FLOWER VISITING BEETLES OF BEDKOT MUNICIPALITY KANCHANPUR, NEPAL

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Submitted To

Central Department of Zoology

Institute of Science and Technology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

March 2023

DECLARATION

I hereby declare that the work presented in this thesis entitled "Flower Visiting Beetles of Bedkot Municipality Kanchanpur, Nepal" has been done by myself, and has not been submitted elsewhere for the award of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

Date: 14 March, 2023

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RECOMMENDATIONS

This is to recommend that the thesis entitled "Flower Visiting Beetles of Bedkot Municipality Kanchanpur, Nepal" has been carried out by Ms. Sangeeta Chand for the partial fulfillment of the Master's Degree of Science in Zoology with special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree inany institution.

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LETTER OF APPROVAL

On the recommendation of supervisor Assoc. Prof. Dr. Daya Ram Bhusal, this thesis submitted by Ms. Sangeeta Chand entitled "Flower Visiting Beetles of Bedkot Municipality Kanchanpur, Nepal" is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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CERTIFICATE OF ACCEPTANCE

The thesis work submitted by Ms. Sangeeta Chand entitled "Flower Visiting Beetles of Bedkot Municipality Kanchanpur, Nepal" has been accepted as a partial fulfillment for the requirement of Master's Degree of Science in Zoology with special paper Entomology.

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Sangeeta Chand

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ABSTRACT

Beetles are highly diverse and most primitive flower visiting insects. Beetles visit portions of flowers and help to disperse pollen grains to support cross pollination. Flowers are also important microhabitat for large number of beetles. This study aims to describe the flower visiting beetles of homegardens in Bedkot Municipality, Kanchanpur Nepal. Sampling was taken during October 2020 to August 2021 covering autumn, winter, spring and summer seasons. Observation was taken in 20×20 m plot size for 45 minute. Only the beetles visiting the plant inflorescence were recorded. This study recorded 1273 individuals, 19 morphospecies of flower visiting beetles from seven beetle families and these are found interacting with 40 plant species belonging to 16 plant families. Chrysomelidae (8 species) are most abundant flower visitor followed by Coccinellidae (4 species), Curculionidae (2 species), Meloidae (2 species), Nitidulidae (1 species), Scarabaeidae (1 species) and Brentidae (1 species). Flower visitors were most abundant during autumn season (n=907) than other season and diverse during spring (H'=1.46) season and were evenly distributed during winter season (J=0.78). Bipartite graph of Plant-Pollinator interaction network was constructed to study the interaction between flower visiting beetles and plants. Cucurbitaceae and Asteraceae were reported as most diverse plant families visited by flower visitors. Cucurbitaceae were visited by 12 species (756 individuals) of beetle representing six beetle families. *Aulacophora foveicollis* was most abundant flower visitor, visiting flowers of 10 species of plants mainly of Cucurbitaceae plants. *Aulacophora lewisii* was second abundant flower visitor, visiting mostly flowers of Cucurbitaceae plants and Coccinelid beetle *Micraspis univittata* was third abundant and most generalist flower visitor visiting 28 plant species.

1. INTRODUCTION

1.1 Background

Globally about 87.5% of flowering plants are pollinated by animals (Ollerton et al. 2011) and of these majorities of species are insects (Ollerton 2017). Most of flower visiting insect species comes under four major insect orders: Coleoptera (beetles), Diptera (flies), Lepidoptera (moths, butterflies) and Hymenoptera (bees, wasps, ants) (Wardhaugh 2015). Among these insects, bees are important pollinators of agricultural crops and wild plants (Potts et al. 2010). Most primitive flower visiting insects were beetles and after these other flower visiting insects were evolved from flies to butterflies and bees (Baker & Hurd Jr 1968). Beetles are those insect groups that visited flowers from the Cretaceous period (Li et al. 2021). These are the most diverse flower visitors after Lepidoptera and about 77,000 beetle species are recorded as flower visitors (Wardhaugh 2015, Ollerton 2017). Also, about 184 species of Angiosperms are pollinated by beetles that belong to 34 families under 85 genera (Bernhardt 2000).

Important flower visiting beetle families are Elateridae, Scarabaeidae, Cleridae, Nitidulidae, Chrysomelidae, Staphylinidae, Meloidae and Cerambycidae (Kevan & Baker 1983). Beetles are important pollinators of eumagnoliids having chamber-like flowers which include the members of Magnoliaceae, Annonacecae and Eupomatiaceae (Li et al. 2021). Most beetle pollinated flowers are of two types; one those with large, bisexual, individual flower with their petals forming salver, bowl or urn- like shapes and others with tiny, unisexual florets condensed in inflorescences (Bernhardt 2000). Flower-visiting beetles structurally modify their mouthparts in various ways to attach and ingest pollen grains (Karolyi et al. 2009). Pollen feeding beetles mostly have prognathous mouthparts whose apical parts of maxillae bear pads and tufts of bristles that help for pollen and nectar uptake, and these mouthparts are found in beetle families such as Scarabaeidae, Oedemeridae, Cerambycidae, Cantharidae, Bruchidae, Meloidae and Mordellidae (Krenn et al. 2005). Flower visiting beetles can be herbivores, pollinators or predators (Kirmse & Chaboo 2020). These visit flowers to feed on pollen, other floral parts like petals, tepals, stamen, carpels and on nectar if present (Gottsberger 1977). Flower visiting beetles devour portions of flowers thus help to disperse pollen grains to support cross pollination (Li et al. 2021).

Flowers provides important microhabitat for beetle diversity supporting high densities and large number of rainforest canopy beetles (Wardhaugh 2013). Wildflower plantings support highly diverse flower-visiting insect communities such as, non-syrphid Diptera, non-bee Hymenoptera, Coleoptera and Lepidoptera other than wild bees and hoverflies (Grass et al. 2016). Although all flower visitors may not act as pollinators, they provide important ecosystem services for both wild plant communities and crops and also, they have variety of ecological roles that include pest control and pollination (Lazarina et al. 2017). The effectiveness of beetle as pollinators is poorly understood, however flowers are important microhabitats for beetles where beetle densities were greater on flowers than on adjacent leaves (Wardhaugh et al. 2012, Wardhaugh 2015). Beetles are abundant flower visitors and also are important pollinator in plant-pollinator interaction (Kirmse & Chaboo 2020).

A large number of plant species and pollinator species make up plant-pollinator communities and the studies of pollinator networks are based on plant-centered visual surveys of plant-pollinator contacts (Bosch et al. 2009). Pollination by insects play an important in pollination process of flowering plants in both natural and agricultural landscapes (Bentrup et al. 2019). Interaction between pollinator and plants is a form of mutualism symbiosis in which flower provides food for insects in the form of pollen and nectar, while plants acquire benefit from the pollination process and thus the presence of insect pollinators help to determine the availability of flowering plants in particular habitat (Koneri et al. 2021). These mutualistic relationship between plant-pollinator interactions are represented by bipartite networks (Seo & Hutchinson 2018). Bipartite networks between flowering plants and their potential visitors are used to study the ecological structure and functions of the interaction between plant and their visitors (Prendergast & Ollerton 2022). Specialized flowers are those which have strong directional selection traits relate to pollination and generalized are those which are attractive and accessible to most flower visitors; whereas flower visitor is generalist if it visits more flowers and is specialist if it visits fewer flowers (Minckley & Roulston 2006). In complex interaction networks, the majority of nodes (species) tend to interact with fewer species, while a small number of nodes are significantly more connected than anticipated (Bascompte & Jordano 2007).

Home gardens are traditional land use practices around a homestead where several species of plants are planted and plays important role in supplying different food crops for household members and in Nepal vegetables, fruits, fodder and spices species are the major component of the home gardens, among these vegetables, fruits and spices are mainly cultivated for daily home consumption, whereas fodder species for livestock (Shrestha et al. 2002). Ornamental flowers and vegetables are the major components of home gardens in Bedkot Municipality. This study aims to explore diversity of flower visiting beetles and their interactions with host plants in the home garden of Bedkot Municipality.

1.2 Objectives

1.2.1 General Objectives

The general objective of the study was to explore flower visiting beetles in the home gardens of Bedkot Municipality Kanchanpur, Nepal.

1.2.2 Specific Objectives

Specific objectives of the study were;

- To explore seasonal variation and diversity of flower visiting beetles.
- To assess the relation of flower visiting beetles with their host plants.

1.3 Rationale of the Study

Beetles are highly diverse groups among the insects and are regarded as most primitive flower visitors. Mostly bees, flies, butterflies and moths are studied as pollinator groups and non-bee insects such as beetles are generally neglected (Rader et al. 2016). However, beetles are distributed worldwide and also are important flower visitors in different habitats and these are second important and diverse insect groups in tropics after bees (Wardhaugh 2015). They visit and devour portion of flowers mainly for food and in return help in pollination. The interaction between flower and flower visitors is well studied from plant pollination perspective. Although all flower visitors may not act as pollinators, they provide important ecosystem services for both wild plant communities and crops. This study may enlist the flower visiting beetles and plants in home gardens. The findings of the research work will be helpful to know the diversity of flowering plants and beetle visiting them.

1.4 Limitations of the Study

Pollen analysis of flower visiting beetles was not done in this study.

2. LITERATURE REVIEW

2.1 Diversity of Flower Visiting Beetles

Beetles are considered as important flower visitors from early time and most flower visiting beetles are from families Elateridae, Scarabaeidae, Cleridae, Nitidulidae, Chrysomelidae, Staphylinidae, Meloidae and Cerambycidae (Kevan & Baker 1983). Inoue et al. (1990) in a study found that Coleoptera had highest number of flower visitors after Diptera and Hymenoptera and among the flower visiting Coleoptera, Chrysomelidae was the most dominant family followed by Nitidulidae, Mordellidae, Cerymbicidae, Byturidae, Staphylinidae, Scarabaeidae, Curculionidae, Oedemeridae, Elateridae and Cantharidae. And most of these flower visiting beetles were pollen feeders, others were predators and plant tissue feeders among which Chrysomelidae and Scarabaeidae were pollen feeders, Carabidae, Canthadidae and Coccinellidae as predators and Apionidae and Curculionidae were plant tissue feeders. Wardhaugh (2013) sampled five microhabitats; mature leaves, new leaves, flowers, fruits and suspended dead woods from 23 locally common canopy plant species in Australian tropical rainforest trees. The result showed that beetle families such as Curculionidae, Staphylinidae and Nitidulidae were abundant on flowers where as Chrysomelidae and Coccinellidae were less abundant. However (Kirmse & Chaboo 2018) found that the most abundant subfamily within Chrysomelidae in tropical lowland rainforest canopy was Galeuricinae, followed by Alticinae, Cryptocephalinae and Eumolpinae. Most canopy chrysomelids are collected from flowers of canopy trees, although some species also fed on extra floral nectaries or fruits. Leaf feeding species of Chrysomelidae were found to occur in subfamilies Cassinidae, Cryptocephalinae, Eumolpinae and Galeuricinae, while Alticinae were restricted predominantly to flowers.

Beetles are abundant flower visitors and flower visitation in beetles have been documented worldwide. In a beetle collection of about 2000 species from passive canopy and ground-based malaise/flight-intercept traps in Australian tropical rainforest, about 20% of beetles were found to be flower visitors (Wardhaugh 2015). In a study over a year, a total of 6698 adult beetles were sampled on canopy trees which were identified to 859 beetle species under 44 beetle families and among them 61.4% were recorded from flowering trees in Neotropical rainforest canopy (Kirmse & Chaboo 2020). Survey conducted to study the influence of grazing intensity on diversity and abundance of flower visiting insects recorded six orders, 54 families and 294 species of flower visitors from insect orders Hymenoptera, Diptera, Coleoptera, Lepidoptera, Heteroptera and Neuroptera and the beetles were found more abundant and species rich in grasslands with tall vegetation (Sjödin et al. 2008). Li et al. (2021) collected a total of 3391 flower visiting beetles from 12 sites in two years on the Yulong Snow Mountain in Yunnan, Southwestern China. These beetles belong to 24 different beetle families and under 153 morpho-species. They were found to forage on flower of 90 different species representing 30 families and 22 angiosperm orders.

Flowers also support high beetle diversity as flowers are important microhabitat for beetles (Wardhaugh 2013). A total of 39,276 invertebrates, including 10,185 beetles from 358 species were collected from mature leaves, flowers, new leaves at Daintree Rainforest Observatory Queensland, Australia. Species level analysis showed high concentration of beetle species on flowers. Chao 1 biodiversity indicator showed that 41% of beetle species utilize flowers and 235 new leaves as microhabitat (Wardhaugh et al. 2012). A study on canopy invertebrates focusing on beetles in an Australian tropical rainforest by comparing their density, species richness and specialization on three microhabitats: mature leaves, new leaves and flowers showed that flowers are unique microhabitat that supports greater densities and disproportionately rich fauna of beetles than adjacent foliage (Wardhaugh 2013).

Only few studies were found in Nepal on flower visiting insects and among them very few studies were done on flower visiting beetles. Bista & Omkar (2011) reported eight species of predaceous Ladybirds from Kanchanpur district, they were *Anegleis cardoni, Brumoides suturalis, Cheilomenes sexmaculata, Coccinella septempunctata, Coccinella transversalis, Micraspis discolor, Micraspis univittata* and *Propylea dissecta*. A study conducted in Rampur, Chitwan, Nepal at Institute of Agriculture and Animal Science (IAAS) and its vicinity in 2004/2005 recorded over 50 species of insects that were found to visit flowers of seventeen crops. Among the recorded insect species, beetles were found to visit flowers of bottle gourd, bottlebrush, brinjal, broccoli, buckwheat, citrus, cucumber, litchi, okra, radish, rapeseed, sponge gourd and squash (Thapa 2006). In a study to assess the abundance and diversity of rapeseed insect flower visitors by using insect pan traps, sweep net and visual observations in Chitwan district Nepal, insect orders such as Hymenpotera, Lepidoptera, Diptera, Coleoptera, Heteroptera, Orthoptera are found to visit the flowers of mustard and among them *Aulacophora foveicollis* was also found to visit flowers of mustard plants (Pudasaini et al. 2015). Subedi & Subedi (2019) recorded *Coccinella undecimpunctuta, Coccinella septempunctata* as a casual visitor of the mustard flowers in Kusma, Parbat where 16 species of pollinator insects belonging to five orders and nine families were recorded and among them Hymenoptera was most abundant family followed by Diptera, Coleoptera, Lepidoptera and Heteroptera. Gautam (2022) conducted a study on diversity of insect pollinators on mustard plants in Itahari and found that Hymenopterans are the major insect pollinators followed by coleopterans, dipterans and hemipterans were least abundant. Study conducted to monitor flower visiting insects on Buckwheat (*Fagopyrum esculentum*) during winter, 2012/13 at Chitwan, Nepal by sweeping and setting insect pantraps at 500m, 1500m, 2800m from the natural habitat showed that most of the flower visiting insects are of order Hymenoptera, followed by Diptera, Coleoptera and Lepidoptera (Aryal et al. 2016).

Some other studies were carried out that cover flower visiting insects other than beetles in different parts of the country such as (Devkota et al. 2021) sampled 1986 flower-visiting insects; bees, butterflies, flies and wasps from mustard crops in a study from Chitwan to measure the effect of pollination on oilseed rape mustard crops; (Devkota et al. 2020) sampled 2154 individuals from 23 species of bees, wasps, flies and butterflies from flowers of mustard in the months of December-January in 2016 from the vicinities of Chitwan National Park; (Mainali et al. 2015) conducted a field experiment in Khumaltar, Lalitpur during summer-rainy season of 2012 to 2014 and recorded seven species of flower visitors belonging to order Hymenoptera and Lepidoptera from eggplant. Similarly other studies on different pollinators were carried out such as (Subedi et al. 2021) on diversity of butterfly and their floral preferences in Rupa Wetland of Nepal; (Chaguthi & Dyola 2018) on flower visitors of White Clover (*Trifolium repens*) in premises of Bhaktapur Multiple Campus, Nepal; (Dyola et al. 2022) on insect pollinator community structure in different habitats of Shivapuri-Nagarjun National Park focusing solely on hymenopteran and dipteran pollinator; (Gurung et al. 2020) on pollinator diversity in Marigold (*Tagetes erecta*) in Ratna Park area of Kathmandu; (Timberlake et al. 2022) on pollinators of micronutrient rich crops in Jumla district.

2.2 Plant-Pollinator Interaction

The interactions between flower visiting species and flowers form ecological networks and these networks are made up of generalists that interact with specialists, ensuring the networks stability (Marín et al. 2020). Frequency of interaction between plant and pollinator can predict the impacts of plants on pollinators and also the impacts of pollinators on plants i.e the most frequent flower visitors have impacts on reproduction of the plants they visit and also the plant species which got most visited have impacts on the reproduction of pollinators (Vázquez et al. 2012). Identification of interspecies interaction patterns help to understand ecological systems and in a typical field study, information on potential pollinators visit to plants within a predetermined area and time period is recorded and referred to as visitation data (Young et al. 2021). Bipartite plant-pollinator networks are used to know the dynamics of ecological interactions and to predict alterations in interaction networks caused by environmental disturbances (Prendergast & Ollerton 2022).

Plant-pollinator networks are used to study the interactions between flower and their visitors and these networks are used to understand plant-pollinator communities and also these networks provide important information on resources used by flower visitors. A total of 367 interactions were observed between 101 insect species and 37 plant species in South American forest. Among these interactions maximal network size occurred in early spring and early autumn, when both the number of mutualistic species and the number of interactions was high (Basilio et al. 2006). Adedoja et al. (2018) found a total of 1344 interactions between flower-visiting insect species and 32 flowering plants in four zones of mountains. In all four zones of mountain these interactions consisted of highest abundance of bees followed by beetles, wasps, flies and these interactions are consistent at each zone, except for peak zone where beetle interaction increases. In different studies on diversity of insect pollinators visiting fruits and flowers in different orchards and wild fields across Korea during the last three decades from the published scientific journals, the most diverse insect pollinators were Hymenoptera, followed by Diptera, Coleoptera and Lepidoptera (Choi & Jung 2015). In a study (Marín et al. 2020) recorded a total of 1301 flower visitor individuals representing 210 species including 14 beetle species in urban gardens and natural areas in Mexico, which are found to visit flowers of 32 plant species with Asteraceae, Brassicae and Fabaceae being most visited. Zhao et al. (2019) recorded 355 insect species and 103 plant species involving in plant-flower visitor interaction in four elevation sites in the Himalaya-Hengduan Mountains region in China, among the recorded insect species Diptera consists highest number of species followed by Hymenoptera, Lepidoptera, Coleoptera and Hemiptera. Also, among the recorded flower visitor’s bees were found to carry highest proportion of pollen of the visited plants which was followed by Coleoptera, other Hymenoptera, Diptera and Lepidoptera.

Also, the plant-pollinator networks are widely used for different aspects such as (Memmott

1999) had used plant-pollinator networks to construct quantitative food web and recorded a total of 2722 interactions among 26 species of flowering plant and 79 species of pollinator. The flower visiting insects were from four insect order; Diptera, Lepidoptera, Hymenoptera and Coleoptera. Similarly, these networks were used to study the food security of smallholder farmers in remote Nepal of Jumla district by developing plant-pollinator-nutrient network from the data obtained by identifying the wild plants supporting pollinators of crop plants that provide key micronutrients to farmers. And during study insects such as Honeybees, Solitary Bees, Bumblebees, Butterflies, Flies, Wasps and Beetles were recorded as pollinator groups visiting Bean, Eggplant, Carrot, Chilli, Cucumber, Bitter Gourd, Mustard, Pumpkin and Radish (Timberlake et al. 2022).

3. MATERIALS AND METHODS

3.1 Study Area

Bedkot Municipality is located in Kanchanpur district of Sudurpaschim Province, Nepal with an area of 158.5 km^2. It lies at 28.99°-28.92°N latitude and 80.21°-80.30°E longitude spreading over Northern Terai and extending up to the foot hills of Siwalik region. The municipality share its boundary with Shuklaphata Wildlife Sanctuary, Arjuni Post (Jhalari Pipladi Municipality) on the east, Bhimdatta Municipality on the west, Chure Range (Dadeldhura District) on the north and Shuklaphata Reserve on the south. People of Bedkot Municipality grow seasonal flowers and vegetables in their home gardens. Elevation of the municipality ranges from 192m to 1401m above sea level. The climate of Bedkot Municipality is Tropical with mean annual air temperature above 26°c and mean annual precipitation within the range of 1,800-2,000 mm. The local of Bedkot Municipality plants seasonal flowers and vegetables in their home gardens for self-consumption as well as for small businesses. Seasonal ornamental flowers such as Marigold, Hibiscus, Dahlia, Roses, and vegetables such as Pumpkins, Gourds, Rapeseed, Amaranth etc. are grown in this area.

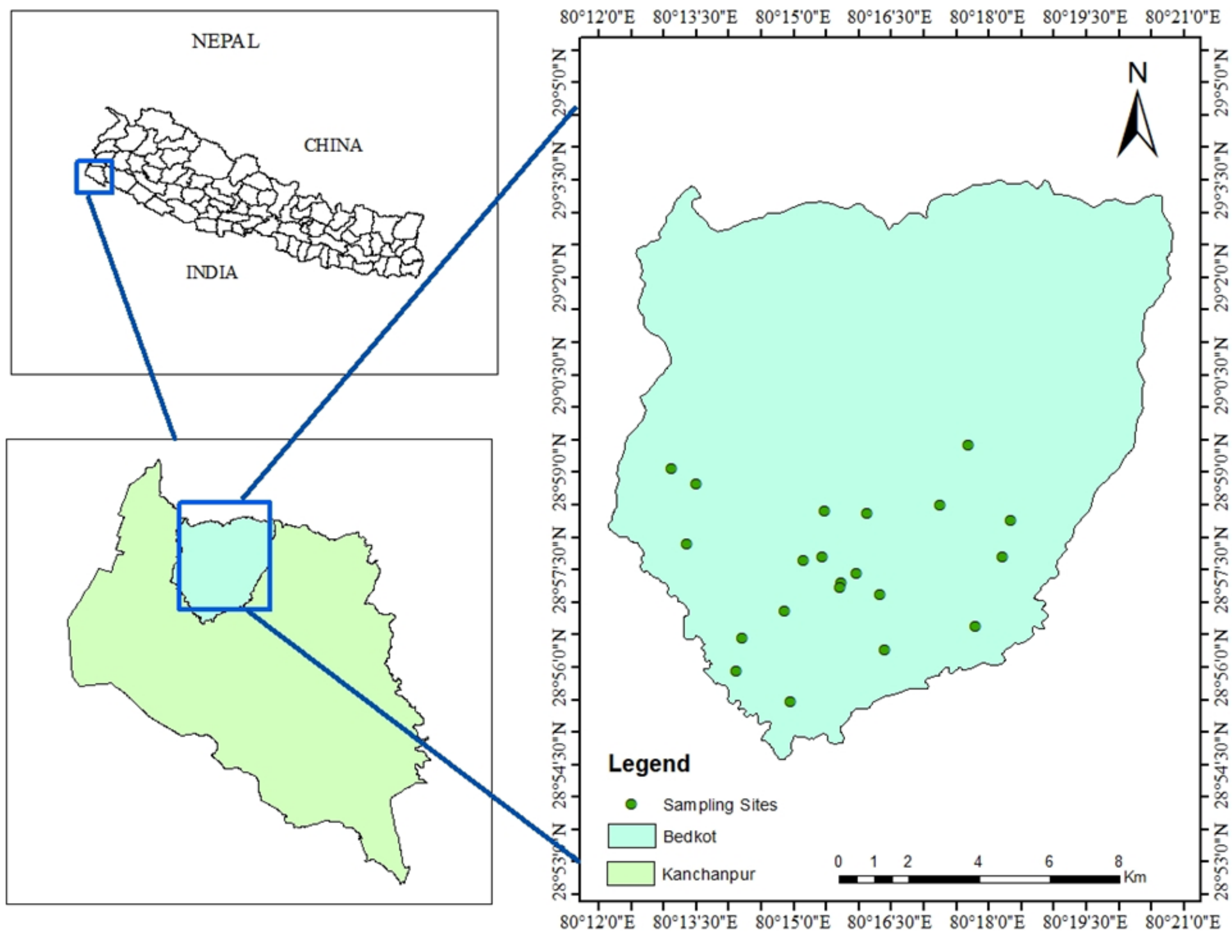

Figure 1. Map of Study Area

3.2 Materials

Following materials were used during field work:

- GPS (Garmin Etrex 10)
- Measuring Tape
- Field Stationary
- Ethyl Alcohol
- Ethyl Acetate
- Killing Jar
- Insect Collection Vials and envelops
- Forceps, Brush and Zip-lock Bags

- Plastic boxes to carry samples

3.3 Sampling Methods

The study was conducted in home gardens, vegetables gardens with abundant blossoms in the Bedkot Municipality. Samples were collected in four seasons from October 2020 to August 2021 (October-November 2020- autumn, December 2020- winter, February- March 2021- spring and July-August 2021- Summer). Before sampling, sampling siteswere assessed and sites with abundance blossom around home gardens were selected for beetle sampling. The plots of area (20×20)m were taken for beetle sampling and each plot were observed for 45 minutes. Sampling of beetles was done by walking at a slow pace during a period of 45 minute. Every sampling site was observed only once in each season i.e., four times during total field data collection. Collection was done during sunny days between sunrise to sunset when there is ambient temperature. Interaction is considered taking place when flower visitor contacts the reproductive structures of flowers (CaraDonna et al. 2017). GPS-point for each sampling plot were also taken and map indicating sampling points was developed after completion of field work. Selected beetle sampling was done by collecting specimens found in flowers while avoiding beetles on leaves and stems.

3.4 Insect Collection and Preservation

The flower visiting beetles were collected by hand picking method. The plant species on which beetle was collected was recorded and photograph was taken for identification of plant species. Collected specimens were kept in vials containing 70% alcohol for preservation. Some specimens were kept in envelops after killing in killing jars for dry preservation. The vials containing collected specimens were then labeled, species codes were given, and numbers of flower visiting beetles and their host plants were recorded. Further the collected specimens were brought to Entomology Laboratory of Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu for identification.

3.5 Insect Identification

Collected specimens were brought to the Laboratory of Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu. At first insects were sorted on the basis of similar morphology. The specimens were examined under BS-3020B (10×4.5) binocular microscope and photographed by Samsung GW1 sensor RMX1992 camera. Specimens were identified up to family with the help of book 'Borror and Delong's Introduction to the Study of Insects' by (Triplehorn & Johnson 2005). Further identification was done using different relevant keys (Pope 1988, Bologna & Pinto 2002, Warchalowski 2010). The identified specimens were labeled properly with taxonomic information of species, date of collection, place of collection and name of collector. Reference specimens of identified flower visiting beetles were pinned with entomological pins in entomological boxes. These specimens were then deposited in the Central Department of Zoology Museum of Tribhuvan University (CDZMTU), Kirtipur, Nepal.

3.6 Data Analysis

The collected data from this study was initially managed in excel (2016). Data were analyzed by using Shannon-Weiner Diversity Index (H'), Evenness (J), Richness (S), Jaccard's Similarity Index (J') in MS Excel 2016. In addition to that, Plant-Pollinator network was constructed by using bipartite package, plot web function in R software.

4. RESULTS

4.1 Diversity of Flower Visiting Beetles

During the observation period a total of 1,273 individuals of flower visiting beetles were recorded from the home gardens of Bedkot Municipality. These beetles belong to seven beetle families. Among the identified beetle families, Chrysomelidae was most abundant family which was made up 58.84% (749 individuals), followed by Coccinellidae with 30.71% (391 individuals), Meloidae with 6.05% (77 individuals), Nitidulidae with 2.67% (34 individuals), Scarabaeidae with 1.26% (16 individuals), Curculionidae with 0.39% (5 individuals) and least abundant Brentidae with 0.08 % (1 individual) (Figure 2).

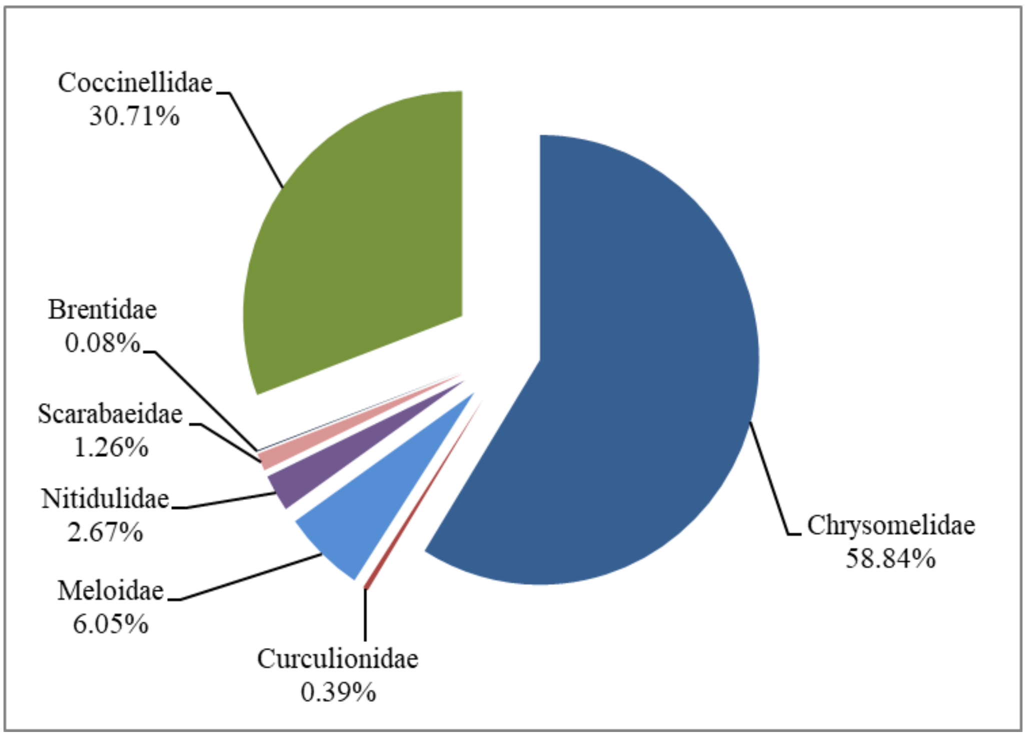

Figure 2. Family composition of flower visiting beetles

Collected beetles were identified to 19 morpho-species within seven beetle families. Out of 19 morpho-species eight were identified up to species level, 10 up to genus level and one up to family level only. Identification of specimen in the Brentidae family could not go further below the subfamily level and this specimen is listed as Unidentified sp.1. Among the identified beetle families, Chrysomelidae was made up with highest number of species i.e with eight species, which is followed by Coccinellidae with four species, Curculionidae and Meloidae each with two species, Nitidulidae, Scarabaeidae and Brentidae each with one species (Figure 3).

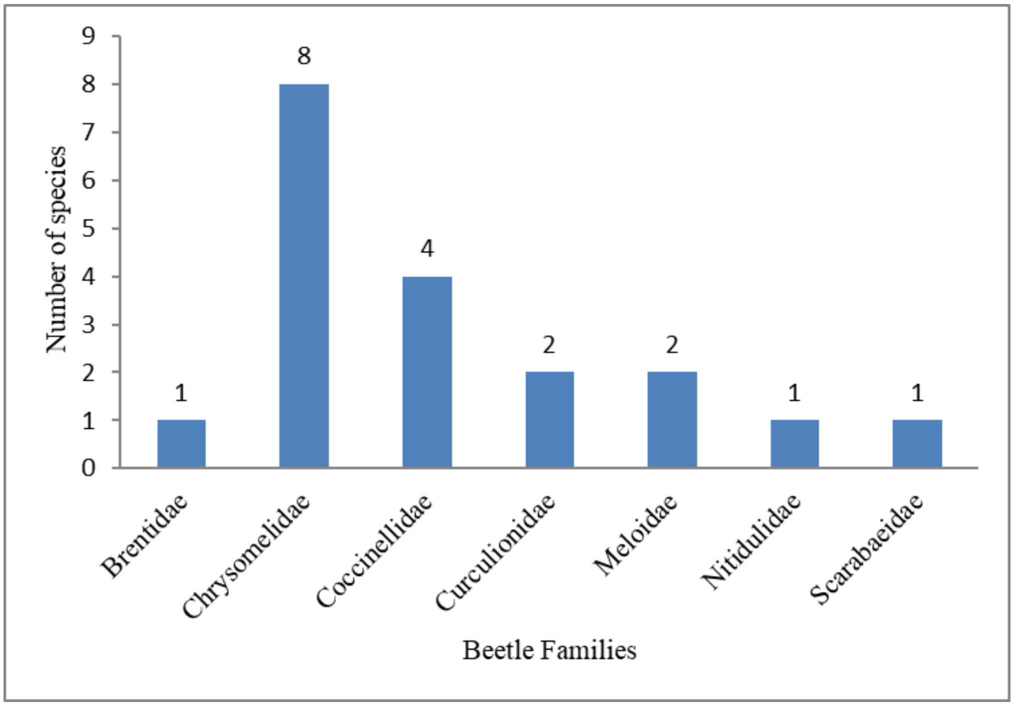

Figure 3. Flower visiting beetle species within Family

The recorded flower visiting beetles were found to be moderately diverse with Shannon Wiener Index (H') 1.89 and Pielou's Evenness J=0.64. Red Pumpkin Beetle (*Aulacophora foveicollis*) was found to be most abundant during the study period which was made up 27.57% (n=351) which is followed by Black Pumpkin Beetle (*Aulacophora lewiisi*) with 24.59% (n=313) and *Micrapis univittata* is third abundant with 24.51% (n=312). *Hycleus* sp. and *Coccinella septempunctata* were made up with 5.97% (n=76) and 5.03% (n=64) respectively. Furthermore *Carpophilus* sp., *Monolepta signata*, *Psylliodes* sp., were made up with 2.67% (n=34), 2.59% (n=33), 2.28% (n=29) respectively. Also, *Popillia japonica* was made up with 1.26% (n=16), *cryptocephalus* sp., was with 0.94% (n=12), *Henosepilanchna cucurbitae* with 0.79% (n=10). Other beetle species were made up with a smaller number of beetle fauna such as *Ivalia* sp., and *Cheilomenes sexmaculata* with 0.39% (n=5), *Altica* sp., *Chatocnema* sp., and *Sitophilus* sp., with 0.24% (n=3). Only two specimens of *Tanymecus* sp., and one specimen of *Meloe* sp., and one specimen of Unidentified sp1 were recorded during the study period (Figure 4).

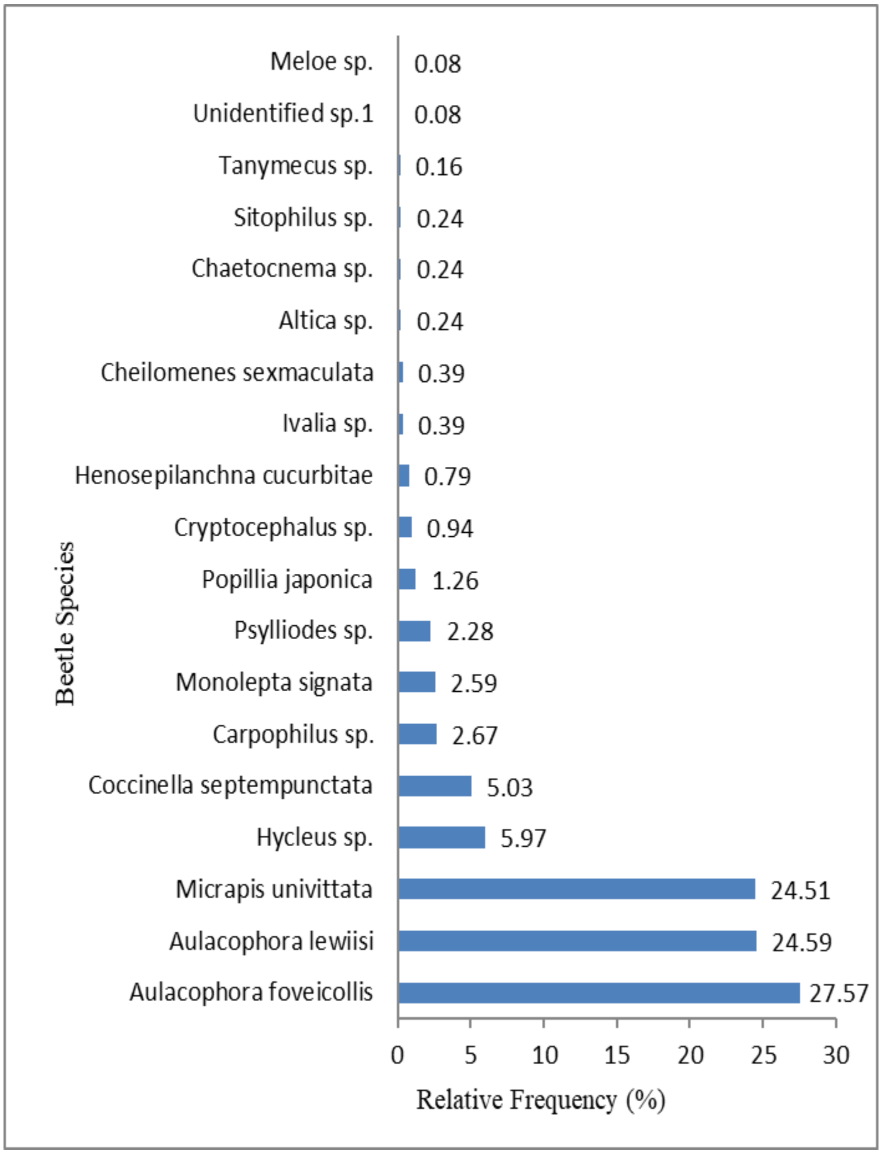

Figure 4. Relative Frequency of Flower Visiting Beetle Species

Beetle fauna were recorded in different proportions in different seasons, a greater number of species were observed in autumn (n=907) season which is followed by summer (n=224), spring(n=103) and winter (n=39). *A. foveicollis* and *M. signata* were found in all four seasons. *Mi. univittata* was most abundant during autumn season, *A. foveicollis* during summer, *Co. septempunctata* during winter and spring (Table 1).

Table 1. Flower Visiting Beetles in All Four Seasons

Flower Visitors	**Autumn**	**Winter**	**Spring**	**Summer**
Altica sp.	3	0	0	0
Aulacophora foveicollis	239	2	16	94
Aulacophora lewisii	289	0	0	24
Chaetocnema sp.	0	0	3	0
Cheilomenes sexmaculata	4	0	1	0
Coccinella septempunctata	4	18	42	0
Carpophilus sp.	34	0	0	0
Cryptocephaus sp.	3	6	2	1
Henosepilanchna cucurbitae	5	0	0	5
Hycleus sp.	2	0	0	74
Ivalia sp.	0	0	0	5
Meloe sp.	0	1	0	0
Micraspis univittata	311	0	0	1
Monolepta signata	7	12	10	4
Popillia japonica	0	0	0	16
Psylliodes sp.	0	0	29	0
Sitophilus sp.	3	0	0	0
Tanymecus sp.	2	0	0	0
Unidentified sp.1	1	0	0	0
Total	**907**	**39**	**103**	**224**

Flower visiting beetles were most abundant during autumn season (n=907), which is followed by summer (n=224), spring (n=103) and winter (n=39). Beetle fauna richness was found during autumn (14 species) and were diverse during spring season (H'=1.46). While during the winter season Beetle fauna were evenly distributed (J=0.78) (Table 2).

Table 2. Diversity Indices of Flower Visiting Beetles of four seasons

Indices	**Autumn**	**Winter**	**Spring**	**Summer**
Abundance	907	39	103	224
Richness	14	5	7	9
H'	1.41	1.25	1.46	1.45
H_{max}	2.64	1.61	1.96	2.20
J	0.53	0.78	0.75	0.66

The similarity between occurrence of beetles was highest in Winter and Spring seasons ($J'_{(W,Sp)}$ = 0.5), which indicates that these two seasons share more common species among themselves (Table 3).

Table 3. Jaccard's Similarity Index of Seasons

Seasons	**Autumn**	**Winter**	**Spring**	**Summer**
Autumn	1			
Winter	0.27	1		
Spring	0.32	0.5	1	
Summer	0.44	0.27	0.23	1

4.2 Plant-Pollinator Interaction

Beetles visited flowers of 40 plant species belonging to 16 families. Asteraceae and Cucurbitaceae were most visited plant families each with eight plant species, followed by Solanaceae with four species, Amaranthaceae, Fabaceae, Malvaceae with three species each. Species in the cucurbitaceae families were the dominant plant families harboring the highest beetle diversity. We found that eight species within the Cucurbitaceae were visited by 12 species (756 individuals) of beetle representing six beetle families. However, two species within Brassicaceae were visited by seven species (124 individuals) of beetle representing three beetle families and three species within Malvaceae were visited by six species (121 individuals) of beetle representing four beetle families (Table 4).

Table 4. Classification of plant species and beetle taxa visiting their flowers

Plant Order	**Plant Family**	**No. of Plant Species**	**No. of Beetle Specie s**	**No. Of Beetle specimens**	**No. of Visiting Beetle Family**
Caryophyllales	Amaranthaceae	3	1	68	1
Asterales	Asteraceae	8	7	88	4
Brassicales	Brassicaceae	2	7	124	3
Commelinales	Commelinaceae	1	1	1	1
Cucurbitales	Cucurbitaceae	8	12	756	6
Poales	Cyperaceae	1	3	13	1
Malphighiales	Euphorbiaceae	1	1	1	1
Fabales	Fabaceae	3	6	42	3
Lamiales	Lamiaceae	1	1	7	1
Malvales	Malvaceae	3	6	121	4
Myrtales	Onagraceae	1	1	1	1
Poales	Poaceae	1	1	2	1
Rosales	Rosaceae	1	1	2	1
Solanales	Solanaceae	4	1	28	1
Rosales	Urticaceae	1	1	2	1
Lamiales	Verbenaceae	1	3	17	2

A total of 1273 individuals of 19 beetle species from seven families were found interacting with 40 plant species from 16 families. Bipartite network was constructed using the recorded interactions between flower visiting beetles and plant species. It was developed from field data to understand the structure of the plant species and flower visiting beetles. Plant species whose flowers were visited by beetles and beetles that were found on floral parts were taken into account for this study. The Plant-Pollinator network was developed using the frequency of interaction between flower visitors and plant species. The network of Plant-Pollinator interactions is shown in Fig. 5. Among the beetle species Red Pumpkin Beetle (*A. foveicollis*) was found to be most abundant flower visitor, visiting 10 species of plants mainly Cucurbitaceae plants. It mostly visited the flowers of *Cucurbita* sp., followed by *Cucumis sativus*, *Lagenaria siceraria*, *Luffa aegyptiaca* and *Luffa acutangula*. Black Pumpkin Beetle (*A. lewiisi*) was second most abundant flower visitor, visiting 11 species of plants mainly from Cucurbitaceae. Unlike *A. foveicollis* it mostly visited *Luffa aegyptiaca*, followed by *Luffa acutangula*. Sometimes it was also found to visit the flowers of *Lantana camara*. *Mi. univittata* was the third abundant and most generalist flower visitor visiting 28 plant species mainly the plants of cucurbitaceae. It mostly visited the flowers of *Celosia argentea*, followed by *Tagetes erecta*, *Sida acuta*, *Vigna unguiculata*, *Cucurbita* sp., *Cosmos sulphureus.* It was found to be only visitors of plant species such as *Capsicum annum*, *Celosia* argentea, *Commelina benghalensis*, *Gomphrena globosa*, *Oscimum Sanctum*, *Pennisetum polystachyon*, *Physalis* sp., *Pouzolziz zeylanica*, *Solanum melogena*, *solanum nigrum* and *Zinnia sp.*

Hycleus sp. was found to visit the flowers of five plant species and among them it was found that it was highly linked with the flowers of *Hibiscus* sp. *Popillia japonica* was found to highly link with flowers of *Abelmoschus esculentus. Co. septumpunctata* was mainly found to visit the flowers of *Brassica* sp. Some beetle species were specialist visitors visiting few flowers or only one plant species. *Ivalia* sp. visited the flowers of *Abelmoschus esculentus*, *Chaetocnema* sp. visited the flowers of *Brassica* sp., *Sitophilus* sp. visited flowers of *Tagetes erecta*, *Psylliodes* sp. visited the flowers of *Brassica oleracea* and *Brassica* sp., *Altica* sp. visited the flowers of *Lantana camara* and *Cucurbita* sp., *Tanymecus* sp. visited the flowers of *Benincasa hispida* and *Cucurbita s*p. Only one specimen of *Meloe* sp. was found to visit the flowers of *Brassica* sp. The Unidentified sp.1 from Brentidae family was found to visit the flowers of *Vigna unguiculata*.

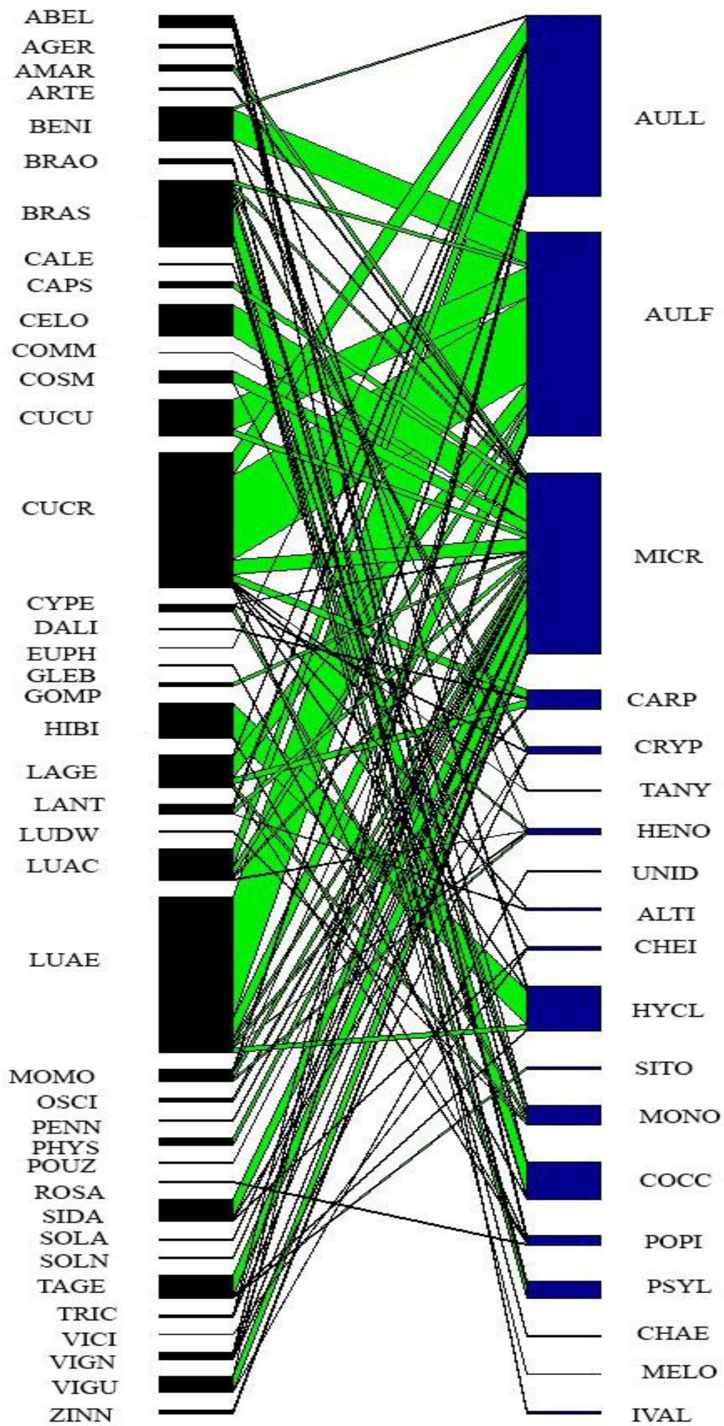

Figure 5. Bipartitie graph of Plant-Pollinator Interaction Network.

[Left side = Plant Species

ABEL- *Abelmoschus esculentus*, AGER- *Ageratum houstonianum*, AMAR- *Amaranthus lividus*, ARTE- *Artemisia* sp., BENI- *Benincasa hispida*, BRAO- *Brassica oleracea*, BRAS- *Brassica* sp., CALE- *Calendula officinalis*, CAPS- *Capsicum annum*, CELO- *Celosia argentea*, COMM- *Commelina benghalensis*, COSM- *Cosmos sulphureus*, CUCU- *Cucumis sativus*, CUCR- *Cucurbita* sp., CYPE- *Cyperus rotundus*, DALI- *Dalhia* sp., EUPH- *Euphorbia hirta*, GLEB- *Glebionis coronaria*, GOMP- *Gomphrena globosa*, HIBI- *Hibiscus* sp., LAGE- *Lagenaria siceraria*, LANT- *Lantana camara*, LUDW- *Ludwigia prostrata*, LUAC- *Luffa acutangula*, LUAE- *Luffa aegyptiaca*, MOMO- *Momordica charantia*, OSCI- *Oscimum sanct*um, PENN- *Pennisetum polystachyon*, PHYS- *Physalis sp*., POUZ- *Pouzolziz zeylanica*, ROSA- *Rosa* sp., SIDA- *Sida acuta*, SOLA- *Solanum melogena*, SOLN- *Solanum nigrum*, TAGE- *Tagetes erecta*, TRIC- *Trichosanthes cucumerina*, VICI- *Vicia faba*, VIGN-*Vigna mungo*, VIGU- *Vigna unguiculata*, ZINN- *Zinnia* sp.

Right side = Beetle Species:

AULL- *Aulacophora lewisii*, AULF- *Aulacophora foveicollis*, MICR- *Micrapsis univittata*, CARP- *Carpophilus* sp., CRYP- *Cryptocethalus* sp., TANY- *Tanymecus* sp., HENO- *Henosepilachna cucurbitae*, UNID-Unidentified sp.1, ALTI- *Altica* sp., CHEI- *Cheilomenes sexmaculata*, HYCL- *Hycleus* sp., SITO- *Sitophilus* sp., MONO- *Monolepta signata*, COCC- *Coccinella septempunctata*, POPI- *Popillia japonica*, PSYL- *Psylliodes* sp., CHAE- *Chaetocnema* sp., MELO- *Meloe* sp., IVAL- *Ivalia* sp.]

5. DISCUSSIONS

5.1 Diversity of Flower visiting Beetles

This study explored the diversity of flower visiting beetles in the home gardens and vegetable gardens of Bedkot Municipality. A total 1273 individuals belonging to seven families were recorded. Among the recorded families Chrysomelidae was most abundant followed by Coccinellidae, Meloidae, Nitidulidae, Scarabaeidae, Curculionidae and Brentidae. The large number of Chrysomelidae beetles was due to the presence of Cucurbits plant in the study sites and their flower supporting large number of *Aulacophora* species. The study conducted by (Li et al. 2021) at higher elevations on the Yulong snow Mountain, Yunnan, China to investigate the diversity of flower visiting beetles showed that Chrysomelidae was most abundant beetle family visiting flowers followed by Nitidulidae, Curculionidae, Coccinellidae and others. However (Wardhaugh 2013) found that beetle families such as Curculionidae, Staphylinidae and Nitidulidae were abundant on flowers where as Chrysomelidae and Coccinellidae were less abundant in Australian tropical rainforest trees. According to (Ødegaard & Frame 2007) beetle families having many flower-visiting species belong to Cerambycidae, Chrysomelidae, Brentidae, and Curculionidae from two phylogenetically distant neotropical canopy trees in Panamanian lowland forest in San Lorenz Protected area.

In this study the number of species and individuals of beetle fauna were high during autumn season i.e from October-November but the species diversity (H'=1.46) was highest during spring season and also the highest number of chrysomelids such as *A. foveicollis* and *A. lewisii* were found high during autumn season (October-November). Inoue (1990) studied flowering phenology and seasonal pattern of insect visits in Temperate Deciduous Forest of Kibune, Kyoto and found that the number of species in Coleoptera increased from May and peaked in June and decreased rapidly in August, however the seasonal activity pattern of Coleopteran families was different such as Staphylinids and Nitidulids were abundant in April and later became abundant in October, Cerambycidae and Mordellidae appeared from May-July and Chrysomelidae were found during April-November. According to study carried by (Totland 1994) to examine the influence of environmental factors on flower visitation activity of insects in middle alpine area in southwestern Norway, visitation activity of flower visitors was highest early in the flowering season i.e July and then after visitation activity decreased as the season progressed and also visitation activity increases as the flower density increases. In the present study *Co. septempunctata* were most abundant during winter and spring season and found to visit mostly the flowers of Brassicaceae family, this may due to the presence of abundant flower density of *Brassica* sp. during that time, this is supported by the fact that visitation activity of flower visitors increases as the flower density increases (Totland 1994) and also the presence of aphids on flowers and shoots of *Brassica* plants results in abundance of *Co. septempunctata*, this is supported by (Inoue 1990) as Coccinellidae were recognized as predators. Similarly, the most abundant Chrysomelid beetles were found abundant in autumn season i.e during October-November. The highest density of Cucurbit plants and the availability of floral resource in the field suggest the abundance of these beetles.

Flower visitors are found to respond to the occurrence of flowers during particular season and density of flowers found and also the, presence of similar flowers harbors the similar type of flower visitors. In the present study more similar beetle species were found during the winter and spring season as the plants of *Brassica* sp. were abundantly present during these seasons in the study area.

5.2 Plant-Pollinator Interaction

In this study Home gardens in the Bedkot Municipality mostly had vine plants of Cucurbitaceae, different ornamental flowers from Asteraceae, mustard plant from Brassicaceae, and different weed plants. In the present study most visited plants by beetles are from Asteraceae family followed by Cucurbitaceae, Solanaceae, Amaranthaceaea, Fabaceae, Malvaceae. A study conducted on floral visitors in urban gardens and natural areas: diversity and interaction networks in a neotropical urban landscape in Mexico by (Marín et al. 2020) found 210 species of bees, butterflies, wasps, beetles, bugs visiting flowers of 99 plants species. These flower visitors visited 32 plants families with Asteraceae, Brassicae and Fabaceae being the most visited. In forest ecosystems floral hosts preferred by Coleoptera were the plant families Saxifragaceae, Rosaceae, Lauraceae, Caprifoliaceae and Compositae (now Asteraceae) (Inoue et al. 1990).

Most of the vegetable plants present in the study area are Cucumber, Gourds, Pumpkin, Squashes, Mustard, Okra, Eggplant. In the present plant-pollinator interaction *A. foveicollis* and *A. lewisii* were found to highly linked with flowers of plants from Cucurbitaceae family. As the home gardens in the study area were abundant with the Cucurbitaceae plants, *A. foveicollis* was abundant in the study area and found to visit mainly the plants of Cucurbitaceae; this is due to high preference of Cucurbitaceae vegetables such as sponge gourd, bottle gourd, bitter gourd, sponge gourd, squash, cucumber by this beetle and also the Cucurbitaceae vegetables, can harbor high population of beetles (Saljoqi & Khan 2007). The study conducted to report the floral biology and diversity of pollinator fauna in bottle gourd in south Gujrat, bottle gourd flowers were visited by nine species of pollinator belonging to eight families and five orders and among these pollinator *A. foveicollis* was one of the visitors visiting bottle gourd flowers (Padhiyar & Patel 2021). The abundance of *A. lewisii* and its high linkage in the network is also due to its dependence on plants of Cucurbitaceae.

Co. septumpunctata, Co. undecimpunctata were found to visit the flowers of mustard plant in Parbat Nepal (Subedi & Subedi 2019) and *Coccinella* sp. were found to visit flowers of vegetable plants such as *Brassica oleracea*, *Cucumis sativus*, *Brassica campestris* and *Cucurbita maxima* in Chitwan, Nepal (Thapa 2006). *Co. septempunctata* was abundantly found in the flowers of *Brassica* sp. followed by weed plant *Ageratum houstonianum* and the ornamental flowers such as *Calendula officinalis*, *Glebionis coronaria* during this study and another coccinellid beetle *Cheilomenes sexmaculata* was mainly found to visit the flowers of weed plant *Sida acuta*. Two species of Coccinelid beetles *Co. septempunctata* and *Menochilus sexmaculata* (now *Cheilomenes sexmaculata*) were found on flowers of cucumber and pumpkin, on a study conducted to investigate insect visitors on cucurbit vegetable plants in Rajasthan India (Bhardwaj & Srivastava 2012). Denning & Foster (2018) also recorded Coccinellidae (ladybird beetles) as flower visitor from remnant and reconstructed tall grass prairies in Kansas. *Mi univittata* was generalist flower visitor in the present network visiting 28 plant species out of 40 plant species. A total of eight ladybird species were reported from different sites of Kanchanpur district, Nepal by (Bista & Omkar 2011) and among these ladybird species Cheilomenes *sexmaculata*, *Co. septempunctata*, and *Mi. univittata* were found to visit flowers during the present study.

Balachandran et al. (2017) on the study to observe insect pollinators and their foraging dynamics on monsoon crop of cucurbits in coastal village of Karnataka, India reported

Aulacophora sp. and *Henosepilachna* sp. as flower visitor of cucurbits such as *Cucumis sativus*, *Cucumis pubescens*, *Momordica charantia*, *Trichosanthes anguina* and *Luffa acutangula*, present study also reported *Henosepilachna cucurbitae* as flower visitor of *Momordica charantia.* In the present study these beetle species were also found to visit these cucurbit flowers except *Cucumis pubescens*. In the present study *Carpophilus* sp. from the family Nitidulidae was found to visit the flowers of plants in the family cucurbitaceae and Asrteraceae, mostly the flowers of *Cucurbita* sp. Nitidulidae beetles are significant flower visitor of the plants belonging to the order Ranunculales, Malvales, Brassicales, Rosales, and also these beetles are also found to visit the flowers of Asteroidae subfamily (Herrera & Otero 2021). Adults of many species of Meloidae feed on foliage or blossoms of plants and plant feeding species mainly feeds on the plants of families Solanaceae, Leguminosae, and compositae (Werner et al. 1966). In the present study *Hycleus* sp. were found to feed mostly on the flowers of *Hibiscus* sp. and single *Meloe* sp. was found on the flowers of *Brassica* sp.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

During the study, the presence of flowers visiting beetle shows moderate diversity in the home gardens of Bedkot Municipality. A total of 1,273 individuals of beetles were recorded belonging to seven families, the highest from Chrysomelidae followed by Coccinellidae, Meloidae, Nitidulidae, Scarabaeidae, Curculionidae and Brentidae. Also, these beetles were observed highly diverse during spring season compared to winter, summer and autumn seasons. The flower visitor beetles were found to visit the flowers of 40 plant species, where Cucurbitaceae harbored maximum followed by Solanaceae, Amaranthaceae, Fabaceae, Malvaceae and other, which includes vegetable plants, ornamental plants and weeds in the home gardens. In the present Plant-Pollinator network *A. foveicollis* and *A. lewisii* were key flower visitors; *A. foveicollis* mainly visiting the flowers of *Cucurbita* sp. and *A.* lewisii mainly visiting the flowers of *Luffa aegyptiaca*. *Mi. univittata* was the most generalist flower visitor visiting flowers of 28 plant species mainly the flowers of Cucurbitaceae.

6.2 Recommendations

Some recommendations made by this study are given below;

- Pollen load analysis to identify and quantify the pollen grains on insect bodies for the efficiency of pollination estimation.
- The study on how the abundance and richness of flower visiting beetles vary in flowers based on vegetation types in different habitat.
- Mouthpart modifications of flower visiting beetles to know the pollen adhering structures and pollen uptake by beetles.

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ANNEX

Annex I: Identified Insect Species with Diagnostic Characters

S.N.	Taxa	Diagnostic characters
1.	*Altica* Geoffroy, 1762 sp.	Antennomeres-11, antenna slender, hind claw tarsomere not thickened, pronotum with transverse impression in basal part, no hairs on elytra, elytral puncturations randomly scattered, metallic blue in colour.
2.	*Aulacophora foveicollis* Lucas, 1849	Antennomeres-11, pronotum broader than long, head not elongate, elytra smooth, not pubescent, Tibiae with spine at apex, Epiplura strongly narrowed behind basal 1/3; Elytra entirely pale, scutellum pale, in male first antennomere thickened, humeral pubescence present, two small elevated tubercles on the pronotum behind transverse furrow.
3.	*Aulacophora lewisii* Baly, 1874	Antennomeres-11, antenna filiform, pronotum broader than long, head not elongate, elytra smooth, not pubescent, tibiae with spine at apex, epiplura strongly narrowed behind basal 1/3, whole elytron black and shining, whole ventral surface yellow.
4.	*Chaetocnema* Stephens, 1831 sp.	Antenna 11 segmented; articulated spur of metatibia with apex narrow, tapered to single point; outer margin of metatibia without series of teeth, tarsal claw simple, body small 1.1-3.5mm.
5.	*Cheilomenes sexmaculata* (Fabricius, 1781)	Pronotum with anterior border always much more strongly curved laterally, usually arcuate medially, hind border without agroove in front of the scutellum, maxillary palpi with last segment of normal shape, middle and hind tibiae with 2 small apical spurs in addition to apical fringe of setae , elytral margins neither form a shallow gutter nor are thickened on external border, anterior clypeal boardly emarginate between lateral projections, antennae about as long as minimum width of head between eyes, pronotal hypomera without foveae, size small to moderate, elytra yellowish or pale with first two band and a dot on each elytron.

6.	*Coccinella septempunctata* Linnaeus, 1758	Pronotum with anterior border always much more strongly curved laterally, usually arcuate medially, hind border without a groove in front of the scutellum, middle and hind tibiae with 2 small apical spurs in addition to apical fringe of setae, explanate external margins form a shallow gutter, or with a thickened external border, anterior clypeal border straight between lateral projections, pronotal hyponera without foveae, prosternal intercoxal process longitudinally carinate, seven black spots on red elytral background.
7.	*Carpophilus* Stephens, 1830 sp.	Outer edge of middle and hind tibiae with two rows of marginal spines; elytra short and truncate apically, not covering pygidium and 1-2 precding tergites; elytra without long marginal hairs at sides, suture striae, longitudinal carinae or longitudinal rows of hairs, setae of punctures; elytra exposing two abdominal segments.
8.	*Cryptocephalus* Geoffroy, 1762 sp.	Antennomeres-11, Antenna longer than half of the body length, filiform, scutellum large and distinct, prothorax not margined posteriorly and closely fitted to base of elytra, third tarsomere broad, claws usually simple, rarely appendiculate, never denticulate.
9.	*Henosepilachna cucurbitae* (Richards,1983)	More than 6mm long, pubescent dorsally, antennae inserted at some distance from finely faceted eyes, tarsal claws with basal tooth, elytra light brown or reddish brown with 10 or more black spots, elytral apex rounded, each elytron with 6-14 spots, each elytron usually with 14 spots, sometimes some absent but always >6 spots.
10.	*Hycleus* (Latreille,1817) sp.	Maxillary palp four segmented, dorsal blade of tarsal claw smooth, winged, elytra well developed, antennal sockets closer to eyes, placed above frontal suture, pronotum not much elongated, ground colour black, metasternum completely black, claws with ventral blade not fringed with micropubescence, dorsa and ventral blades of claw separate and of similar length, greatest width of ventral blade wider than half of the basal width of dorsal blade, antenna 11 segmented, slightly widened to apex, mesosternum with a smooth glabrous anterior area whose surface is distinct from that of remaining area, elytra with yellow-black fasciae, elytra convex with apical margin rounded,

		size 10-35mm, mesepisterna with a relatively wide and distinctly furrowedanterior border area, pronotum with a very fine median line and depression at center of disk.
11.	*Ivalia* Jacoby, 1887 sp.	Antennomeres-11, apical part of hind tibia much shorter than the remaining part of tibia, apical spur of hind tibia simple, metatibial spur long, claw tarsomere not thickened, pronotum smooth, primary elytral puncturations random, first antennomere shorter than antennomeres 2-4 measured together, interantennal space as broader than transverse diameter of eye.
12.	*Meloe* Linnaeus, 1758 sp.	Maxillary palp four segmented, fore femora without a ventroapical excavation, dorsal blade of tarsal claw smooth, wingless with elytra abbreviated, elytra reduced only extending up to abdominal tergum II, abdominal terga completely black, pronotum uniformly darkin colour, head completely dark, elytra overlapping at base and unicolorous, dark.
13.	*Micapsis univittata* (Hope, 1831)	Pronotum with anterior border always much more strongly curved laterally, usually arcuate medially, hind border without a groove in front of the scutellum, Apices of middle and hind tibiae without a pair of spurs among fringing setae. Pronotal hypomera and elytral apiplura without foveae, head much broader between relatively small eyes, Scutellum unusually small, c1/15 as broad at base as elytra at shoulders. Tarsal claws appendiculate, head broader between eyes, antennae clearly 11-segmented, surface of pronotum and elytra smooth between punctures, shining; Dark red elytral pattern including a simple black single vertical line on each elytron.
14.	*Monolepta signata* Olivier, 1808	Antennomeres-11, pronotum transverse without longitudinal impressions, claws appendiculate, first tarsomere of hind legs as long or longer than remaining tarsomeres combined, third antennomere at least 1.2× or more longer than the second, elytra bicolorous with 2 large yellowish or pale spots on black background in each elytron, abdomen and head pale reddish.

15.	*Popillia japonica* Newman, 1841	Protibial spur present, labrum visible in apex only, frontoclypeal suture complete, clypeus not snout like, but quadrate, mesepimeron partially visible anterior to base of elytron in dorsal view, base of pronotum tri-emarginate, mesometasternum produced anteriorly beyond base of mesocoxae, metallic green body with brinze wing covers that do not completely cover the abdomen, five patches of hairs on each side of abdomen, and one pair on the last abdominal segment is key character of this species from other similar looking beetles.
16.	*Psylliodes* Latreille, 1829 sp.	Antennomeres-10, filiform, completely black and tiny beetles.
17.	*Sitophilus* Schoenherr, 1838 sp.	Antenna with funicle of 6 articles; tarsus with 5 articles but with article 4 small; pygydium exposed at apex of elytra; antenna with scape projected at least past anterior margin of eye.
18.	*Tanymecus* Germar, 1817 sp.	Rostrum and sides of head not recessed, mandible without deciduous process; tarsi with pads on ventral surface, tarsal claws free; side of prothorax with anterior margin straight; anterior edge of prothorax laterally with postocular vibrissae in a cluster or tuft; front coxae contiguous; hind tibia with straight comb of setae on outer edge; corbel open.
19.	Unidentified sp.1	

Annex II: Classification of Flower Visiting Beetles

S.N.	Subfamily	Tribe	Genus	Species
CHRYSOMELIDAE				
1	Galeuricinae	Luperini	*Aulacophora*	*foveicollis*
2	Galeuricinae	Luperini	*Aulacophora*	*lewisii*
3	Galeuricinae	Luperini	*Monolepta*	*signata*
4	Alticinae	Alticini	*Altica*	
5	Alticinae	Alticini	*Psylliodes*	
6	Alticinae	Alticini	*Ivalia*	
7	Alticinae	Alticini	*Chaetocnema*	
8	Cryptocephalinae	Cryptocephalini	*Cryptocephalus*	
COCCINELLIDAE				
9	Coccinellinae	Coccinellini	*Coccinella*	*septempunctata*
10	Coccinellinae	Coccinellini	*Cheilomenes*	*sexmaculata*
11	Coccinellinae	Coccinellini	*Micrapsis*	*univittata*
12	Epilachinae	Epilachnini	*Henosepilachna*	*cucurbitae*
CURCULIONIDAE				
13	Dryophthorinae	Litosomini	*Sitophilus*	
14	Entiminae	Tanymecini	*Tanymecus*	
MELOIDAE				
14	Meloinae	Mylabrini	*Hycleus*	
16	Meloinae	Meloini	*Meleoe*	
NITIDULIDAE				
17	Carpophilinae		*Carpophilus*	
SCARABAEIDAE				
18	Rutelinae	Anomalini	*Popillia*	*japonica*
BRENTIDAE (Unidentified sp.1)				

Annex III: Host Plants Visited by Flower Visiting Beetles

S.N.	Family	Scientific Name	Common Name	English Name
1	Amaranthaceae	*Amaranthus lividus*	Marshi/Latte	Amaranth
2	Amaranthaceae	*Celosia argentea*	Makhamali Phul	Cocks Comb
3	Amaranthaceae	*Gomphrena globosa*	Makhamali	Globe Amaranth
4	Asteraceae	*Ageratum houstonianum*	Nilo Gandhe	Floss Flower
5	Asteraceae	*Artemisia* sp.	Titepati	Mugwort
6	Asteraceae	*Calendula officinalis*		Pot Marigold
7	Asteraceae	*Cosmos sulphureus*	Putali Phul	Sulfur Cosmos
8	Asteraceae	*Dalhia* sp.	Lahureful	Dahlia
9	Asteraceae	*Glebionis coronaria*		Crown Daisy
10	Asteraceae	*Tagetes erecta*	Sayapatri	Mexican Marigold
11	Asteraceae	*Zinnia* sp.	Chhitke Phul	
12	Brassicaceae	*Brassica oleracea*	Broccoli	Broccoli
13	Brassicaceae	*Brassica* sp.	Lahi/Sarson	Rapeseed
14	Commelinaceae	*Commelina benghalensis*	Kane	Bengal Dayflower
15	Cucurbitaceae	*Benincasa hispida*	Kubhindo	Wax Gourd
16	Cucurbitaceae	*Cucumis sativus*	Kakra	Cucumber
17	Cucurbitaceae	*Cucurbita* sp.	Farsi	Pumpkin
18	Cucurbitaceae	*Lagenaria siceraria*	Lauki	Bottle Gourd
19	Cucurbitaceae	*Luffa acutangula*	Toriya	Ridged Gourd
20	Cucurbitaceae	*Luffa aegyptiaca*	Ghiraula	Sponge Gourd
21	Cucurbitaceae	*Momordica charantia*	Karela	Bitter Gourd
22	Cucurbitaceae	*Trichosanthes cucumerina*	Chichinda	Snake Gourd
23	Cyperaceae	*Cyperus rotundus*	Mothe	Java Grass
24	Euphorbiaceae	*Euphorbia hirta*	Dudhe Jhar	Asthma Plant
25	Fabaceae	*Vicia faba*	Bakula Chana	Faba Bean
26	Fabaceae	*Vigna mungo*	Kalo Daal/Mas	Black Gram

27	Fabaceae	*Vigna unguiculata*	Bodi	Yardlong Beans
28	Lamiaceae	*Oscimum sanctum*	Tulasi	Holy Basil
29	Malvaceae	*Abelmoschus esculentus*	Vindi	Okra
30	Malvaceae	*Hibiscus* sp.	Ghanti Phul	Hibiscus
31	Malvaceae	*Sida acuta*	Balu Jhar	Common Wireweed
32	Onagraceae	*Ludwigia prostrate*		
33	Poaceae	*Pennisetum polystachyon*		Mission Grass
34	Rosaceae	*Rosa* sp.	Gulab	Rose
35	Solanaceae	*Capsicum annum*	Khursani	Chillies
36	Solanaceae	*Physalis* sp.	Rashbhari	Golden Berry
37	Solanaceae	*Solanum melogena*	Vanta	Brinjal
38	Solanaceae	*Solanum nigrum*	Kali Kunyo	Black Nightshade
39	Urticaceae	*Pouzolziz zeylanica*	Chiple Jhar	Pouzolz’s Bush
40	Verbenaceae	*Lantana camara*	Banmara	Wild Sage

Annex IV: Seasonal Variations in Flower Visiting Beetles and Flowering Plants Visited
(0 means absence and 1 means present)

Autumn Season

Host Plant	AUF	AUL	MIC	CAR	CRY	TAN	HEN	UNI	ALT	CHE	HYC	SIT	MON	COC
Amaranthus lividus	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Artemisia sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Benincasa hispida	1	1	1	0	0	1	1	0	0	0	0	0	0	0
Brassica sp.	0	1	1	0	0	0	0	0	0	0	0	0	0	1
Capsicum annum	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Celosia argentea	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Commelina benghalensis	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Cosmos sulphureus	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Cucumis sativus	0	1	1	0	0	0	0	0	0	0	0	0	0	0
Cucurbita sp.	1	1	1	1	0	1	1	0	1	0	0	0	0	0
Cyperus rotundus	0	0	1	0	1	0	0	0	0	0	0	0	1	0
Dalhia sp.	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Euphorbia hirta	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Gomphrena globosa	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Lagenaria siceraria	1	1	0	1	0	0	0	0	0	0	0	0	0	0
Lantana camara	1	0	1	0	0	0	0	0	1	0	0	0	0	0

Ludwigia prostrata	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Luffa acutangula	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Luffa aegyptiaca	1	1	1	1	0	0	1	0	0	0	0	0	0	0
Momordica charantia	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Oscimum Sanctum	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pennisetum polystachyon	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Physalis sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Pouzolziz zeylanica	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Sida acuta	0	0	1	0	1	0	0	0	0	1	0	0	0	0
Solanum melogena	0	0	1	0	0	0	0	0	0	0	0	0	0	0
solanum nigrum	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Tagetes erecta	0	0	1	0	0	0	0	0	0	0	1	1	0	0
Trichosanthes cucumerina	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Vigna mungo	1	1	1	0	1	0	0	0	0	0	0	0	0	0
Vigna unguiculata	1	0	1	0	0	0	0	1	0	0	0	0	0	0
Zinnia sp.	0	0	1	0	0	0	0	0	0	0	0	0	0	0

Winter Season

Host Plant	AUF	CRY	MON	COC	MEL
Brassica sp.	1	1	1	1	1

Spring Season

Host Plant	AUF	CRY	CHE	MON	COC	PSY	CHA
Ageratum houstonianum	0	0	0	1	1	0	0
Brassica sp.	0	1	0	1	1	1	1
Brassica oleracea	0	0	0	0	0	1	0
Calendula officinalis	0	0	0	1	1	0	0
Cucurbita sp.	1	0	0	0	0	0	0
Glebionis corinaria	0	0	0	0	1	0	0
Lagenaria siceraria	1	0	0	1	0	0	0
Vicia faba	0	0	1	0	0	0	0

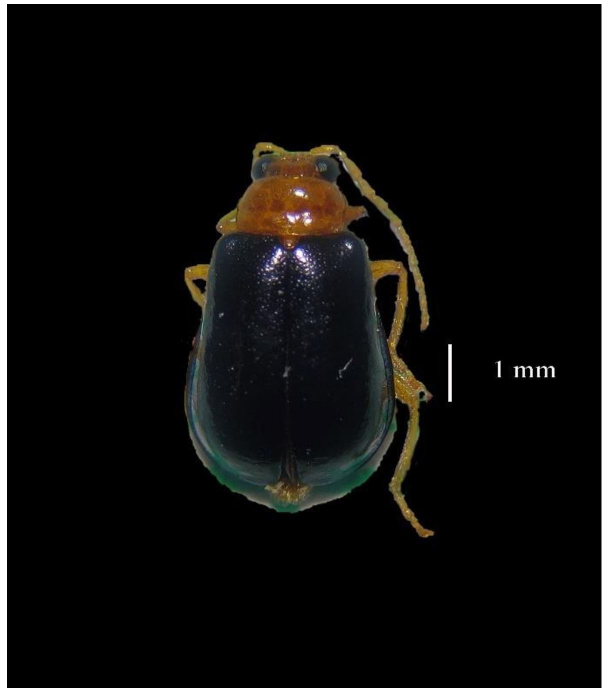
Summer Season

Host Plant	AUL	AUF	MIC	CRY	HEN	HYC	MON	POP	IVA
Abelmoschus esculentus	0	0	0	0	0	1	0	1	1
Amaranthus lividus	0	0	1	0	0	0	0	0	0
Benincasa hispida	0	1	0	0	0	0	0	0	0
Cucumis sativus	0	1	0	0	0	0	0	0	0
Cucurbita sp.	1	1	0	0	0	1	0	1	0
Cyperus rotundus	0	0	0	1	0	0	1	0	0
Hibiscus sp.	0	0	0	0	0	1	0	1	0
Lagenaria siceraria	0	1	0	0	0	0	0	1	0
Luffa acutangula	1	1	0	0	1	0	0	0	0
Luffa aegyptiaca	1	1	0	0	0	1	0	0	0
Momordica chanrantia	1	0	0	0	1	0	0	0	0
Rosa sp.	0	0	0	0	0	0	0	1	0
Trichosanthes cucumerina	1	1	0	0	0	0	0	0	0

[AUL- *Aulacophora lewisii*, AUF- *Aulacophora foveicollis*, MIC- *Micrapsis univittata*, CAR- *Carpophilus* sp., CRY- *Cryptocethalus* sp., TAN- *Tanymecus* sp., HEN- *Henosepilachna cucurbitae*, UNI-Unidentified sp.1, ALT- *Altica* sp., CHE- *Cheilomenes sexmaculata*, HYC- *Hycleus* sp., SIT- *Sitophilus* sp., MON- *Monolepta signata*, COC- *Coccinella septempunctata*, POP- *Popillia japonica*, PSY- *Psylliodes* sp., CHA-*Chaetocnema* sp., MEL- *Meloe* sp., IVA- *Ivalia* sp.]

PHOTOPLATES

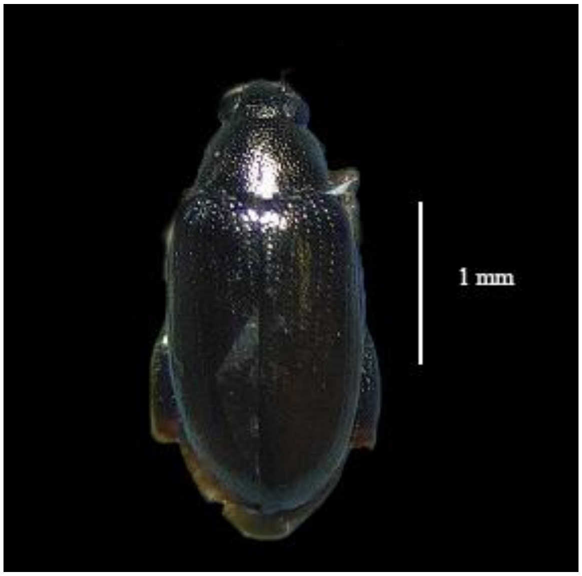
Aulacophora foveicollis



Aulacophora lewisii

Monolepta signata

Cryptocephalus sp.



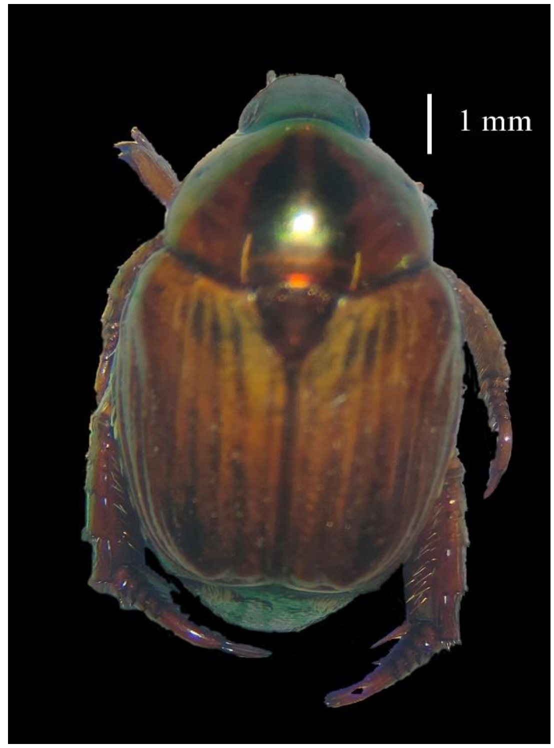
Psylliodes sp.

Ivalia sp.

Cheilomenes sexmaculata

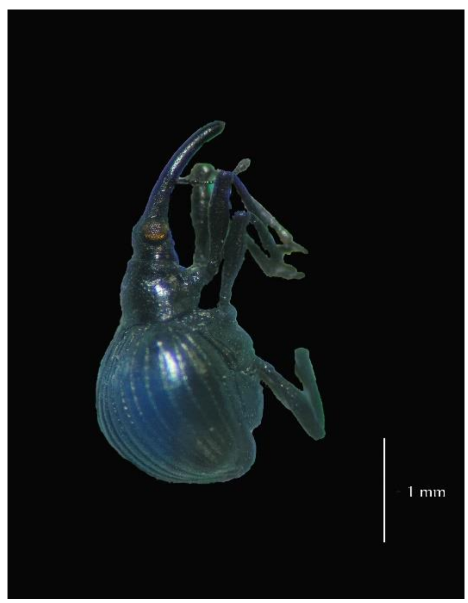
Micraspis univittata

Hycleus sp.



Popillia japonica

Sitophilus sp.



Unidentified Sp.1