous insects were recorded on the medicinally important plant B. aristata. The recorded anthophilous insects were belonging to the order Diptera, Hymenoptera, and Lepidoptera. The I_{VR} index value of Apis cerana was recorded as maximum showing that it is a potential pollinator of B. aristata. The study reported a good abundance of anthophilous insects on B. aristata, which revealed that it is a good food source for insects during winter. The study concluded that more efforts should be made to investigate resources that could support and provide switching platforms for pollinators during the winter.

Keywords: *Abundance, Anthophilous Insects, Diversity, Family, Pollinator*

1. Introduction

Insects are the most diverse and dominant creatures on Earth. They occur everywhere, from frozen Antarctica to the scorching sun of the tropics, in water, land, air, deserts, and high mountains (Alfred et al., 1998, Wang et al., 2022). Anthophilous or flower-visitor is a general term for animals, especially insects that are frequently on flowering plants to collect pollen, nectar, oils, or floral tissues (Kevan & Baker, 1983 & 1998, Badoni and Arya, 2022a). According to the plant type, pollen contains varying amounts of protein, fat, carbohydrate, vitamins, and minerals. Floral nectar contains three common sugars, viz. Fructose, Glucose, and Sucrose are significant rewards to pollinators (Kevan & Baker, 1983, Torres & Galetto, 2002). Pollination is an essential ecological process for the maintenance and conservation of biodiversity, which involves the transfer of pollen from the anther to the flower's stigma with the help of abiotic and biotic pollen dispersal agents (Sharma & Mitra, 2012). Pollination is helpful in the reproduction of approx. 60-90% of the flora and is an important requisite for gene transfer within or between populations of wild plant species (Kearns et al., 1998, Renner, 2006), fertilization, and fruit formation (Free, 1963). Insects benefit society by increasing food security and improving livelihoods by enhancing the yield and quality of many agricultural and

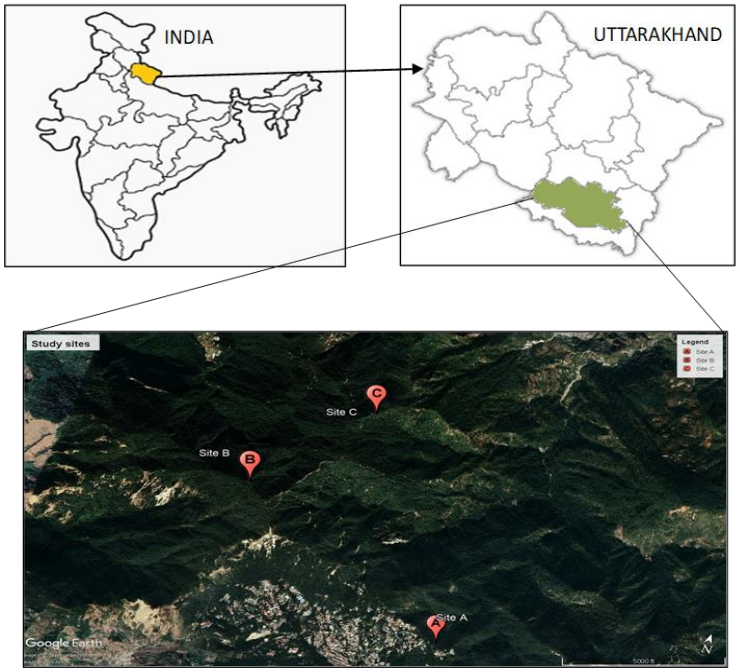
horticultural crops and conserving biological diversity in agro and forest ecosystems (Pratap et al., 2012, Garibaldi et al., 2016). Among diverse anthophilous insects, bees are potentially superior pollinators to other insects providing the most effective pollination service in natural and agricultural ecosystems (Robertson, 1895, Klein et al., 2007). The insects that visit the flower is categorized into 4 orders: Hymenoptera, Diptera, Lepidoptera, and Coleoptera (Memmott, 1999). The flower attracts insects due to the bright color of its petals, the tempting scent, the appearance of nectar glands, and the edible pollen (Badoni & Arya, 2022b).

The plant family Berberidaceae is consisting about 600 species across the globe (Chander et al., 2017), of which three genera and 68 species are available in India (Rao & Hajra, 1993). Biodiversity is well preserved in the Himalayas, which are known as one of the world's richest hot spots. It opens up enormous opportunities in various areas of advanced biology that are related to sustainable life support systems (Kumar et al., 2018). About >95 % of *Berberis* species are distributed in the Himalayan Region (Tiwari et al., 2012). A total of 24 species with 32 different taxa are found in Uttarakhand, including six endemics (Rao et al., 1998, Uniyal et al., 2007). *Berberis aristata*, sometimes referred to as "Daruhaldhi" and "Citra," is a plant that is indigenous to the Himalayan regions of Northern India and Nepal. It is also present in Sri Lanka and the Nilgiri Hills of Southern India (Komal et al., 2011, Rathi et al., 2013). B. *aristata* is known for its pharmaceutical and medicinal properties (Alvarez et al., 2009). B. *aristata* roots has been used for the treatment of jaundice, and liver toxicity. It also has antidiabetic, anticancer antimalarial, antimicrobial, anti-inflammatory, and antioxidant properties (Komal et al., 2011). Previous studies have shown that the flowers of Genus *Berberis* are hermaphrodite and insect-pollinated, also very attractive to many important pollinator taxa (Sood et al., 2013). Thus, the present study has been done to identify the anthophilous and potential pollinator insects of *Berberis aristata*.

2. Materials And Methods

Study area

The present study was done in Nainital, Western Himalaya at three different study sites from December 2019 to February 2020. The study sites were selected based on selected plant species abundance. The study area is rich in flora and fauna. It is situated between an altitude of 6303 ft. - 8603 ft. The forest is covered with predominantly Oak, Maple. Temperatures vary from -2°C at the minimum to 33°C at the maximum. The description of study sites along with dominant flora is given in Table 1. The location of study sites is provided in Map 1.



Map 1: Location map of selected study sites in study area (Source: Google Earth)

Description of Plant Species

Berberis aristata is an evergreen spiny shrub growing approx. 250-400 cm tall. The ventral surface of the leaves is light green, while the dorsal surface has a deep green color. The leaves have pinnate venation and are simple. The leaves have a leathery texture, are toothed, and have numerous tiny indentations along their margins. Flowers are hermaphrodite, yellow, complete, present in clusters (10-17 flowers per cluster) and hang downwards from the stem. Flowers are generally observed between December-February months.

Insect Sampling, Collection and Identification

Samplings were done during blooming months i.e., December–February (once a week) from 700 to 1700 hr on every field visit day through direct method i.e., sweep netting and visual count (Cooper & Whitmore, 1990, Lebuhn, 2013). Field visits were done during sunny days due to the high activity of insects. Anthophilous insects were observed in the field using Nikon D5300 digital camera. Data were collected from the plants unequally distributed among the selected study area. Unidentified collected insects were labeled, preserved and identified from Insect Biodiversity Laboratory, Department of Zoology, D.S.B. Campus, Kumaun University, Nainital and Entomological section of Forest Research Institute, Dehradun. Insects observed with pollen attached to their body or carrying pollen load are considered as pollinators whereas insects having no pollen attached or load on their body considered visitors.

Visitation Activity of Anthophilous Insects

Berberis aristata possess 10-17 small flowers and are clustered tightly into inflorescences. For these, we found it impractical to quantify visits to individual flowers and instead defined a flower visit as an inflorescence visit. Sampling was done once a week during the blooming or flowering period. A total of 10 plants were selected for the sampling from each site located roughly 10 m distance from each other and the number of flowers was also calculated on each sampling day. Sampling was done from 700 to 1700 hr on a sunny day due to the high activity of insects. This method enabled later calculation of the number of visits per minute (visits/min). We recorded the number of flowers visited per min. by each individual species (10 individuals of each species). For the species of visiting insects with different AR (Activity rate), the following classes were created: Class I: 0.1 visits/min, Class II: 0.1 to 0.5 visits/min, Class III: 0.5< visits/min. For each field, the number of individuals of different species relative to the total number of insects included in the census (relative frequency) was calculated. For each field, the number of individuals of different species relative to the total number of insects included in the census (relative frequency) was calculated. The percentage of frequency (F) was obtained by multiplying each of the relative frequency values by 100. Data were standardized by converting the number of individuals of each species into the number of individuals per flower (number of individuals/flower). The efficiency of a particular visiting insect was calculated by measuring the Index of visitation rate (IVR) for different plant species (Talavera et al., 2007):

$$\mathbf{I_{VR} = F \times AR}$$

Where F= Percentage of frequency= relative frequency (number of individuals belonging to a visiting-insect category relative to the total number of insects included in the census) ×100; AR= Activity rate (mean number of flowers that a visiting-insect category visited per unit time).

Statistical Analysis

Diversity indices (Shannon diversity index, Simpson index, Marglef's index and Evenness etc.) among the study sites were calculated in the software PAST 3.04 (Hammer et al., 2001). The similarity matrix was calculated by using the software Bio-diversity Pro Version 2.0 (Lambshead et al., 1997).

3. Result and Discussion

Species Composition of Anthophilous Insects

A total of 11 species under nine genera belonging to five families of anthophilous insects were recorded on *Berberis aristata* (Table 2 and Table 3). Among the recorded anthophilous insect species, nine species were recorded as pollinators and the remaining two were visitors only (*Calliphora vicina* and *Orthellia indica*). Among the recorded anthophilous insects, eight species belonged to the order Diptera followed by two species in the order Hymenoptera and single species in the order Lepidoptera. *Berberis aristata* was visited by various anthophilous insects from which Syrphidae

(Order: Diptera) was recorded as the most dominant family including six species i.e., *Eristalis tenax, Eristalis cerealis, Eristalis himalayensis, Episyrphus balteatus, Scaeva pyrastri* followed by family Calliphoridae with two species (*Calliphora vicina* and *Orthellia indica*) whereas, families Apidae, Formicidae, Lycaenidae, included single species each (Table 2 and Table 3). The activity of anthophilous insects belonging to different orders showed peak activity during 11:00 to 12:00 hr and the anthophilous insect's activity completely ceased 16:00 hr onwards (Figure 1).

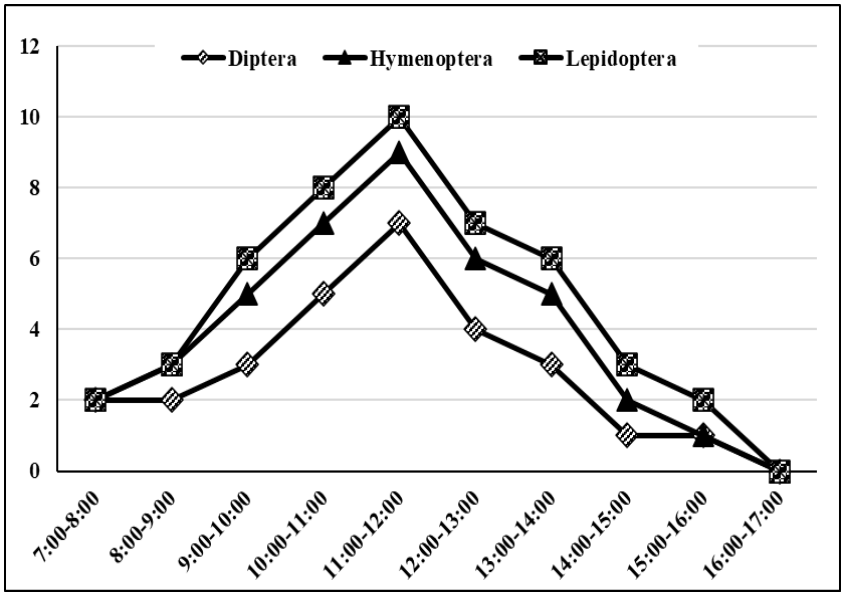


Figure 1: The total number of Anthophilous insect species observed within observation time during the blooming period of Berberis aristata in the study area

Relative Frequency of Anthophilous Insects

The relative frequency of *Episyrphus balteatus* was recorded as maximum (1.50±0.38) followed by *Apis cerana* (1.00±0.39), *Eristalis tenax* (0.92±0.40), *Camponotus sp.* (0.75± 0.33) whereas, the minimum relative frequency was recorded in case of *Scaeva pyrastri* (0.17±0.11) (Figure 2).

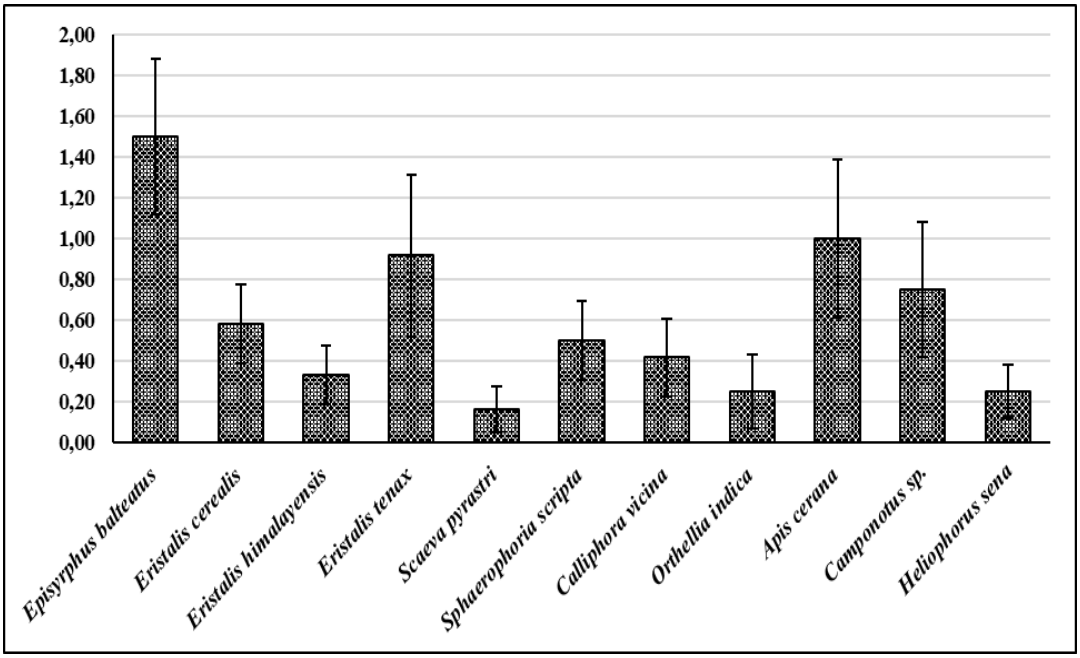


Figure 2: Relative frequency of anthophilous insects (Mean±SE) on *Berberis aristata* recorded during the study period

Table 1: Description of selected study sites and their dominant flora

Study site	Site A	Site B	Site C
Latitude	29°23'50.67" N	29°24'24.14" N	29°25'04.28" N
Longitude	79°27'32.05" E	79°26'23.60" E	79°26'46.35" E
Altitude	2208 m asl	2620 m asl	2311 m asl
Dominant flora	*Quercus floribunda, Quercus leucotrichophora* and *Cupressus torulosa*	*Cedrus deodara, Quercus floribunda,* and *Rhododendron arboreum*	*Quercus floribunda, Cedrus deodara* and *Cupressus torulosa*

Visitation Rate of Anthophilous Insects of Berberis Aristata

Table 2: Species composition and abundance of anthophilous insects on *Berberis aristata*

Order: Family	Species composition	Behaviour		Activity *Rate*	I_{VR}
		P	V		
Diptera: Syrphidae	*Episyrphus balteatus* De Geer	P		III	3.25
Diptera: Syrphidae	*Eristalis cerealis* Fabricius	P		III	0.44
Diptera: Syrphidae	*Eristalis himalayensis* Brunetti	P		III	0.19
Diptera: Syrphidae	*Eristalis tenax* Linnaeus	P		III	0.84
Diptera: Syrphidae	*Scaeva pyrastri* Linnaeus	P		II	0.06
Diptera: Syrphidae	*Sphaerophoria scripta* Linnaeus	P		III	0.50
Diptera: Calliphoridae	*Calliphora vicina* Robineau-Desvoidy		V	II	0.21
Diptera: Calliphoridae	*Orthellia indica* Robineau -Desvoidy		V	II	0.06
Hymenoptera: Apidae	*Apis cerana* Fabricius	P		III	6.50
Hymenoptera: Formicidae	*Camponotus sp.*	P		III	0.69
Lepidoptera: Lycaenidae	*Heliophorus sena* Kollar	P		III	0.17

***P: Pollinator; V: Visitor**

Visitation rate (I_{VR}) was calculated maximum for *Apis cerana* (I_{VR}= 6.50) therefore, it can be concluded that its potential as a pollinator of this medicinal plant is relatively very high, followed by *Episyrphus balteatus* (3.25) Whereas, the I_{VR} value of *Eristalis cerealis, Eristalis himalayensis, Eristalis tenax, Scaeva pyrastri, Sphaerophoria scripta, Calliphora vicina, Orthellia indicia, Camponotus sp.* and *Heliophorus sena* were recorded <1 hence this can be concluded that their potential as pollinators is relatively low for this plant species (Table 2).

Table 3: Number of families, species, genera and individuals recorded during the study period

Order	Number of family	Number of Genera	Number of Species	Number of individuals
Diptera	2	6	8	56
Hymenoptera	2	2	2	21
Lepidoptera	1	1	1	3
Total	5	9	11	80

Alpha Diversity of Anthophilous Insects

Table 4: Alpha diversity of anthophilous insects recorded across different study sites

Diversity Indices	Site A	Site B	Site C
Simpson_1-D	0.820	0.851	0.887
Shannon_H	1.809	2.02	2.28
Evenness_e^H/S	0.872	0.838	0.889
Margalef	1.312	1.749	2.186
Fisher_alpha	1.714	2.397	3.154
Berger-Parker	0.26	0.22	0.20
Chao-1	7	9	11

The Shannon diversity was calculated maximum in Site C i.e., 0.887 followed by Site B (0.851) and Site A (0.820). Similarly, species richness observed with Margalef's index revealed maximum values in Site C (2.186) followed by Site B (1.749) and Site A (1.312), respectively. Likewise, Site C also showed maximum evenness i.e., 0.889 followed by Site A (0.872) and Site B (0.838) (Table 4).

Plants play a very important role in the anthophilous insect's availability. The anthophilous insect's abundance is directly proportional to the availability of flower sources in their surroundings. Different plant species have different blooming periods and during the winter season very few species of plants have their blooming period, Hence, the food source for anthophilous insects is very low. Winter-blooming plant species act as bridges to maintain the abundance of anthophilous insects during winters. Along with *Berberis aristata*, *Duhaldea cappa, Duhaldea cuspidata*, *Rumex hastatus*, *Erigeron multiradiatus, Echinops sp. were* also observed with their blooming period. Among the few observed forage species *Berberis aristata* was found to be an important species that support a diverse group of anthophilous insects including pollinators by providing necessary forage. During the present study, *Apis cerana* was corded as a potential pollinator of *B. aristata*. Familywise, Syrphidae was recorded as the most dominant family in terms of number of species.

Genus *Berberis* has yellow flowers present in clusters that produce sugar-rich nectar that attract several insect pollinators (Radice & Arena, 2019). Despite the *Berberis aristata* enormous therapeutic value and being native to the Himalayas, there is no literature about the insect visitors of *B. aristata*. Therefore, the current study is important since it offers first-hand baseline data on insects connected to *B. aristata* in Western Himalayas. Therefore, the present finding discussed and correlated with published literature on other species of genus *Berberis* across the globe, including the Himalayan region, Macior (1968) recorded *Bombus affinis* (Apidae, Hymenoptera) as a primary pollinator of *Berberis thunbergii* in Racine County, Wisconsin. Smith-Ramírez et al. (2005) reported pollination in *Berberis buxifolia* and *B. darwini* by plethora species of Hymenoptera including *Bombus* from the temperate rain forests of Chiloe Island, Chile. Radice and Arena (2019) documented the species belonging to the family Syrphidae (Diptera) as the pollinators of *Berberis microphylla* in Tierra de Fuego. Badoni and Arya (2022b) study the pollinators of the genus Berberis (*Berberis asiatica, Berberis chitria, Berberis lycium*) in Western Himalaya and reported order Lepidoptera as the most dominating order in terms of species richness followed by Diptera, Hymenoptera and Coleoptera. *Berberis aristata* recorded with the rich diversity of anthophilous insects also has medicinal values therefore, this plant species is to be protected and managed to provide forage to pollinators as well as anthophilous insects during the winter season.

4. Conclusion

The present study provides information on the quantitative spectrum of anthophilous insects on *Berberis aristata* in Western Himalaya. It also reveals that the visitation activity of anthophilous insects varies as per visiting hours. The diversity of anthophilous insects was found to be maximum at Site C which is due to the availability of less nearby blooming vegetation. The abundance of anthophilous insects in terms of species diversity indicates a good nectar/ pollen source in winter. Thus, this species despite its medicinal values also a good food source for anthophilous insects and this study is a preliminary study on anthophilous insects of *B. aristata*. Thus, this information provides baseline information about the anthophilous insects of *B. aristata*. Hence, conservation and management of this plant species should be required as it has numerous medicinal and ecological values.

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Conflict of interest:
The authors declare that there is no conflict of interest regarding the publication of this manuscript.

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