FLOWER VISITING BEETLES IN VEGETABLE AND HOME GARDEN PLANTS OF BHEEMDATTA MUNICIPALITY, KANCHANPUR, NEPAL

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DECLARATION

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

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RECOMMENDATIONS

This is to recommend that the thesis entitled "Flower Visiting Beetles in Vegetable and Home Garden Plants of Bheemdatta Municipality, Kanchanpur, Nepal" has been carried out by Ms. Prakriti Pant for the partial fulfillment of the degree of Master 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 in any institution.

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LETTER OF APPROVAL

On the recommendation of the supervisor, Assoc. Prof. Dr. Daya Ram Bhusal, this thesis submitted by Ms. Prakriti Pant entitled "Flower Visiting Beetles in Vegetable and Home Garden Plants of Bheemdatta Municipality, Kanchanpur, Nepal" is approved for the examination for the partial fulfillment of the requirements for the degree of Master of Science in Zoology with special paper Entomology.

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CERTIFICATE OF ACCEPTANCE

The thesis work submitted by Ms. Prakriti Pant entitled "Flower Visiting Beetles in Vegetable and Home Garden Plants of Bheemdatta Municipality, Kanchanpur, Nepal" has been accepted as partial fulfillment for the requirements of the degree of Master of Science in Zoology with special paper Entomology.

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ABSTRACT

Beetles are most abundant insect fauna and many of them are herbivores feeding variously on the floral parts as well. While feeding on flowers they pollinate different plants in tropics and interact to their host plants with different preferences. Study on composition and such interactions of beetle fauna to vegetable and home garden plants is scanty in Nepal so, this investigation was initiated to explore the flower visiting beetles at Bheemdatta municipality, Kanchanpur district, Nepal. Sampling was carried from October 2020 to July 2021 covering autumn, winter, spring and summer seasons. Sampling plots of area 20 m ×20 m area were chosen randomly and observed for 45 minutes, only sites that have optimum blooming were carried further for observations. Study results documented 1,219 individual beetles representing 20 species belonging to five families as flower visitors which were found interacting with 27 plant species from 15 plant families. Chrysomelidae was the most abundant beetle family recorded both by species number (8 species) and number of individuals contributing (68.50%, i.e. 835 individuals). Beetle fauna were most abundant in autumn (n=819) with highest diversity and richness (H'=1.60 and S=11) in summer while evenly distributed (J=0.70) in spring season. Overlapping of beetle species was highest between autumn and summer seasons ($J_{A,Su}$=0.4), indicating they share more common species. Bipartite plant-pollinator interaction network was developed to find the interaction pattern among the flowering plants and visiting beetle species in the study area. Among the plants visited by beetles, Cucurbitaceae was the most visited plant family by 871 beetle individuals. Seven plant species of the family were present in study area and major were *Cucurbita* sp., *Luffa acutangula, Luffa aegyptica, Lagenaria siceraria* which were visited dominantly by *Aulacophora foveicollis* and *Aulacophora lewisii.* Coccinellid beetle *Micraspis univittata* visited the most number of plants i.e. 16 out of 27 plants observed.

1. INTRODUCTION

1.1. Background

Coleoptera, generally called as beetles, is the largest order in the class Insecta with wide range of diversity within the order with respect to size, morphology, biology and behavior. Beetles have strong mandibulate mouthparts that feed on a wide variety of diets and inhabit in all terrestrial and fresh-water environments. Many species are herbivorous that are variously adapted to feed on the roots, stems, leaves, or reproductive structures of their hosts including flowers and pollen (Samuelson 1994, Bieńkowski 2010). Others are predators, scavengers and parasites as well. Generally, flower visiting beetles can be regarded as the beetles that are seen on and around flowers. The beetles can visit flowers for various purposes; they may function as pollinators or predators or floral or reproductive parts feeders. The predatory Adephaga do not visit flowers, but among the Polyphaga, families Chrysomelidae, Elateridae, Scarabaeidae, Nitidulidae, Cleridae, Staphylinidae, Meliodae, Cerambycidae and Mordellidae are notable flower visitors (Kevan & Baker 1983). Flower-visiting behavior is thought to have evolved independently across more than a dozen modern invertebrate orders, and it is estimated that nearly 30% of described arthropod species (>350,000) may use flowers on a regular basis to feed, find a mate, or acquire other resources (Wardhaugh 2015). Flower visiting beetles consists of structurally modified mouthparts in numerous ways to adhere and ingest pollen grains (Karolyi et al. 2008), especially prognathous mouthparts are more adequate for feeding on nectar, pollen and flower petals (Krenn et al. 2005).

Coleoptera are considered as most primitive pollinators and found associated with heavily constructed, open bowl-shaped flower pollination e.g. *Magnolia* (Kevan & Baker 1983) in which the beetles imbibe floral secretions, eat pollen, and chew on floral parts of special food bodies. In only a few groups of angiosperms, beetles are the most predominant or even the exclusive pollinators e.g. Magnoliaceae, Annonaceae, Eupomatiaceae and Calycanthaceae (Gottsberger 1990). Many flowers that are specialized for beetle pollination but do not exhibit the cantharophily syndrome are visited by beetles and some of those beetles seem restricted to floral diets as adult; such as Mordellidae are exclusively anthophilous as adults (Kevan & Baker 1983). In tropical rain forests beetles are one of the dominant pollinators but they do not dominate as pollinators in tropical monsoon forests, might be due to long dry seasons in tropical monsoon forests (Kato et al. 2008). Larvae of leaf beetles (Chrysomelidae) consume leaves, roots, detrite, or plant sap. Most of the adult leaf beetles feed on leaves, some of them occurring on flowers e.g. Cryptocephalinae were found involved in anthophagy (Bieńkowski 2010). The scarab beetles in the subfamilies Melolonthinae, Rutelinae, Cetoninae and Dynastinae are mainly phytophagous causing damage to agricultural crops, and often are flower visitors that feed on nectar sap, and juice of ripe fruits and vegetables (Valois et al. 2019).

Networks between flowering plants and their possible pollinators that visit flowers are being used to study the ecological structure and functions of those interactions (Prendergast & Ollerton 2022). Plant-pollinator interaction networks represent the mutualistic interactions between a group of plant species and a group of pollinator species within a space, which are bipartite in nature (Seo & Hutchinson 2018). These are free flowing networks that depend on activities of the both plant and pollinator species in that community. Plant or pollinator species in the network are called as nodes and the line connecting them is link, and the width of link between a pair of plant and pollinator reflects frequency of visitation. An ecosystem, can support multiple nested networks depending upon the time and season, is not limited to a single one. Processes like network turnover and interaction rewiring were are often observed within a year or even within a season as well (CaraDonna et al. 2017) that might be brought by phenology of plants and/or weather conditions during different seasons in a year. Visitation data collected by biologists are used for network construction then after ecologists study structure and function of the network in scientific, conservation and agricultural aspects (Seo & Hutchinson 2018).

Plant-pollinator networks are characterized by nestedness, asymmetry and heterogeneity (Bascompte & Jordano 2007). Specialist pollinator species visit plant species that are subsets of those that are visited by more generalist pollinator species, this nestedness configuration is most likely to be seen in a community that has full range of species growth rates during community formation due to the added mutualistic stability it imparts (Samraat 2014). Dependence of a pollinator or plant species to its different interacting partners vary within a network. For example, a pollinator species depends more upon one particular plant species than on others contributing to the network, and/or a plant species rely on a particular pollinator species than others pollinating that plant. Such conditions in any interaction brings asymmetry in the network. Again complex interaction networks tend to be more heterogeneous where the bulk of nodes (species) interact with few species but a few nodes are much more connected than expected (Bascompte & Jordano 2007).

Most of the vegetable plants are found pollinated by insect borne self or cross pollination (Westerfield 2000) such as Gourds, Pumpkins, Cucumbers, Okra, Eggplants etc. Pollinating beetles pose modifications in mandibles, bristles for pollen manipulation and elaborate feeding movements (Krenn et al. 2005). Mouthpart specializations are not found in petal feeding flower visitors instead pollen get entangled on body surfaces and hairs of beetles, and transfer during feeding from one flower to another. Pollinator diversity is generally found high in orchards (Choi & Jung 2015) because diverse floral resources are available in orchards than in fields cultivating single crop species. Although flowers are regarded among one of the important beetle microhabitat in forest ecosystems (Wardhaugh et al. 2012) the role of beetles in agro-ecosystems is still poorly known and many insect species were reported both as pollinators and pests in different literatures according to focus of the research.

Bheemdatta municipality has small urbanized area surrounded by traditional village housing systems, so people plant ornamental flowers and vegetables in small to medium garden around their house. This study aimed to explore beetle species that visit flowers in vicinity of residence focusing on their taxonomy and interaction to the host plants.

1.2. Objectives

1.2.1. General Objective

The overall aim of the study was to explore flower visiting beetles in vegetable and home garden plants of Bheemdatta Municipality, Kanchanpur.

1.2.2. Specific Objectives

The specific objectives are as follows:

i. To identify seasonal composition and diversity of flower visiting beetles

ii. To determine their relationship with host plants via plant-pollinator interaction network

1.3. Rationale of the Study

It is so known fact that insects possess both negative and positive interactions to the plants as well as to humans. Insects as pests harm plants and consequently to humans by causing crop yield loss while as pollinators increase crop production and ensure global food security. The flower-insect interactions were found well studied from the perspective of plants in the form of pollination biology while only a few were carried out from entomological perspective where flowers are resources to exploit. Due to which insects that do not carry out pollination but are flower visitors remain widely ignored in pollination studies (Wardhaugh 2015). Nowadays concepts like Integrated Pest and Pollinator Management (IPPM) and prioritizing pollinators over pests are being adopted where major role of insect species and output/impact of its service is analyzed (Lundin et al. 2021, Leach & Kaplan 2022). Species that generally recognized as pests may aid in other beneficial ecosystem services such as pollination and food chain balancing. Those species should also be studied and conserved if their positive roles out-weight negative impacts on plants and ecosystem. Flower visitors that utilize flowers as a resource but do not pollinate should also be given emphasis. By conducting this study an attempt was made to explore overall flower visiting beetles on vegetable and home garden plants of the study area.

1.4. Limitations of the Study

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

2. LITEREATURE REVIEW

2.1. Diversity of Flower Visitors

Earlier only foliage were used to sample for the canopy invertebrate studies, later on Wardhaugh (2013) studied 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. Results of that study clearly showed flowers as a unique microhabitat that support greater densities and disproportionately rich fauna of beetles than adjacent foliage, and also species richness of beetles utilizing mature leaves was highest followed by flowers and new leaves. Similar study by Ødegaard (2000) in a tropical protected natural forest of Panama focused on leaves, flowers and suspended dead wood as different microhabitats to study habitat specificity of three beetle superfamilies *viz.* Buprestoidea, Chrysomeloidea and Curculionoidea; and concluded each microhabitat type supported a unique beetle community of which approximately 20% species were flower visitors.

Coleoptera had the third most number of anthophilus species after Diptera and Hymenoptera; in Coleoptera, Chrysomelidae was the most dominant family followed by Nitidulidae, Mordellidae, Cerymbicidae, Byturidae, Staphylinidae, Scarabaeidae, Curculionidae, Oedemeridae, Elateridae and Cantharidae (Inoue et al. 1990). The study shown most of the Coleopteran insects as pollen feeders, and others as predators and plant tissue feeders among which Chrysomelidae and Scarabaeidae were recognized as pollen feeders, Carabidae, Cantharidae and Coccinellidae as predators, and Apionidae and Curculionidae were plant tissue feeders. While assessing the influence of grazing intensity on diversity and abundance of flower visiting insect groups: bees, butterflies, hoverflies and beetles, Sjödin et al. (2007) found beetles as more abundant and species rich flower visiting insect group in grasslands with tall vegetation. Although flower abundance should be important to all flower visitors but was not found to determine flower visiting beetle population in semi-natural ecosystems. Landscape variation and composition was also not so significant in determining flower visiting beetle population. In the tropical monsoon forests of South-East Asia abundance pattern shown by flower visitors based on number of individuals was Hymenoptera (55%), Coleoptera (16%), Lepidopeta (14%), Diptera (11%), Thysanoptera (3%) and others (Kato et al. 2008).

Chrysomelidae, Scarabaeidae, Curculionidae were most abundant families and visited on trees and shrubs more than on liana, perennial and annual plants during dry season than during wet season (Kirmse & Chaboo 2018). Among chrysomelids, Galeuricinae was the most abundant subfamily in canopies, followed by Alticinae, Cryptocephalinae and Eumolpinae, and mostly collected from flowers of canopy trees, although some species also fed on extra floral nacteries or fruits. They also reported the leaf feeding species of Chrysomelidae were found to occur in subfamilies Cassinidae, Cryptocephalinae, Eumolpinae and Galeuricinae, while Alticinae were restricted predominantly to flowers. Their findings revealed abundant flower-visiting species occurred on their host trees commonly over the entire flowering season, and after termination of one tree's flowering season, many flower-visiting leaf beetles moved to other flowering trees. However, certain congeneric species of Galeuricinae and Eumolpinae occurred together on their host plants within the same periods.

Cantharophily was found to be adopted mostly by primitive angiosperms such as families Cyclanthaceae, Annonaceae and Araceae in tropical forests (Gottsberger 1990) also on the other hand beetles were documented as major pests of forests (Tripathy et al. 2020). Though beetles generally found not considered as to be as abundant, diverse or important as species from other pollinator orders, they are the common flower-visitors (Kevan & Baker 1983). Wardhaugh et al. (2012) found flowers in tropical rainforests attracting high density and diversity of beetles in comparison to adjacent foliage, and results of Wardhaugh (2015) stated flower visiting beetles were second most important insect pollinator group after Lepidoptera in tropical forests.

Only a few documented literatures related to flower visiting insects are available in context of Nepal. Most of the studies were focused on cash crops and only few beetles were recorded as flower visitors. 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.* Lady Bird Beetles were found on Mustard flowers in Chitwan district along with other major pollinators (Pudasaini 2014, Pudasaini et al. 2015). A three yearlong study (2012-2014) to find the abundance of flower visitors of Eggplant (*Solanum melogena*) in Khumaltar, Lalitpur revealed Hymenoptera as most dominant flower visiting order followed by lepidopteran species (Mainali et al. 2015). The weekly end-to-end walks using a sweep net at three distinct times of the day, *viz.*7-8 am, 12–1 pm, and 4-5 pm, were used to monitor the flower visitors of *S. melogena* by the authors where they found Hymenoptera as the most abundant flower visitor and no coleopteran species was observed. During that study significantly higher visitations were recorded in the morning time than in evening and daytime.

Aryal et al. (2016) monitored the insect visitors on Buckwheat (*Fagopyrum esculentum)* crop in Chitwan district at different elevations (500m, 1500m and 2800m asl) using insect nets and pan traps. Among the flower visitors, most abundant were Hymenoptera, followed by Diptera, Coleoptera and Lepidoptera. In the studied area, Lady Bird Beetle (*Coccinella* sp.), Weed Beetle (*Agasicles* sp.) and Flea Beetle (*Phyllotreta cruciferae*) were the coleopteran species recorded on Buckwheat flowers. Subedi & Subedi (2019) enlisted *Co. septempunctata* and *Coccinella undeipunctata* as flower visitor of mustard (*Brassica campestris)* in Kusma of Parbat district, where most abundant flower visitors were hymenopteran insects followed by dipteran, coleopteran, lepidopteran, and heteropterans.

In another study by Devkota et al. (2020), a lower diversity was observed on increased distance from forest fragment. For this study four localities sharing similar cropping pattern in the vicinities of Chitwan National Park were selected for observing flower visiting insects on Mustard (*B. campestris*) blossoms and their diversity at different distances from forest area were compared. Twenty-three species belonging to three orders: Hymenoptera, Diptera and Lepidoptera were found as flower visitors of mustard plant during the study. Also in fields nearer to natural vegetation (i.e. forests) fruit set and yield was found more in comparison to farther fields, and the study concluded that species richness plays more important role than species abundance for mustard production (Devkota et al. 2021). Some other studies were carried out on focusing either particular pollinator group or particular plant species e.g. butterfly species diversity and floral preferences shown by them in Rupa Wetland of Pokhara (Subedi et al. 2021), insect visitors of white clover (*Trifolium repens*) in Lalitpur (Chaguthi & Dyola 2018), flower visiting insects of Litchi (*Litchi chinensis*) (Dubey et al. 2020), pollinator diversity in Marigold (*Tagetes erecta*) in Ratna Park area of Kathmandu (Gurung et al. 2020), insect pollinator community structure in different habitats of Shivapuri-Nagarjun National Park focusing solely on hymenopteran and dipteran pollinators (Dyola et al. 2022), insect pollinators of Mustard (*B. campestris*) in Itahari, Sunsari (Gautam 2022) , pollinators of micronutrient rich crops in Jumla district (Timberlake et al. 2022).

2.2. Plant-Pollinator Interaction

Network based method of analyzing ecological systems has enhanced our understanding of ecological systems by identifying interaction patterns between species. In a typical field study, potential pollinators that visit plants within a predetermined observation area for a predetermined time period are recorded and referred as visitation data (Young et al. 2021). By constructing networks of plant and pollinator species, network ecologists examine visitation data where a connection between two species denotes the existence of a plant-pollinator relationship between them. Prendergast & Ollerton (2022) stated that at present bipartite plant-pollinator networks are being used enormously to know the dynamics of these ecological interactions as they were found most promising in predicting alterations in interaction networks caused by environmental perturbations

Like the abiotic factors (e.g. moisture, temperature, humidity) and interactions among species (e.g. competition, mutualism) influence the assembly of a plant community, pollinator mediated interactions also impact on community establishment. To predict the impact of different pollinator mediated interactions on community structure, Sargent & Ackerly (2008) dealt three types of plant-pollinator interactions- filtering, facilitation and competitive exclusion. And it was predicted that communities with phenotypically similar species tend to be supported by filtering and facilitation interactions, while competitive exclusion be likely to generate communities of less closely related species.

Insect pollination is considered as a crucial ecosystem function for boosting ecosystem productivity as well as agricultural crop yield because including in vegetable plants insect borne self or cross pollination is adopted by most of plant species (Westerfield 2000). Crops that are self-incompatible and cross-pollinated require the effective pollination services of bees and other pollinators (Thapa 2006). He also mentioned that even self-pollinated plants can get benefit from insect pollination since insect pollinated plants yield more fruit and produce seeds of excellent quality seeds. Such insect pollinated seeds exhibit hybrid vigor without losing any of their natural qualities. On a study conducted to investigate insect visitors on cucurbit vegetable plants in Rajasthan India by Bhardwaj & Srivastava (2012), two species of beetles *Co. septempunctata* and *Menochilus sexmaculata* were found on flowers of Cucumber and Pumpkin,. Also, different species of order Hymenoptera, Diptera, Lepidoptera, Neuroptera, Hemiptera, Orthoptera, Odonata were also listed as flower visitors. In different studies focusing on insect pollinators of orchards and wild fields in Korea, Hymenopteran pollinator species were most diverse followed by Diptera and Coleoptera, concluding the higher bee diversity in orchards (Choi & Jung 2015). There were about 71 species of beetle in 27 families found serving as pollinators of orchards and wild fields making them third most diverge pollinator group.

Networks are now being used in wide range of disciplines, in a recent publication (Timberlake et al. 2022) general network concept was used to quantify contributions of social and ecological factors to food security of smallholder farmers in remote Nepal of Jumla district. The wild plants supporting pollinators of crop plants that provide key micronutrients to the farmers were identified and a plant-pollinator-nutrient network was developed. Honeybees, Solitary Bees, Bumblebees, Butterflies, Flies, Wasps and Beetles were pollinator groups visiting Bean, Eggplant, Carrot, Chilli, Cucumber, Bitter Gourd, Mustard, Pumpkin and Radish. Flies visiting Carrot flowers and carrots providing Vitamin A to the smallholder farmers, and those flower visitors in turn supported by wild plants in periods when there is no flowering in carrots was the key interaction in the network.

3. MATERIALS AND METHODS

3.1. Study Area

Bheemdatta Municipality is located in Kanchanpur district of Sudurpaschim province, Nepal. The spatial extent of the municipality is between 28.895°–29.137°N and 80.105°–80.244°E enclosing an area of 171.34 km^2 (Fig. 1). The municipality is surrounded by Bedkot Municipality in the east, Dadeldhura District in the north, Shuklaphanta National Park in the south and Uttarakhand, India in the west. The elevation of municipality ranges from around 175 m to 1500 m asl. This municipality has an annual rainfall about 1,745 mm with majority of the rainfall occurring during the monsoon season. The temperature in the area varies depending upon the season, with an average maximum temperature of around 28.3°C during the summer months (June is the hottest month) and an average minimum temperature of around 12.7°C during the winter months (January is the coldest month). The climate in Bheemdatta Municipality is generally characterized as sub-tropical, with hot summers and cool winters (Climate-Data 2022). Bheemdatta municipality has small urban area, surrounded by small peri-urban settlements and larger rural settings or typical village systems. The locals plant seasonal flowers and vegetables in their home gardens for self-consumption as well as for small businesses. Seasonal ornamental flowers such as Marigold, Calendula, Dahlia, Roses, etc.; and vegetables such as Pumpkins, Gourds, Rapeseed, Amaranth etc. are found grown in this area.

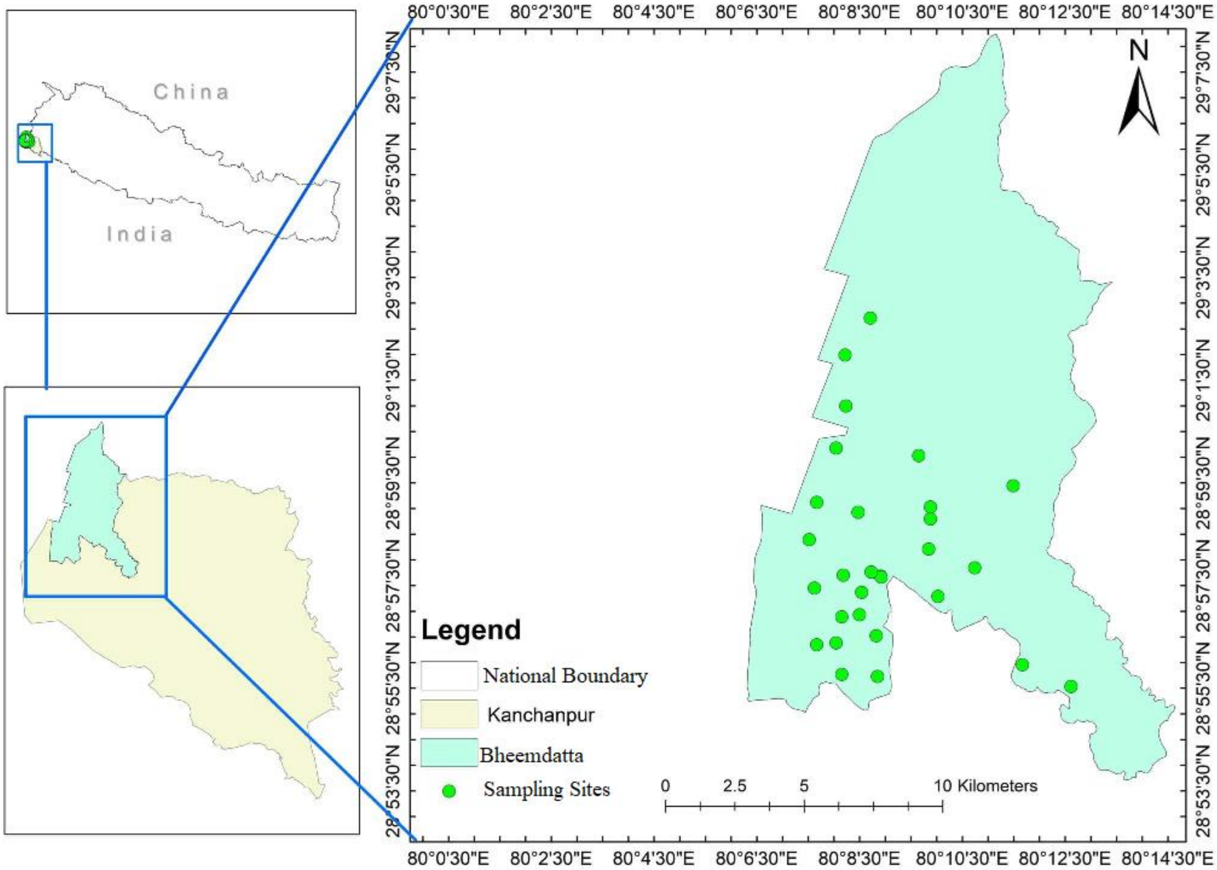

Figure 1. Map of Study Area

3.2. Materials

Materials used for the data collection were:

- GPS (Garmin eTrex® 10)
- Mobile phone for taking photos
- 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 flower visiting beetles were sampled from different sites of Bheemdatta municipality covering as much settlement area as possible. The sampling sites were chosen purposively and randomly within study area; especially focusing the vegetable and home gardens where there was good blooming of flowers. The plots of area 20 m × 20 m were taken for insect sampling and each plot was observed for 45 minutes. Field work was carried out during four seasons from October 2020 to July 2021 covering October 2020 as autumn, December 2020 as winter, February- March 2021 as spring and July 2021 as summer seasons. Every sampling site was observed only once in each season i.e. four times during total field data collection period. Prior to the each observation, proper permissions were made from every owner to carry out observations on their gardens/fields. The collections were done on sunny days between sunrises to sunset when there was ambient temperature. Collections were paused on rainy and windy days as rain and wind affect the feeding and flight ability of beetles, but gentle breeze do not affect them. GPS-point for each sampling plot were also taken and map indicating sampling points was developed after completion of field work. All observed plant-pollinator interactions were recorded. Here in this study, visitation of any floral visitor of any beetle species to reproductive structures of flowers within the sampling units forms an interaction as mentioned by CaraDonna et al. (2017) where all floral visitors were referred as pollinators considering their quality as mutualists may vary widely.

3.4. Insect Collection and Preservation

The flower vising beetles were collected by hand picking methods. Beetles on leaves and stem were not recorded unless they visited flowers. During field observations, beetles were observed for flower visitations and then collected. Name of host plants and/or weeds were also recorded. Host plant's names were noted as suggested by local people, and photographs were taken for further identification. Collected insect specimens were kept in insect collection vials with 70% alcohol immediately after collection. Few other specimens were killed using Ethyl Acetate in Killing jar and kept in Paper Envelops for dry preservation. The collected specimens were then labeled with sample site name, sample plot name, date and time of collection, host plant name and sample specimen code.

3.5. Insect Identification

Collected specimens were brought to Entomology Laboratory of Central Department of Zoology, Tribhuvan University, Kirtipur, Kathmandu. 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 level by using family keys in '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, Reid 2006, Warchałowski 2010). The identified beetle fauna were well preserved and labeled properly with the mention of taxonomic information of species, name of host plant, date of collection, place of collection and name of collector. Host plants were identified by using valid online sources (POWO 2023). Reference specimens of identified flower visiting beetles were pinned with entomological pins in entomological boxes. The specimens were deposited in the Central Department of Zoology Museum of Tribhuvan University (CDZMTU), Kirtipur, Nepal.

3.6.Data Analysis and Interpretation

All the field observation data were managed in MS Excel 2013. Data were analyzed for obtaining diversity indices using Shannon-Weiner Diversity Index (H'), Pielou's Evenness Index (J), Richness (S) and Jaccard's Similarity Index (J') in MS Excel 2013. In addition to that, the plant-pollinator interaction network was developed by using abundance data to get weighted bipartite interaction network. Network was constructed by using bipartite package, plot web function software in R software (R-Core-Team 2022).

4. RESULTS

4.1. Diversity of Flower Visiting Beetles in Vegetable and Home Garden Plants of Bheemdatta Municipality

Beetles from five families were identified as flower visitors in vegetable and home garden plants of the study area. Of sorted 20 morphospecies 10 were identified up to species level, eight up to genus level and two up to family level only (Table 1 and Annex I). Species identification of specimens of Curculionidae could not go further below family level and documented as morphospecies (Curculionidae sp1 and Curculionidae sp2) only. Among total species Chrysomelidae contributed highest number of species i.e. eight species, followed by Coccinellidae with five species, Meloidae with three species and Scarabaeidae and Curculionidae with two species each.

Table 1. List of Flower Visiting Beetles in Study Area

S.N.	**Subfamily**	**Tribe**	**Scientific Name**	**Author**
CHRYSOMELIDAE				
1	Galeuricinae	Luperini	*Aulacophora foveicollis*	Lucas, 1849
2	Galeuricinae	Luperini	*Aulacophora lewisii*	Baly, 1874
3	Galeuricinae	Luperini	*Monolepta signata*	Olivier, 1808
4	Alticinae	Alticini	*Altica*	Geoffroy, 1762
5	Alticinae	Alticini	*Psylliodes*	Latreille, 1829
6	Alticinae	Alticini	*Ivalia*	Jacoby, 1887
7	Cryptocephalinae	Cryptocephalini	*Cryptocephalus*	Geoffroy, 1762
8	Chrysomelinae	Phyllocharitini	*Ethomela*	Lea, 1916
COCCINELLIDAE				
9	Coccinellinae	Coccinellini	*Coccinella septempunctata*	Linnaeus, 1758
10	Coccinellinae	Coccinellini	*Coccinella transversalis*	Fabricius, 1781
11	Coccinellinae	Coccinellini	*Cheilomenes sexmaculata*	(Fabricius, 1781)

12	Coccinellinae	Coccinellini	*Micraspis univittata*	(Hope, 1831)
13	Epilachinae	Epilachnini	*Henosepilachna cucurbitae*	(Richards, 1983)
MELOIDAE				
14	Meloinae	Mylabrini	*Hycleus*	(Latreille, 1817)
15	Meloinae	Epicautini	*Denierella*	(Kaszab, 1952)
16	Meloinae	Meloini	*Meleoe*	(Linne, 1758)
SCARABAEIDAE				
17	Cetoninae	Cetoninii	*Gametis versicolor*	(Fabricius, 1775)
18	Rutelinae	Anomalini	*Popillia japonica*	Newman, 1841
CURCULIONIDAE (2 Morphospecies; Curculionidae sp1 and Curculionidae sp2)				

Altogether 1,219 beetle individuals were recorded during total sampling period. Chrysomelidae was observed as most abundant family in terms of both number of species and number of individuals comprising 68.50% (835 individuals within eight species) of total recorded fauna followed by family Coccinellidae with 21.58% (263 individuals) of beetles. Families Meloidae, Scarabaeidae and Curculionidae were less abundant contributing 8.12% (99 individuals), 1.56% (19 individuals) and 0.25% (3 individuals) of the recorded beetles respectively (Figure 2).

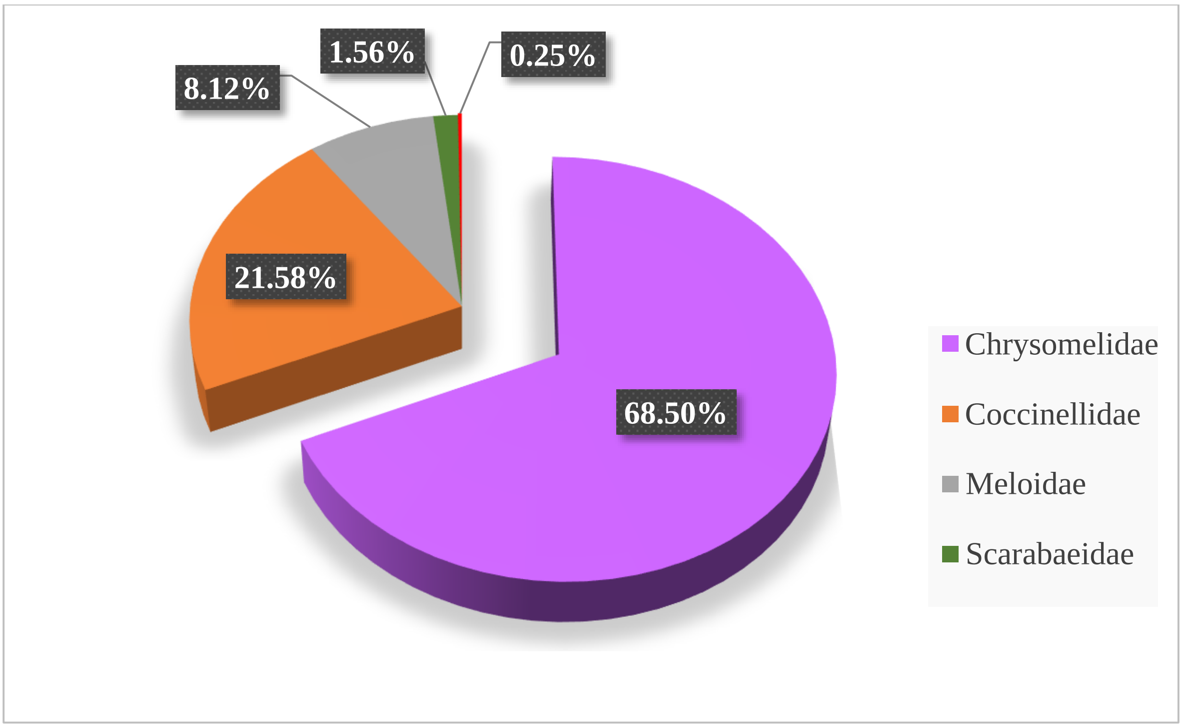

Figure 2. Beetle Individuals in each Family of Flower Visiting Beetles

The beetle fauna was found to be moderately diverse with Shannon Wiener Index 1.79, and Pielou's Evenness Index, J=0.60. Pumpkin beetles were most abundant throughout the study, of them Red Pumpkin Beetle (*Aulacophora foveicollis*) was more abundant comprising 39.62% (n=483) of total observations followed by Black Pumpkin Beetle (*Aulacophora lewisii)* with 25.02%. (n=305). Combined together genus *Aulacophora* has contributed more than half of the flower visitators i.e. 788 individuals of total 1,219 individuals recorded. Further, 10.25% (n=128) of fauna was contributed by *Micraspis univittata*, and was the most abundant flower visitor from family Coccinellidae in the study area. *Co. septempunctata* and *Hycleus* sp. were 6.97% (n=85) and 6.89 % (n=84) respectively. *Henosepilachna cucurbitae* commonly known as Hudda Beetle was 3.69% (n=45) and *Monolepta signata* made 2.54% (n=31) of the total. Other beetle species contributed relatively small fractions to the total beetle fauna *viz. Denierella* sp. 1.15% (n=14), *Popillia japonica* 0.82% (n=10), *Gametis versicolor* 0.74% (n=9), *Cryptocephalus* sp. 0.49% (n=6), *Ivalia* sp. 0.33% (n=4). *Psylliodes* sp. and *Cheilomenes sexmaculata* contribute 0.25% or 3 individuals each; and two individuals each of *Altica* sp., *Co. transversalis,* Curculionidae sp.1 were recorded making 0.16% of each species. Only one specimen of *Ethomela* sp., *Meloe* sp., and Curculionidae sp.2 were recorded throughout the sampling period (Figure 3).

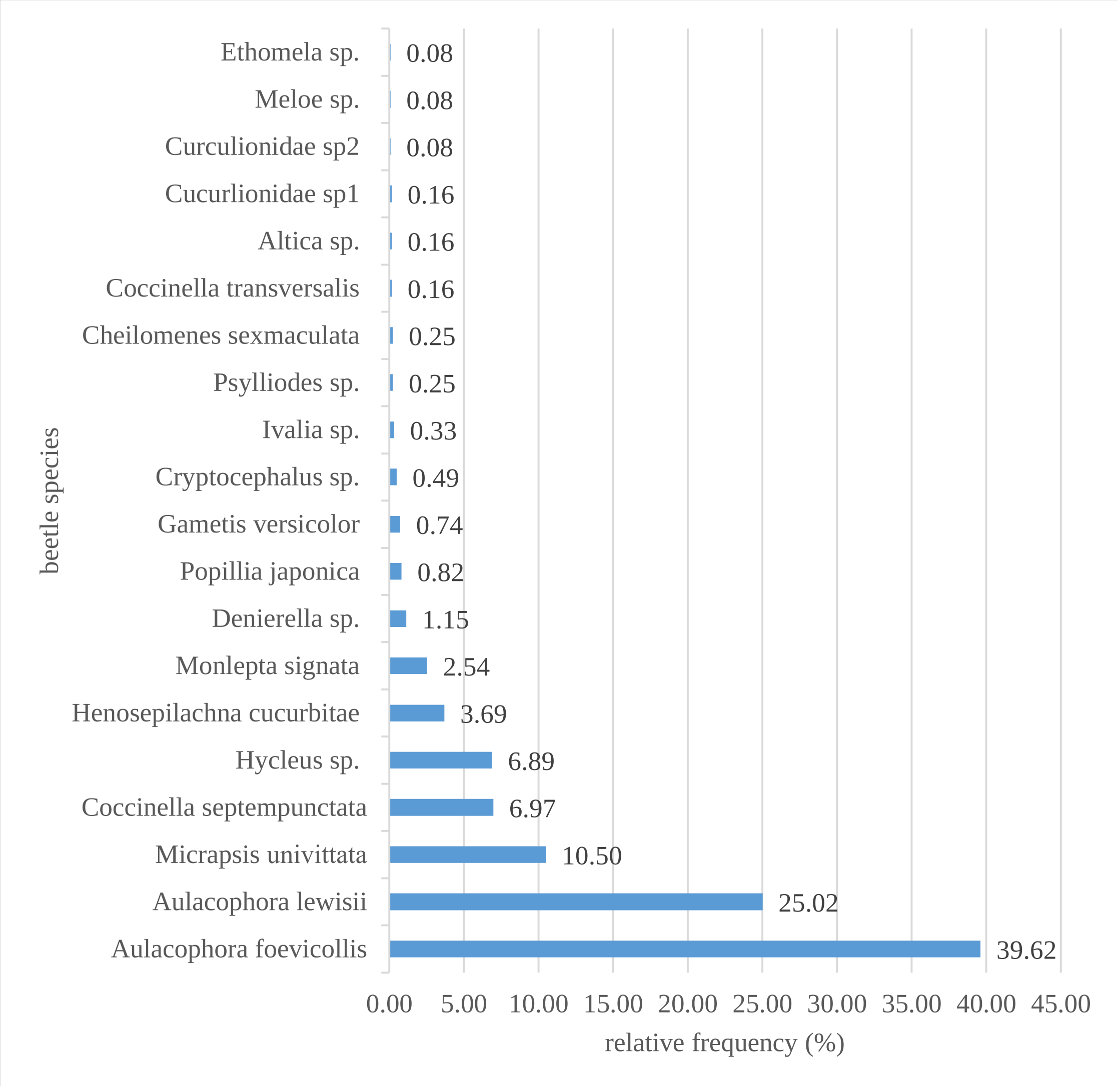

Figure 3. Relative Frequency of Flower Visiting Beetle Species

Beetle fauna were recorded in different proportions in different seasons, the highest number of individuals were observed in autumn. Among the beetles collected throughout the sampling period, 67.18% of the individuals were observed solely in autumn season. *A. foveicollis* and *A. lewisii*, the most abundant visitors, those were recorded maximum during autumn and summer season while *Co. septempunctata* was recorded abundantly during winter and spring season. *Hycleus* sp. was only observed during summer in significant numbers whereas, *Mi. univittata* was the only species observed in all four seasons (Table 2).

Table 2. Flower Visiting Beetles in All Four Seasons

Flower Visitors	**Autumn**	**Winter**	**Spring**	**Summer**
Aulacophora foveicollis	392	1	0	90
Aulacophora lewisii	259	0	0	46
Monolepta signata	6	16	9	0
Altica sp.	1	1	0	0
Psylliodes sp.	0	0	3	0
Ivalia sp.	0	0	0	4
Cryptocephalus sp.	0	4	2	0
Ethomela sp.	0	0	1	0
Coccinella septempunctata	0	50	33	2
Coccinella transversalis	0	0	2	0
Cheilomenes sexmaculata	2	1	0	0
Micraspis univittata	108	2	14	4
Henosepilachna cucurbitae	44	0	0	1
Hycleus sp.	0	0	0	84
Denierella sp.	3	0	0	11
Meloe sp.	0	1	0	0
Gametis versicolor	2	0	0	7
Popillia japonica	0	0	0	10
Cucurlionidae sp.1	2	0	0	0
Curculionidae sp.2	0	0	0	1
Total	**819**	**76**	**64**	**260**

Among the four seasons the flower visiting beetles were most abundant during autumn (n=819) season followed by summer, winter and spring (n= 260, 76 and 64 respectively). However, the beetle fauna was found rich and diverse in summer (11 species and H'=1.60), while in the spring beetle distribution was more even (J=0.70) among the all other seasons (Table 3).

Table 3. Diversity indices of Flower Visiting Beetles in Four Seasons

Indices	**Autumn**	**Winter**	**Spring**	**Summer**
Abundance	819	76	64	260
Richness (S)	10	8	7	11
H'	1.25	1.08	1.37	1.60
H_{max}	2.30	2.08	1.95	2.40
J	0.54	0.52	0.70	0.66

The similarity between occurrence of beetles was highest in autumn and summer seasons ($J'_{(A,Su)}$ = 0.4), indicating these two seasons shared more common species i.e. 40% among themselves than other pair of seasons (Table 4). The species overlap was found least between spring and autumn seasons, and spring and summer seasons having similarity index 0.13 only.

Table 4. Jaccard's Similarity Indices for All Four Seasons

Seasons	**Autumn**	**Winter**	**Spring**	**Summer**
Autumn	1			
Winter	0.38	1		
Spring	0.13	0.36	1	
Summer	0.4	0.19	0.13	1

4.2. Plant-Pollinator Interaction

Twenty-seven species of plants belonging to 15 families were found visited by beetles during the observation. In the study area seven plant species of family Cucurbitaceae were found to visit by different beetles and it was the most abundantly visited plant family by seven species of beetles. A total 871 out of 1,219 (71.45%) visits were made by different beetles to Cucurbitaceae flowers. Two plant species of both families Malvaceae and Brassicaceae were visited by beetles and each family was visited by highest number of beetle species (i.e. eight species). However, number of visitations were recorded more in

Malvaceae (n=109) than in Brassicaeae (n=82). Malvaceae, Brassicaceae and Cuucurbitaceae were found to be most important plant families as they support higher species and abundance of flower visiting beetles. Among the single plant species families, *Amaranthus lividus* of family Amaranthaceae was visited by 73 beetle individuals of five species. The other families Apocynaceae. Balsaminaceae, Bignoniaceae, Fabaceae, Lamiaceae and Cypereaceae which had only one plant species and each was found to be visited by only one beetle species (Table 5).

Table 5. Plant Families and Visitation Frequency of Flower Visiting Beetle

S.N.	**Plant Family**	**No. of Plant Species**	**No. of Beetle Species**	**No. of Beetle Families**	**Flower visiting individuals**
1	Cucurbitaceae	7	7	3	871
2	Malvaceae	2	8	4	109
3	Brassicaceae	2	8	3	82
4	Amaranthaceae	1	5	4	73
5	Rosaceae	1	4	3	29
6	Solanaceae	3	5	3	22
7	Apiaceae	1	4	2	8
8	Asteraceae	2	3	2	7
9	Poaceae	2	2	1	6
10	Apocynaceae	1	1	1	2
11	Balsaminaceae	1	1	1	1
12	Bignoniaceae	1	1	1	2
13	Fabaceae	1	1	1	2
14	Lamiaceae	1	1	1	4
15	Cyperaceae	1	1	1	1

Plant pollinator network on 20 flower visiting beetle species with 27 plant species was constructed. Only plant species whose flowers were visited by beetles were taken into account for this study (Annex II), also only beetle individuals that were found on floral parts were counted as flower visitors. Bipartite weighted interaction network was developed from field data where not only the presence or absence but frequency of interactions was used. Beetle abundance data was used and even a single visitation of an insect species to a single flower was counted as evident for network construction. *A. foveicollis* was observed as the most abundant flower visitor and mainly visited the plant species of Cucurbitaceae family. Seven plant species were visited by this beetle and had widest link with *Cucurbita* sp, followed by *Cucumis sativus* and *Luffa aegyptica*. Another species from same genus *A. lewiisi* was found to be second most abundant flower visitor that visited 10 plant species and had widest link with *Lu. aegyptica* followed by *Cucurbita* sp. and *Luffa acutangula*. Both the beetles from genus *Aulacophora* visited similar kind of flowers, typically cucurbits *viz. Cucurbita* sp., *Cu. sativus*, *Lu. aegyptica* and *Lu. acutangula* during autumn and summer seasons. Individuals of beetles *Mo. signata* and *Cryptocephalus* sp. were mainly noted on flowers of Rose plant (*Rosa* sp.). Beetle species *Mi. univittata* was the most generalist flower visitor among the all, found visiting on flowers of 16 plant species out of the total 27 plants observed during the study. *Mi. univittata* was major and sometimes only flower visitor for plants *Am. lividus*, *Oscimun sanctum* and *Capsicum* sp. Ladybird species were found occasionally on floral parts; *Co. septempunctata* mainly visited on *B. campestris* and *Brassica an*. *Co. transversalis* and *Ch. sexmaculata* were found on flowers of *S. melogena* only. Four plant species were visited by *H. cucurbitae* but found abundantly on flowers of *Cucurbira* sp. and *Lu. aegyptica.* In the present network *Hycleus* sp. was found to visit flowers of three plant species among them the most visited plant was *Hibiscus* sp. (Figure 4).

Both pumpkin beetle species were found mostly during autumn and summer seasons; *A. foveicollis* was found abundantly on flowers of *Cucurbita* sp., *Cu. sativus* and *Lu. aegyptica*, while *A. lewisii* was found visiting predominantly the flowers of *Lu. aegyptica, Cucurbita* sp. and *Lu. acutangula*. Although *Mi. univittata* was recorded during all four seasons, it was found in higher numbers on flowers of *Am. lividus* and *Lu. aegyptica* during autumn season. *Hycleus* sp., *Ivalia* sp. and *Popillia japonica* were found only during summer season, of them former one was found mostly on *Hibiscus* sp. flowers white latter two species were found exclusively on *Abelmoschus esculentus* flowers. During winter and spring seasons, *Co. septempunctata* was found most dominant among other beetle species; and found visiting *B. campestris* and *B. napus.* Rose flowers were found visited mostly by *Mo. signata* and *Cryptocephalus* sp. during these seasons, along with them a few individuals of *Co. septempunctata* were also recorded from Rose flowers. Only individual of *Meloe sp.* on *B. campestris* during winter season, and only individual of *Ethomela* sp. on *Coriandrum sativum* during spring season were recorded (Annex III).

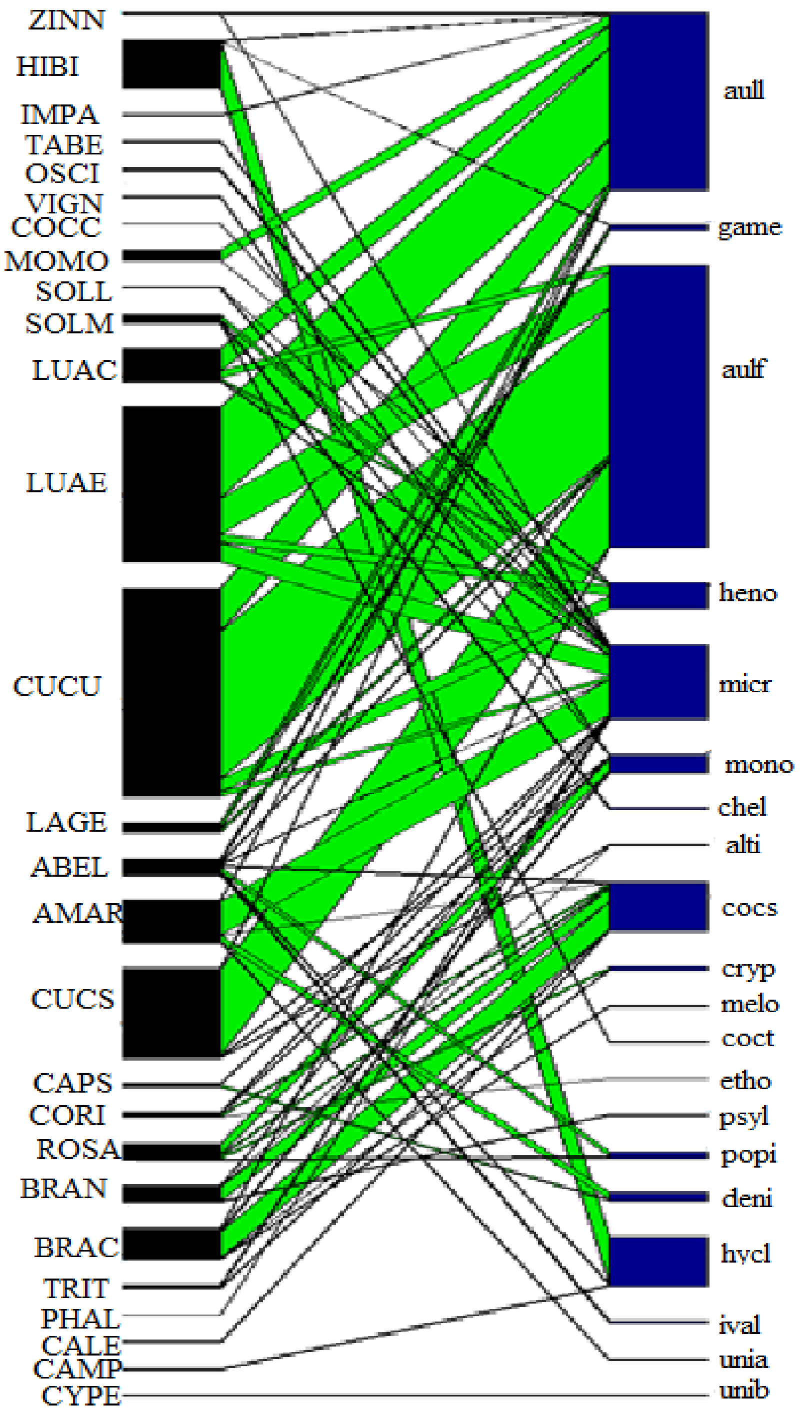

Figure 4. Plant-Pollinator Interaction Network

[**Plant species (on left)**: ZINN-*Zinnia* sp., HIBI-*Hibiscus* sp., IMPA- *Impatiens balsamina*, TABE-*Tabernaemontata divaricate*, OSCI-*Oscimum sanctum*, VIGN-*Vigna mungo*, COCC-*Coccinia grandis*, MOMO-*Momordica charantia*, SOLL-*Solanum lycopersicum*, SOLM-*Solanum melogena*, LUAC-*Luffa acutangula*, LUAE-*Luffa aegyptica*, CUCU-*Cucurbita* sp., LAGE-*Lagenaria siceraria*, ABEL-*Abelmoschus esculentus*, AMAR-*Amaranthus lividus*, CUCS-*Cucumis sativus*, CAPS-*Capsicum* sp., CORI-*Coriandrum sativum*, ROSA-*Rosa* sp., BRAN-*Brassica napus*, BRAC-*Brassica campestris*, TRIT-*Triticum aestivum*, PHAL-*Phalaris* sp., CALE-*Calendula officinalis*, CAMP-*Campsis* sp., CYPE-*Cyperus rotundus*; **Beetle species (on right)**: aull-*Aulacophora lewisii,* game-*Gametis versicolor,* aulf-*Aulacophora foveicollis,* heno-*Henosepilachna cucurbitae,* micr-*Micraspis univittata,* mono-*Monolepta signata,* chei-*Cheilomenes sexmaculata*, alti-*Altica* sp., cocs-*Coccinella septempunctata,* cryp-*Cryptocethalus* sp., melo-*Meloe* sp., coct-*Coccinella transversalis,* etho-*Ethomela* sp., psyl-*Psylliodes* sp., popi-*Popillia japonica*., deni-*Denierella* sp., hycl-*Hycleus* sp., ival-*Ivalia* sp., unia-Curculionidae sp.1, unib-Curculionidae sp.2]

5. DISCUSSIONS

5.1. Diversity of Flower Visiting Beetles

Flower visiting beetle fauna of Bheemdatta Municipality were observed in vegetable and home gardens where 20 species belonging to five family were listed as flower visiting beetles. Among the recorded families Chrysomelidae was the most abundant followed by Coccinellidae, Meloidae, Scarabaeidae and Curculionidae with temporal variations during sampling periods. The number of species in Coleoptera were found to increase from May, peaked in June, after that in August decreased rapidly (Inoue et al. 1990), here in this study as well species diversity and richness (H'=1.60 & S=11) was highest in summer (i.e. in July) though abundance was highest during autumn season. Total abundance of flower visiting flies was found highest in rainy season but visitors of more number of families were observed in dry seasons (Souza-Silva et al. 2001). Likewise seasonal bees were abundant during dry seasons in seasonal neotropical habitats in Costa Rica (Heithaus 1979); also, in nectar thieving flower visiting ants of Brazilian Caatingas, richness and evenness remained equal in all seasons while diversity was found more in green seasons versus dry season (Brito et al. 2012), suggesting each flower visitor group pose seasonal variation in their diversity and abundance. In the present study most observed beetles were Chrysomelids and were more abundant in autumn season (October). There was good blooming in Cucurbitaceous plants during October and availability of enough floral resources might resulted in highest abundance of Chrysomelidae flower visitors in this season. In a similar way, during winter and spring *Co. septempunctata* were most abundant and visited mostly flowers of Brassicaceae family. Coccinellidae were recognized as predators (Inoue et al. 1990) and this fact support the abundance of *Co. septempunctata* on flowers of *B. campestris and B. napus* as aphid pests infest these plants and the beetle visits flowers and tip shoots to feed upon the aphids.

Since anthophagus species rely on flowering seasons of host plants and presence of plants with similar traits attract similar pollinators. In the present study, more similar beetles were recorded in autumn and spring than other season pairs because of the occurrence of similar plant species in both seasons. Similarity Index was least for season pairs spring and autumn; and spring and summer, as there was distinctly different in pairing seasons.

Most of the beetle species observed and identified in this study were commonly found and known to this region. Few of them were found poorly documented as flower visiting species, such species were explained here. *Denierella* Kaszab, 1952 was observed on tip shoots and flowers of *Capsicum* sp. and on inflorescence of *Am. lividus.* This species was described from type species *Cantharis incompleta* Fairmaire, 1896, later (Kaszab 1952) proposed as new genus and finally confirmed as valid in latest taxonomic publication of Meloidae (Bologna & Pinto 2002) and found reported from India, South China, Burma and Thailand. This genera is very similar to *Epicauta* Dejean, 1834 and can be distinguished only by two rows of teeth along ventral margin of dorsal blade of tarsal claw (Bologna & Pinto 2002).

Only a few individuals of *Ivalia* sp. were found on flowers of Okra (*Ab. esculentus*) in compared to found on leaves and stems from plots where they were present. This genus is previously reported in Asia from the Nilgiri Hills in South India (Duckett et al. 2006), Hong Kong (Damaška & Aston 2019), Malaysia, Philippines, Taiwan and mainly identified as moss-inhabiting beetle. *G. versicolor* was recognized mostly as pest different plants such as Brinjal, Sunflower, Okra, Cotton and others; where the beetle was found infesting on tender shoots and petals of flowers (Chinna Babu Naik et al. 2019, Patel et al. 2020, Ray & Banerjee 2022). *G. versicolor* was found majorly on Okra flowers which is in contrast to available published works where the beetle was observed on floral parts of Sunflowers where they fed on petals, pollens, nectars and ovaries (Ray & Banerjee 2022). In literatures this beetle can be found under names *Oxycetonia versicolor* and *Cetonia versicolor* using synonyms. Differences in colour and white markings were treated as ‘phases’ or ‘varieties’ and reported accordingly. Beetles of this genera were recorded as pollinators of different fruit, horticulture and wild plants in Korea (Choi & Jung 2015).

5.2. Plant-Pollinator Interactions

Interaction between plant species and beetle fauna was established by constructing bipartite plant-pollinator network, where number of individuals of beetle species that visit particular plant within sampling time was used to develop network. To better understand ecological systems by identifying patterns of interaction between species network based analyses were considered as important methods. In forest ecosystems floral hosts preferred by Coleoptera were the plant families Rosaceae, Saxifragaceae, Lauraceae, Caprifoliaceae and Compositae (now Asteraceae) where beetle family Chrysomelidae was regarded as generalist visitor and found on almost every plant family (Inoue et al. 1990). Chrysomelidae with eight beetle species within it, was the most dominant and diverse flower visitor during this study, making more than half of the total interactions.

Majority of vegetable plants in the study area such as Cucumbers, Eggplant, Gourds, Mustard, Okra, Pumpkins, Squashes are grouped as insect mediated cross-pollinating flowers either by pollens from same plant or from different plants of same species. Both self and cross pollinated plants get benefited by insect pollinators. Cucurbit blossoms open immediately after sunrise and are remain so until the late afternoon or early evening, therefore they are only open for a brief period of time each day (Westerfield 2000). During non-flowering periods of vegetable or crop plants in agro-ecosystem, flower visiting beetles rely on wild flowers for floral resources. Beetles were found pollinating Beans, Eggplant, Chilli, Cucumber, Mustard and Pumpkin flowers in Jumla district, Nepal (Timberlake et al. 2022). A unique fauna was found supported by *Ab. esculentus* as beetle species *G. versicolor, P. japonica* and *Ivalia* sp. predominantly visited flowers of *Ab. esculentus* than of other plant species in the study area. Likewise of the total 83 visitations made to *Hibiscus* sp. 81 visitations were made by *Hycleus* sp., other two visits were by one individual of *A. lewisii* and *G. versicolor* each.

Here in this network *A. foveicollis* and *A. lewisii* form the core network with plants of family Cucurbitaceae. *A. foveicollis* was found as flower visitor of *La. siceraria, Brassica oleracea, Cu. sativus, Lu. aegyptica, Cucurbita maxima* and *Citrus* sp. (Thapa 2006, Padhiyar & Patel 2021), as results of this study also shown Cucurbitaceae were major hosts of *A. foveicollis* and its congeneric species *A. lewisii* also dependent mainly on plants of same family. *A. foveicollis* abundantly visited *Cucurbita* sp. making widest interaction link with it, while *A. lewisii* visited *Lu. aegyptica* with higher frequencies. Both *A. foveicollis* and *A. lewisii* were observed abundantly during autumn and summer only, which might be due to the availability of flowers in cucurbits during those seasons. Different chrysomelids mentioned as Flea Beetles, Pollen Beetles and Flower beetles were observed on flowers of *Cu. sativus, S. melogena* and *Ab. esculentus* (Thapa 2006).

Co. septempunctata, Henospilachna vigintioctomaculata and other *Coccinella* sp. were identified as pollinators of different vegetable plants *S. melogena, Fagopyrum esculentum,* *Cu. sativus, B. campestris* and *Cucurbita maxima* in Chitwan and Parbat, Nepal (Thapa 2006, Subedi & Subedi 2019); and of orchard flowers and wild plants in Korean fields (Choi & Jung 2015). Ladybird beetles *Co. septempunctata*, *Co. transversalis, Ch. sexmaculata* and *Mi. univittata* were observed as flower visiting beetles during this study among eight species of ladybirds reported previously from different sites of Kanchanpur district (Bista & Omkar 2011). Two of the ladybird species *Co. transversalis* and *Ch. sexmaculata* visited only *S. melogena* flowers. *Co. septempunctata* made widest interaction link with plants *B. camprestris* followed by with *B. napus*; and recorded mainly during winter and spring seasons when there was good flowering in these plants. In the fields adjacent to mustard crops, *Co. septempunctata* was observed on *Coriandrum sativum* along with *Ethomela* sp.

Interactions such as visitation of *Mi. univittata* to 16 out of the total 27 plant species and on the other side visitation of *Co. transversalis* and *Ch. sexmaculata* to *S. melogena* flowers only made the network heterogeneous. Individuals of *Denierella* sp. were found crawling on floral parts of *Am. lividus* and *Capsicum* sp. in the home gardens during late afternoon. Which is supported by (Werner et al. 1966) where adults of many species of Meloidae were found feeding on foliage or blossoms of plants during daytime, and plant feeding species had very specific preferences such as plant families Solanaceae, Leguminosae, Amaranthaceae, and Compositae. But in contrast to that only specimen of *Meloe* sp. was observed on *B. campestris* and *Hycleus* sp. fed mostly on flowers of *Hibiscus* sp.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

This study documented 20 species of beetles as flower visitors in vegetable and home garden plants and found that species composition and abundance of flower visitors vary according to season in response to availability of their preferred host plant flowers in the study area. The flower visiting beetles were highly diverse and rich in summer, most abundant in autumn while more even in spring. Autumn and summer seasons share more similar type of fauna than other pair of seasons. Network analysis showed *A. foveicollis* and *A. lewisii* as major visitors throughout the study period visiting mainly cucurbit flowers making widest interaction link to *Cucurbita* sp. and *Lu. aegyptica* respectively. *Mi. univittata* was the most generalist flower visitor found visiting on flowers of 16 plants out of total 27 plants observed.

6.2. Recommendations

Some recommendations made from the present study are as follows:

i. Mouthpart modifications of the flower visiting beetles can be studied in detail so as to find out their service in pollination.
ii. Proportion of damage they cause to pollen load they carry can be investigated and compared to refer them on the basis of major service they provide, as they are pests or pollinators.
iii. Abundance and seasonality of flower visiting beetles could indicate their role in ecosystem so emphasis should be given to such studies
iv. Inventory of flower visiting beetles along with pollen analysis should be done, as it could give more information about dependence of beetles to plants and vice-versa.

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ANNEX

Annex I: Distinguishing Taxonomic Features of Identified Taxa

S.N.	Beetle Taxa	Identifying Characters Examined
1	*Aulacophora foveicollis*	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.
2.	*Aulacophora lewisii*	Antennomeres-11, 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.
3	*Monolepta signata*	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
4	*Psylliodes* sp.	Antennomeres-10, filiform, completely black and tiny beetles
5	*Altica* 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.
6	*Ivalia* 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,.

7.	*Cryptocephalus* 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,.
8.	*Ethomela* sp.	Procoxal cavities closed, claws simple, with at most angulation at base, Pronotal angles without trichobothria, third tarsomere distinctly bilobed, apical palpomere not broader than penultimate, black beetle, genal ridge and groove present, frontoclypeal groove usually reduced to a pair of lateral pits
9	*Coccinella septempunctata*	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 elytral 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
10	*Coccinella transversalis*	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 elytral 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, postcoxal plates of first abdominal sternite have diagonal furrow, bright red or orange elytra with a black band down the midline and two lateral three lobed markings
11	*Cheilomenes sexmaculata*	Pronotum with anterior border always much more strongly curved laterally, usually arcuate medially, hind border without a groove 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
12	*Micapsis univittata*	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 elyral 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, marks on pronotum curved backward, two median larger black spots on pronotum.
13	*Henosepilachna cucurbitae*	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
14	*Denierella* sp.	Maxillary palp four segmented, forefemora with apical half of ventral surface slightly excavated, dorsal blade of tarsal claws with two rows of teeth along ventral margin. Black coloured beetle with silver vertical line on elytra
15	*Meloe* sp.	Maxillary palp four segmented, forefemora without a ventroapical excavation, dorsal blade of tarsal claw smooth, wingless with elytra abbreviated, elytra reduced only extending

		upto abdominal tergum II, abdominal terga completely black, pronotum uniformly dark in colour, head completely dark, elytra overlapping at base and unicolorous, dark
16	*Hycleus* 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 completey 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 furrowed anterior border area, Pronotum with a very fine median line and depression at centre of disk.
17	*Gametis versicolor*	Oval and flattened beetle, orange or yellowish elytra and white dots on sides of elytra, not shiny, white on pronotum restricted to a narrow lateral border on each side, a white dot on tip of scutellum
18	*Popillia japonica*	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,

Annex II: Host Plants Visited by Flower Visiting Beetles during Sampling Period

S.N.	Family	Scientific Name	Common Name	English Name
1	Brassicaceae	*Brassica campestris*	Lahi/ Sarson	Rapeseed
2	Brassicaceae	*Brassica napus*	Todo/ Gobi Sarson	Rapeseed
3	Cucurbitaceae	*Luffa acutangula*	Toriya	Ridged Gourd
4	Cucurbitaceae	*Luffa aegyptiaca*	Ghiraula	Sponge Gourd
5	Cucurbitaceae	*Cucumis sativus*	Kakra	Cucumber
6	Cucurbitaceae	*Lagenaria siceraria*	Lauki	Bottle Gourd
7	Cucurbitaceae	*Cucurbita sp.*	Farsi	Pumpkin
8	Cucurbitaceae	*Coccinia grandis*	Kundru	Kundru
9	Cucurbitaceae	*Momordica charantia*	Karela	Bitter Gourd
10	Solanaceae	*Capsicum annuum*	Khursani	Chillies
11	Solanaceae	*Solanum melogena*	Vanta	Brinjal
12	Solanaceae	*Solanum lycopersicum*	Tamatar	Tomato
13	Fabaceae	*Vigna mungo*	Kalo Daal/ Mas	Black gram
14	Poaceae	*Triticum aestivum*	Gahu	Wheat
15	Poaceae	*Phalaris sp.*		
16	Amaranthaceae	*Amaranthus lividus*	Marshi/ Latte	Amaranth
17	Malvaceae	*Hibiscus* sp.	Ghanti Phool	Hibiscus
18	Malvaceae	*Abelmoschus esculentus*	Vindi	Okra
19	Rosaceae	*Rosa* sp.	Gulab	Rose
20	Bignoniaceae	*Campsis* sp.		Trumpet Vine
21	Cyperaceae	*Cyperus rotundus*	Mothe	Java Grass
22	Apiaceae	*Coriandrum sativum*	Dhaniya	Coriander
23	Asteraceae	*Calendula officinalis*		Pot Marigold
24	Asteraceae	*Zinnia* sp.	Chhitke ful	
25	Lamiaceae	*Oscimum sanctum*	Tulasi	Holy Basil

26	Apocynaceae	*Tabernaemontata divaricate*		Crape Jasmine
27	Balsaminaceae	*Impatiens balsamina*	Tiuri Phool	Balsam Flower

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

Autumn Season

Host Plants/ Beetle Species	*A. foveicollis*	*A. lewisii*	*G. versicolor*	*H. cucurbitae*	*Mi. univittata*	*Denierella* sp.	*Mo. signata*	Cucurlionidae sp.1	*Ch. sexmaculata*	*Altica* sp.
Zinnia sp.	0	1	0	0	0	0	0	0	0	0
Hibiscus sp.	0	0	1	0	0	0	0	0	0	0
Impatiens balsamina	0	1	0	0	0	0	0	0	0	0
Tabernaemontata divaricate	0	0	0	0	1	0	0	0	0	0
Oscimum sanctum	0	0	0	0	1	0	0	0	0	0
Vigna mungo	0	0	0	0	0	0	1	0	0	0
Coccinia grandis	0	0	0	0	1	0	0	0	0	0
Momordica charantia	0	1	0	0	0	0	0	0	0	0
Solanum lycopersicum	0	0	0	0	1	0	1	0	0	0
Luffa acutangula	1	1	0	1	0	0	0	0	0	0
Luffa aegyptica	1	1	0	1	1	0	0	0	0	0
Cucurbita sp.	1	1	0	1	1	0	0	0	0	0
Lagenaria siceraria	1	1	0	0	0	0	0	0	0	0
Abelmoschus esculentus	1	0	1	0	1	0	0	0	0	0
Solanum melogena	0	0	0	0	1	0	0	0	1	0
Amaranthus lividus	0	1	0	0	1	0	0	1	0	0
Cucumis sativus	1	0	0	0	0	0	1	0	0	1
Capsicum annuum	0	0	0	0	1	1	0	0	0	0

Winter Season

Host Plants/ Beetle Species	*Altica* sp.	*Co. septempunctata*	*A. foveicollis*	*Ch. sexmaculata*	*Mo. signata*	*Mi. univittata*	*Cryptocephalus* sp.	*Meloe* sp.
Solanum melogena	0	0	0	1	0	0	0	0
Amaranthus lividus	0	0	0	0	0	1	0	0
Coriandrum sativum	0	1	0	0	0	0	0	0
Rosa sp.	0	0	0	0	1	0	1	0
Brassica napus	1	1	0	0	0	0	0	0
Brassica campestris	0	1	1	0	1	0	1	1

Spring Season

Host Plants/ Beetle Species	*Psylliodes* sp.	*Co. septempunctata*	*Mi. univittata*	*Mo. signata*	*Cryptocephalus* sp.	*Co. transversalis*	*Ethomela* sp.
Triticun aestivum	0	1	1	0	0	0	0
Zinnia sp.	0	0	1	0	0	0	0
Solanum melogena	0	0	1	0	0	1	0
Phalaris sp.	0	0	1	0	0	0	0
Coriandrum sativum	0	1	1	1	0	0	1
Brassica napus	1	1	1	0	0	0	0
Calendula officinalis	0	1	0	0	0	0	0
Amaranthus lividus	0	1	1	0	0	0	0
Rosa sp.	0	1	0	1	1	0	0

Summer Season

Host Plant	*A. foveicollis*	*A. lewisii*	*P. japonica*	*Denierella* sp.	*Mi. univittata*	*Hycleus* sp.	*G. versicolor*	*Co. septempunctata*	*Ivalia* sp.	Curculionidae sp2	*Henosepilachna* sp.
Cucurbita sp.	1	1	0	0	0	0	0	0	0	0	0
Amaranthus lividus	0	0	0	1	1	0	0	0	0	0	0
Campsis sp.	0	0	0	0	0	1	0	0	0	0	0
Rosa sp.	0	0	1	0	0	0	0	0	0	0	0
Cyperus rotundus	0	0	0	0	0	0	0	0	0	1	0
Luffa aegyptica	0	1	0	0	0	0	0	0	0	0	0
Abelmoschus esculentus	0	0	1	0	0	1	1	1	1	0	0
Luffa acutangula	1	1	0	0	1	0	0	0	0	0	0
Lagenaria siceraria	1	1	0	0	0	0	1	0	0	0	0
Hibiscus sp.	0	1	0	0	0	1	0	0	0	0	0
Cucumis sativus	1	1	0	0	0	0	0	0	0	0	0
Momordica charantia	0	1	0	0	0	0	0	0	0	0	1

PHOTO PLATES

Aulacophora foveicollis

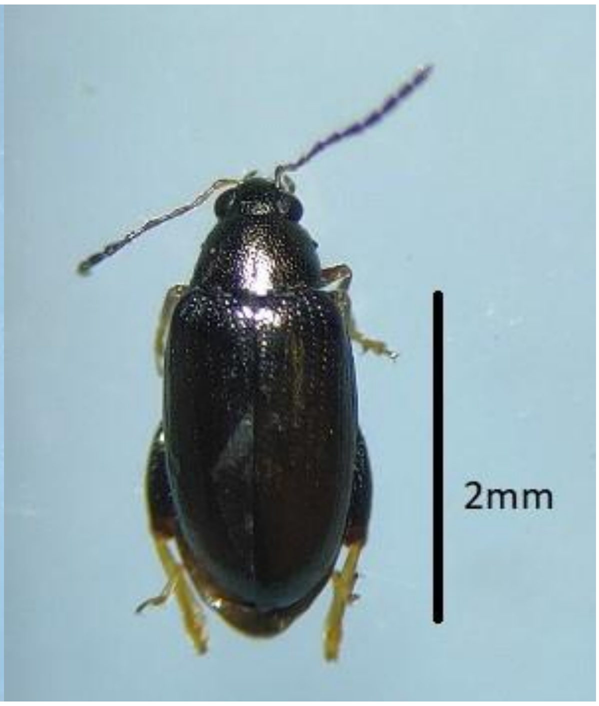
(CDZMTU-COL-24)

Aulacophora lewisii

(CDZMTU-COL-25)

Monolepta signata

(CDZMTU-COL-26)



Psylliodes sp.

Ivalia sp.

Cryptocephalus sp.

Ethomela sp.

Coccinella septempunctata
(CDZMTU-COL-27)

Coccinella transversalis
(CDZMTU-COL-28)

Cheilomenes sexmaculata
(CDZMTU-COL-29)

Micraspis univittata
(CDZMTU-COL-30)

Hycleus sp.

Denierella sp.

Gametis versicolor
(CDZMTU-COL-31)

Popillia japonica
(CDZMTU-COL-32)

Beetles on Flowers