DIVERSITY OF INSECT POLLINATORS ON MUSTARD PLANT (*Brassica campestris* L. 1753) IN ITAHARI, SUNSARI, NEPAL

Submitted by

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Submitted to

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Institute of Science and Technology
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Lainchaur, Kathmandu
Nepal

July, 2022

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 of any degree. All sources of information have been specifically acknowledged by reference to the author(s) or institution(s).

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RECOMMENDATION

It is certified that the dissertation work entitled, Nepal **"DIVERSITY OF INSECT POLLINATORS ON MUSTARD PLANT (*Brassica campestris* L. 1753) IN ITAHARI, SUNSARI, NEPAL"** has been carried out of by **Mrs. Nirmala Gautam** for the partial fulfillment of the Master of Science in Zoology with special paper "Entomology" under my supervision. This entire work is a record of her original research carried out in field and the laboratory. The outcome of this work has not been published or submitted for any other academic degree to the best of my knowledge.

I recommended that this dissertation work for approval and be accepted as the partial fulfillment of Master of Science in Zoology, Amrit Campus, Lainchaur, Kathmandu, Nepal.

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LETTER OF APPROVAL

On the recommendation of supervisor this thesis submitted by Mrs. Nirmala Gautam entitled **"DIVERSITY OF INSECT POLLINATORS ON MUSTARD PLANT (*Brassica campestris* L. 1753) IN ITAHARI, SUNSARI, 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

This thesis work submitted by Mrs. Nirmala Gautam entitled **"DIVERSITY OF INSECT POLLINATORS ON MUSTARD PLANT (*Brassica campestris* L. 1753) IN ITAHARI, SUNSARI, NEPAL"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

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Nirmala Gautam

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LIST OF ABBREVIATIONS

APG	Angiosperm phylogeny group
Dec	December
E	East
Feb	February
FAO	Food and agriculture organization
Ha	Hectare
IPBES	IntergovermentalPlatform on Biodiversity and Ecosystem Services
IGKV	Indira Gandi Krishi Vishwavidyalaya
Jan	January
Km^2	Square Kilometer
L	Linnaeus
Mt	Metric Ton
MoAC	Ministry of Agriculture and Co-operatives
Mm	Millimeter
M	Meter
M^2	Square meter
Nov	November
N	North
No.	Number
S.N	Serial Number
Sp	Species
U.S.	United States
°C	Degree celcious
%	Percentage

ABSTRACT

Mustard is winter season oilseed crops of Nepal. Insect pollination increase yield and quality of the fruits. Insect pollinators and flowering plants have mutual relationships. Various insect groups play an important role in pollination of different agricultural, horticultural and medicinal plants. The study was done in Itahari, Sunsari, Nepal to explore the diversity of pollinator insects on mustard plant. Field visit was done in flowering season of mustard in two years (2020-21 and 2021-22). Altogether, Five sampling plots of area $15m^2x15m^2$ was selected randomly in each sampling plots. Pollinator insect species was observed from 10.00 am to 3.00 pm in a day time (twice a week) for three months (Nov-Jan) during the period of year 2020-21 and from (Dec-Feb) during the period of year 2021-22 in planting season of mustard.The study was done in three stages of mustard i.e., non-flowering stage, flowering stage and late stage of flowering (about 10% flowering remaining). Different insects were collected from mustard plant by using sweep net as well as hand picking methods. Altogether, 52 insect species were recorded in both years from 7 different orders and 22 different families. Among them, 34 species were pollinators, 5 species were predators and 13 species were pest. During year 2020-21, 43 species were recorded while 38 species were recorded during year 2021-22. Hymenoptera (67%) was most abundant insect order visiting mustard flowers followed by coleoptera (37%), diptera (35%), lepidoptera (31%) and hemiptera (1%). *Apis cerana* was abundantly found insect species followed by *Apis mellifera, Episyrphus bateatus* and *Anthophora urbana* which were observed in both years. Species diversity was higher in year 2020-21 (Shannon index 3.14, evenness index 0.83613) than year 2021-22 (Shannon index 3.07, evenness index 0.84454). Organic products (Ash, cattle's urine, cattle's dung) are used for the proper production and productivity of crop yield. Pollinator insects as a part of crop management must be considered by farmers for the higher production and productivity of mustard crop.

1. INTRODUCTION

1.1. Background of study

Nepal is rich in plant and insect diversities. They are distributed in terai, mid hills and high hills (Woyke, 1999). Plant-insect interactions shows mutualistic, antagonistic and communalistic relationship. Most of the flowering plants are pollinated by animals. Agricultural production forms important economic sector where the quality is increased by pollination (Klein *et al.*, 2007; Gallai *et al.*, 2009). Insect pollinators are important for the agro-ecosystem (Siregar *et al.*, 2016).

Pollination plays as important role in terrestrial ecosystem which provides an ecosystem service for the maintenance of agricultural plant communities. Most angiosperm depends on animals for sexual reproduction (Potts *et al*., 2010; Albrech *et al*., 2012). Pollination occurs from pollen transferred from the anther (male part) to the stigma (female part) of another flower. The pollinators are the biotic agent, animal or vector which help to move the pollen from anther to the stigma of a flower (Willmer *et al.*, 1994; Das *et al*., 2018).Pollination by insect increase crop yield and improve quality of the fruits (Bashir *et al.*, 2018). Insect pollinators and flowering plants have mutual relationships (Bezzi *et al.*, 2010; Arenas and Farina, 2012). Pollinators are not only responsible for the reproduction of wild plant species, but also for pollination of large number food crops for human (Corbet *et al.*, 9991). Pollination increases the seed quality and quantity (Abrol, 2007). It increases the yields in the number of pods, seed per pod, seed weights per plant (Atmowidi *et al.*, 2007). Insect pollination is the most economic and important to increase the yield of crops (Tara and Sharma, 2010; Sushi *et al.*, 2013).Various insect groups play an important role in pollination of different agricultural, horticultural and medicinal herbs crops. It belongs to the orders hymenoptera, diptera, coleoptera, lepidoptera, thysanoptera, hemiptera and neuroptera (Free, 1993; Kearns *et al.*, 1998; Mitra and Parui, 2002; Mitra *et al.*, 2008). Bees are best pollinator because of suitable body size, hairiness, thoroughness, steadfastness, floral constancy and its populations (Stewart, 2002).

Nectar and pollen presence in huge amount in the flowers attracts insects like honeybees, flies, ants and wasp.The pollen grains are sticky and aggregated, which is typical for insect pollinated plants (Cresswell *et al.*, 2004). It is estimated that one-third of the total human food supply relies on insect pollination (Riscu and Bura, 2013; Said *et al*., 2015). Pollinators provide various benefits in food quality and quantity, seed production and fertility leading to a greater next generation of plant species (Miller *et al.*, 2018; Lee *et al*., 2015; Gill *et al*., 2016). Thirty nine of 57 leading world food crops have higher production with pollination with 35% of the world's food supply coming from insect pollinated crops (Klein *et al.*, 2007).

Brassica campestris L. belongs to brassicaceae family (APG, 2009). It is dominant winter season oilseed crops of Nepal and occupies about 85% of the oilseed in the country (Basnet, 2005). It is one of the important cash crops of the Nepal which occupied 224,595Ha area with production of 245,866Mt and productivity of 0.78Mt/Ha, whereas in 2018/19, area increases to 260,307Ha, with production of 280,530Mt and productivity of 1.08Mt/Ha (MoAC, 2018/19). According to FAO, total commercial production of mustard seed was 59.1 million tons worldwide, harvested from 31.7million hectares. Canada and Nepal were the leading producers for 321 thousand metric tons followed by Ukraine, Myanmar, the Russian Federation and U.S (FAOSTAT, 2013). It is mostly grown after monsoon maize in upload and after early rice in lowland of terai, inner terai and mid-hills (Ghimire *et al.,* 2000).

Mustard has green foliage, leaves in which upper leaves partially clasping the stem. The stem is well branched. The branching depends on variety and each terminates in an inflorescence. The inflorescence is an elongated raceme, the flowers are pale yellow, densely clustered at the top with open flowers borne at or above the level of terminal buds and open upwards from the base of the raceme (Downey *et al*., 1980; Subedi and Subedi, 2019). Flower of mustard is formed in the stem elongates after the leaf stop growing which are highly attractive to pollen and nectar feeding insects due to its bilateral, bright yellow flowers (Abrol, 2007). The stem has many branches, small leaves and bright yellow stamens and ovary (Subedi and Subedi, 2019). This crop is important from income generation point of view and is prominent sources of fats, vitamins and protein as compared to cereals and legumes in Nepalese diet (Chaudhary, 2001). Its seeds contain 40-45% oil and 20-25% protein (Hasanuzzaman *et al*., 2008; Subedi and Subedi, 2019).

Brassica crops are very attractive for insect pollinators for a good source of pollens and nectar (Masierowska, 2003). Cross-pollination is favored in mustard and self-pollination can assure pollination at late flowering (Eisikowitch, 1981; Free, 1993; Abrol, 2007). The yellow color of the flower with shallow placement of visible nectar mostly attracts bees, flies and butterflies. It is cross-pollinated crop and requires sufficient pollinating agents for better pollination and seed production. Honeybees have also been documented as the most frequent visitor of mustard flowers (Free and Nuttall, 1968). Honeybees visit rapeseed flowers for collection of both pollen and nectar which results into florets cross-pollination (Williams, 1994; Sharma *et al.,* 2004).This crop benefited from cross pollination and insects play an important role in this process because it is mostly pollinated by insects and has a rapid life cycle, does not self-pollinate and require insects for cross pollination (Stewart, 2002). Insects consider as one among the primary groups of pollinating agents which shows the better association between insects and flower (Ollerton *et al.,* 2011). Insect pollination is the most economic and efficient way to increase the yield of rapeseed (Tara and Sharma, 2010; Sushi *et al.*, 2013).

1.2. Objectives

1.2.1 General Objective

- To explore the diversity of pollinator insects on mustard plant.

1.2.2. Specific Objectives

- To identify the insect species (pollinators and non-pollinators) of mustard plant.
- To estimate variation of insect species on mustard plant.
- To study variation of insect species according to the flowering stages.

1.3. Justification of study

Pollinators performed an important service which supports most of the plant's diversity. It is the significant portion of agriculture which enhances the quality and quantity of the crops. Diversity and abundance of wild insect pollinators play crucial roles in crop pollination, particularly for insect-pollinated crops. Conservation of pollinator's diversity is important for the quality crop yield and also plays role for insect biodiversity. There is lack of studies on insect pollinator of crops and only the little work done in the context of Nepal. Knowledge of specific pollinators of mustard crops is limited in Nepal. There are many reports and research regarding the pollinators of Nepal. Due to continuous use of pesticides and declining of natural habitats, insect pollinators are reducing rapidly which could pose a serious threat on crop plant pollination and seed production. Therefore, this study may enlist pollinator insect species of mustard plants. This research may be helpful to know diversity of pollinator species of mustard. It also helps in future research work in field of insect pollinator species of mustard plants.

1.4. Limitation of study

Collection of insects by light trap, malaise trap was not applicable due to informed consent.

2. LITERATURE REVIEW

Pollination is the most essential regulating, supporting and cultural ecosystem services. Insect plays a great significant role in pollination of mustard plants. It increases a yield and quality of crop. Different studies were carried out in the field of insect pollinators.

Negi and Negi (2021) observed 13 species from 4 orders (hymenoptera, diptera, lepidoptera and coleoptera) in India. Hymenoptera was most diverse insect pollinators on both mustard and cauliflower followed by diptera and lepidoptera. *Apis mellifera* was the most abundant insect species compared to second most abundant *Musca domestica* in cauliflower crops. *A. mellifera* was the most abundant insect in mustard crops during onset and full bloom but *Syrphus* spp was most abundant in the end of bloom compared to *M. domestica* was most abundant during onset and full bloom. Duara and Borah (2020) studied about diversity and abundance of insect pollinators of *Brassica juncea* in Assam, India. It was concluded that 21 species were identified belonging to 4 orders (hymenoptera, lepidoptera, diptera and coleoptera). Among them, hymenopteran species showed a high abundance i.e., *A. cerena, A. dorsata and Trigona. Sp.* followed by lepidopteran, dipteran and coleopteran species visited mustard flower.

Shakeel *et al.* (2019) found four orders i.e., hymenoptera, diptera, lepidoptera and coleoptera. A total of 20 major species of insect pollinators were recorded. The highest abundance of pollinator species belonged to Hymenoptera. The most prominent insect pollinator species were *Apis mellifera* followed by other three honey bee species of *A. cerana, A. florea,* and *A. dorsata* in Saudi. Subedi and Subedi (2019) studied the diversity of insect pollinators and their impact on the mustard plant on Kusma, Parbat, Nepal. Study concluded 16 pollinator insects belonging to five insect orders and nine families. Hymenoptera was the most abundant order visiting the mustard flowers. Bashir *et al.* (2019) found 8,812 specimens of 154 species in 22 families and 2 orders (diptera and hymenoptera) in four forested ecosystems of southern Punjab, Pakistan. Study reported pollinators were broadly categorized in three major groups: bees, wasps and flies. Among the pollinators bees comprised the highest proportion of the total pollinator species.

Singh *et al*. (2018) studied the diversity and abundance of different insect pollinators on mustard (*B. juncea)* at IGKV, Raipur. Total 8 insect visitors belonging to three different ordershymenoptera, diptera and coleoptera were found visiting on mustard flower. The highest contribution of percent relative abundance was observed in the order hymenoptera. Das and Jha (2018) recorded a total 13 insect visitors belonging to order hymenoptera (comprising of 6 species), diptera (comprising of 5 species) and lepidoptera (comprising of 2 species) in India. The abundance of hymenopterans was maximum followed by the dipterans and lepidopterans. Among the hymenopterans *Apis spp*. were observed maximum of 74.52% of the total pollinators.

Mandal *et al.* (2018) found that the total 8 species of pollinator insects of 8 different families in 3 orders and their abundance ranged from 0.5 to 6.6/30 sweeps in gazipur, Bangladesh. Among the pollinators, ensign fly and sweat bee showed higher abundance. Giri *et al.* (2018) studied the abundance of insect pollinators and visitors in rapeseed mustard at student instructional farm in Faizabad, India. Study found that the insects of order hymenoptera namely *Apis cerena, Apis mellifera, Trigona irimidipennis* were the major floral visitors belonging to family Apidae. Devi *et al.* (2017) studied the diversity of insect visitors on mustard at Dr. Y.S. Parmar University of horticulture and forestry in India. A total of 88 insects belonging to 63 genera under 31 families and nine orders were found to visit mustard bloom. Hymenoptera was the most abundant order with 12 families. Diptera was the second most dominant order with four families followed by Lepidoptera with five families. Rijal *et al. (*2017) studied on the pollinator diversity and their effect on rapeseed in Chitwan, Nepal. An experiment was conducted at three agro ecological sites, semi-natural (Megauli), organic (Fulbari) and intensive agriculture (Jutpani) Village Development Committees of Chitwan district in 2012/013 and 20013/014. Hymenoptera appeared in greater number in all sites during the both years followed by Diptera, Lepidoptera and Coleopteran. Highly available Hymenopterans were *A. cerana, A. mellifera, A. dorsata, A. florea.*

Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) concluded that pollinator and the pollination service they provide are threatened by land-use change, agricultural intensification, climate change, pesticide use, pathogens, genetically modified organisms and invasive species (Dicks *et al.*, 2016; IPBES, 2016; Potts *et al.*, 2016). Siregar *et al*. (2016) shows the 43 species of 497 individuals were found on different agricultural land in Jambi, Sumatera, Indonesia. It represents 31 species of 2,127species of 97 individuals in jungle rubber which belongs to three orders (Hymenoptera, Diptera and Lepidoptera). Among them hymenoptera were most abundant in rubber and oil palm plantations and Diptera were dominant in jungle rubber. Choi *et al.* (2015) studied the diversity of insect pollinators in different agricultural crops and wild flowering plants in Korea. All total 368 specie in 115 families of 7 orders were recorded to serves as pollinators in 43 different agricultural crops and wild flower. Pudasaini *et al. (*2015) studied the abundance and diversity of rapeseed insect flower visitors at Jutpani VDC, Chitwan district and found that pollinator fauna of rapeseed included 21 species from six different insect orders whereas hymenopterans (77.95%) were the most abundant insects visiting. Bhowmik *et al.* (2014) carried out study from South Bengal region to explore the diversity of insect pollinators of *Brassica juncea* and their influence on seed yield and quality. Study recorded 19 different insect species under four orders. Among the four orderslepidoptera and diptera showed maximum number of species (six and seven species) followed by hymenoptera (four species) and coleoptera (two species).

Kunjwal *et al.* (2014) observed a total of 30 species belonging to four orders hymenoptera, diptera, lepidoptera and coleopteran visiting mustard, *B. juncea* flowers in India. Hymenoptera were the major insect pollinators. It observed that *A. mellifera* was most abundant species in all the varieties of *B. juncea* than other bees. Goswami and Khan (2014) studied diversity and abundance of different insect visitors on mustard at Pantnagar. A total 19 insect visitors belonging to order hymenoptera (15) and diptera (4) were found to visit the mustard. The abundance of hymenopterans was highest followed by dipterans and others. Lautenbach *et al*. (2012) estimated values of bee pollination at €265 billion in global food supply. Honey bees pollinate 16% of the total of 0.25 million of flowering plant species in the world.

Kumar and Naidu (2010) evaluate about 1200 species of vertebrate pollinators and 80,000 species of insect pollinators are present worldwide and among 80,000 species of insect pollinators 17,533 species are of bee pollinators worldwide, out of these 633 species from 60 genera belongs to 6 families were reported from India.Thapa (2006) observed 50species of insects visited flowers of 17 different species of selected crops during flowering periods in Rampur Chitwan, Nepal. Among the total pollination over 80% is performed by insects and bees contribute nearly 80% of the total pollination. Study concluded bee as a best pollinator. Dhakal (2003) and Atmowidi *et al*. (2007) listed four orders of insect viz. hymenoptera, lepidoptera, diptera and coleoptera occurring in rapeseed field.

3. MATERIALS AND METHODS

3.1. Study area

The study was conducted in the agriculture field cultivated on mustard plant at the Simarbana area, Itahari, Sunsari district, Province 1 eastern part of Nepal. Itahari is a city located in the Sunsari, district in the Koshi Zone of south-eastern Nepal. It is the center of the east-west Mahendra Highway and north-south Koshi Highway. Itahari is 117m above sea level. This region mainly covers terai (lowland) area which is 93.78km^2. It lies between 26^0 40'0N latitude and 87^{0}16'60 E longitude. Itahari falls in tropical climate zone. It has a warm and temperate climate with an average mean daily temperature of 24.6 °C. The temperature ranges between 30-40 ^{0}C during summer and 10-18^{0}C during winter. Summer has much more rainfall. The average annual rainfall is 2007 mm from June to September (Source- SFD Report). The study area consists of land with forest land, grassland and cultivated land which shows wide range of biodiversity.

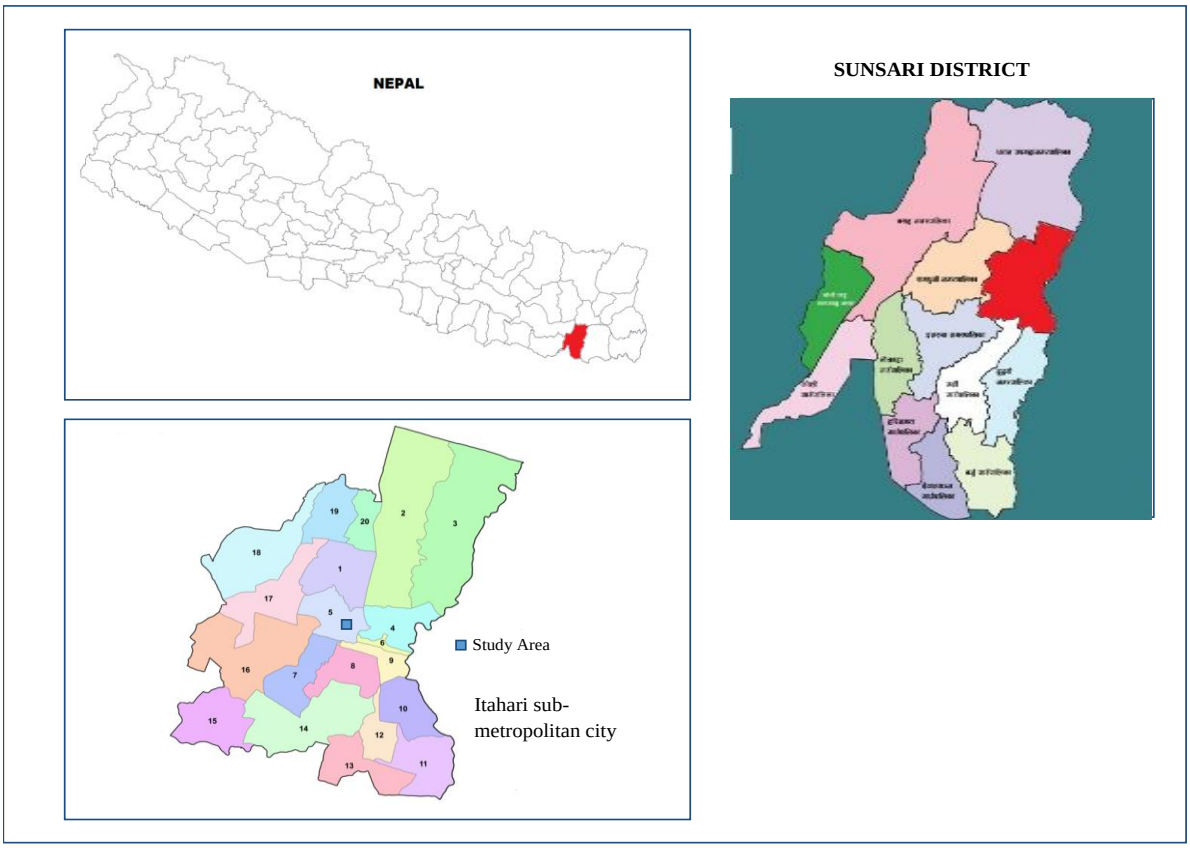

Figure 1. Showing map of study area

3.2. Material

Different materials were used during the study

Equipments:

- Insect net
- Killing jar
- Measuring tape
- Camera
- Stereo zoom microscope
- Triangle paper
- Brush
- Hard paper
- Forceps
- White form
- General pin
- Insect box

Chemicals:

- Ethyl acetate
- Naphthalene balls

3.3 Methods

3.3.1 Collection and Preservation

Field visit was done in the two conjugative year i.e., 2020-21 and 2021-22. Direct observation method was done twice a week for the sampling of pollinator insect species. Sampling area was 10935 square feet (3 kattha). Altogether 5 sampling plots of 12 dhur ($15m^2$x$15m^2$) was selected randomly. Pollinator insect's species was observed from 10.00am to 3.00pm in day time for three months (Nov-Jan) during the period of year 2020-21 and from (Dec-Feb) during the period of year 2021-22 in planting season of mustard. The observation was done in three stages of mustard flowering i.e., non-flowering stage, flowering stage and late stage. The number of pollinators visiting each sampling plots were observed through direct observation method with minimum 45 minutes to1 hour time interval in each plots observing its each 4 sides.

Different insect was collected from mustard plant by using sweep nets as well as hand picking methods.The collected specimens were kept in killing jar containing ethyl acetate. Species were preserved through pinning and carding methods. Carding and pinning of insect were done by general pins.

Butterflies were caught using sweeping net and knocked down using ethyl acetate and were kept in envelope made of triangle paper for the temporary storage.The photographs were taken during the field visit.Collected specimens were deposited in Department of Zoology, Amrit Campus for futher identification.

3.3.2. Identification

The collected specimens were identified with the help of identification keys of Borrer *et al.* (1954). Similarly, butterfly species were identified by Smith (1994). Identification was also done using Thapa (2015) and Bug guide online database.

3.4. Data analysis

Data were analyzed in Microsoft Excel 2007. All data were subjected to statistical analysis to the abundance and diversity indexes of insects. The relative abundance, shannon-wiener diversity index (H) and Pielou's evenness species index (J) was analysed.

Relative abundance (%)

Relative abundance was used to show the genus, family-wise and order-wise composition of insects.

Relative abundance (%) = $(n/N) \times 100$

Where,

n= Number of each individual

N= Total number of individuals

Diversity Indexes

The diversity of insect species was calculated using Shannon-Winner diversity index (H), given by the equation, $H' = -\Sigma Pi\ (lnPi)$

Where,

Pi = the proportion of individuals in the i^{th}species, Pi= ni/N

ni = Impotance value for each species (Number of individuals)

N = Total importance value for each species (Total number of individuals)

ln = the natural log

Σ = the sum of Pi (lnPi)

Pielou's evenness species index (J) given by: J = H/Hmax

Where,

$H' = -\Sigma pi * ln\ (pi)$

Hmax = ln (n)

n is the total number of species richness

4. RESULTS

4.1. Diversity of Insects

All together 7,120 specimens of 52 insect species with 22 different families and 7 different orders were collected from the study sites in two years (2020-21 and 2021-22). Among them 34 pollinator species from five different insect orders (hymenoptera, coleoptera, diptera, lepidoptera and hemiptera) and 12 different families (apidae, syrphidae, muscidae, coccinellidae, formicidae, nymphalidae, pieridae, lycaenidae, vespidae, scoliidae, scarabaeidae and pentatomidae) were found in mustard plant. The insects were identified by some their major characters (Appendix 1). Thirty four insect pollinators, 5 predators and 13 pest were found visiting the mustard plant in both years. (Figure 2).

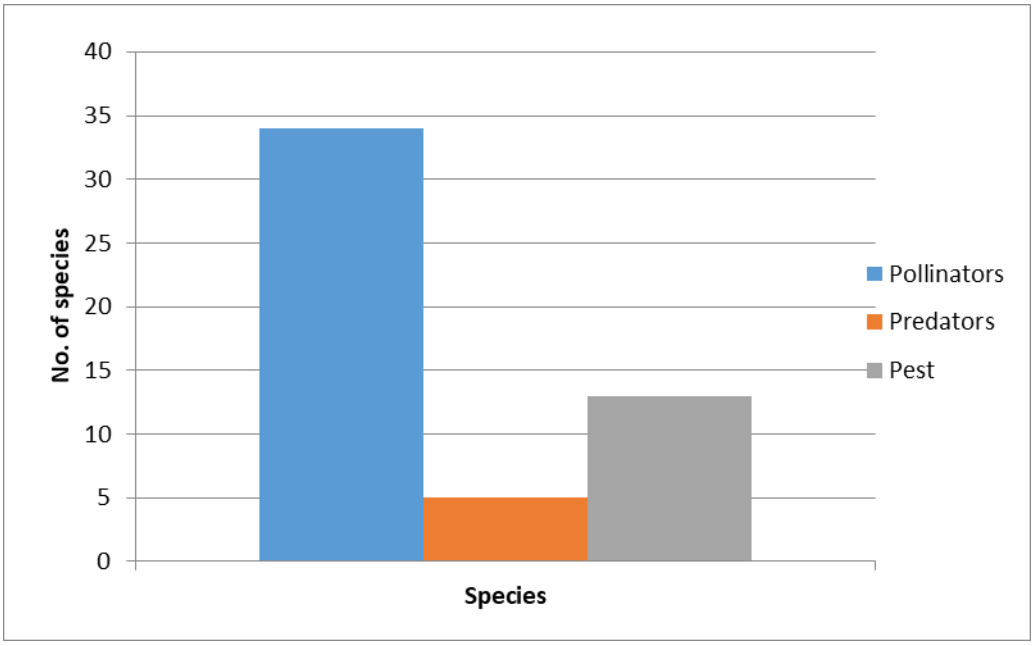

Figure 2. Insect pollinators, Predators and Pest observed on mustard crop in year (2020-21 and 2021-22)

4.2. Relative abundance of insects

Altogether 52 insect species were collected from the study sites during two years. Among them 43 species were recorded in the year (2020-21) and 38 species in the year (2021-22) belonging to 7 different insect orders (hymenoptera, coleoptera, diptera, lepidoptera, orthoptera, odonata and hemiptera).

From the study, it was found that the insects of mustard plant included 7 different orders in both years. Among them hymenopterans (34%) were most abundant order visiting mustard flower followed by coleopterans (21%) and dipterans (18%) and lepidopterans (15%), orthopterans (8%), odonata (3%) and least abundant hemipterans (1%) in year 2020-21 (Figure 3).

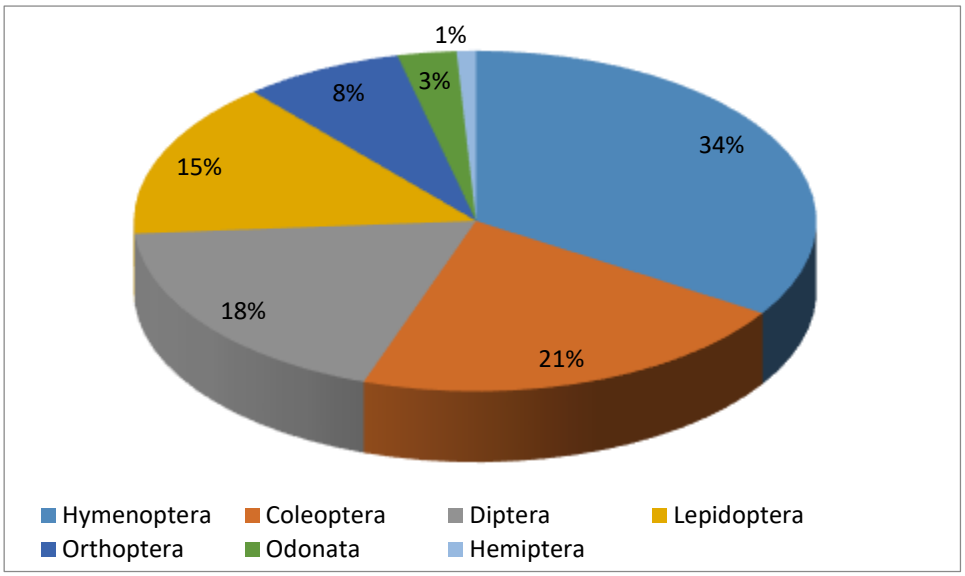

Figure 3. Insect orders found in year 2020-21

Similarly, hymenopterans (33%) was most abundant order visiting mustard flower followed by coleopterans (22%), dipterans (19%), lepidopterans (16%), orthopterans (9%), least abundant odonatan (1%) and hemipterans (1%) in year 2021-22 (Figure 4).

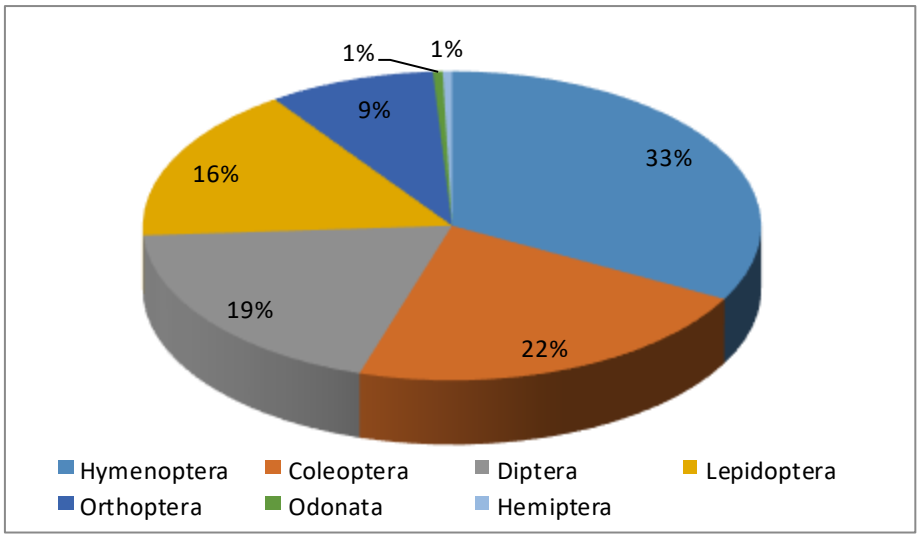

Figure 4. Insect orders found in year 2021-22

In year 2020-21, hymenoptera of four different families of seven orders were recorded. Among them apidae was most abundant family (27.81%) followed by formicidae (4.07%), vespidae (2.05%) and least abundant scoliidae (0.15%). In diptera, syrphidae was highly abundant family (13.62%) followed by muscidae (4.85%). In Coeloptera, four different families were present. Among them coccinnellidae was most abundant family (18.55%) followed by scarabaeidae (1.25%), chrysomellidae (1.13%) and least abundant carabidae (0.20%).Lepidoptera consists of four families i.e., nymphalidae (7.03%), pieridae (3.8%), lycaenidae (3.39%) and pyralidae (0.65%). Similarly, hemiptera consists of two families- pentatomidae (0.82%) and reduviidae (0.07%) of least abundant. Odonata also consists of two different families- gomphidae (1.46%) and libellulidae (1.30%).Orthoptera consists of only one family acrididae (7.59%) (Figure 5).

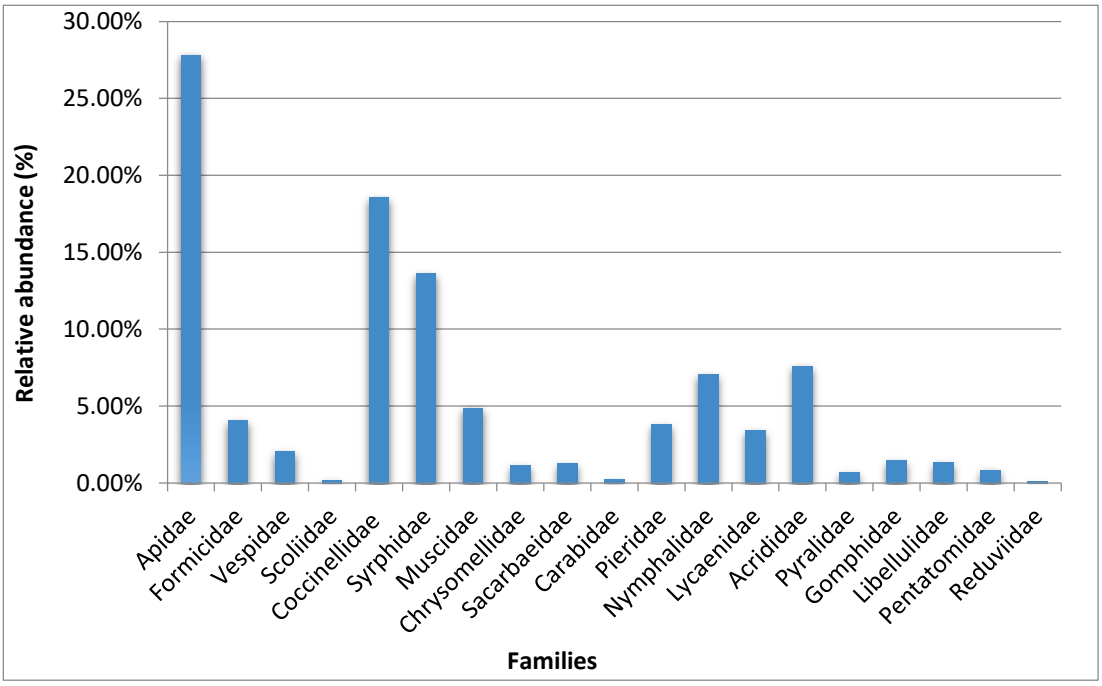

Figure 5. Families of insects with their relative abundance in 2020-21

Similarly, in 2021-22, apidae was highly abundant family of hymenoptera (27.96%) followed by formicidae (4.25%) and least abundant vespidae (0.63%). Sryphidae was most abundant family (12.19%) followed by muscidae (5.32%) in diptera. Three different families of coleopteran were found. Among them coccinnellidae was most abundant family (17.92%) followed by chrysomellidae (2.12%) and least abundant scarabaeidae (1.85%). Lepidoptera consists of four families i.e., nymphalidae (7.65%), pieridae (4.49%), lycaenidae (3.70%) and pyralidae (0.39%). Odonata and hemiptera consist of only one family libellulidae (0.51%) and pentatomidae (0.48%) of insect.Similarly, Orthoptera consists of only one family acrididae (8.75%) (Figure 6).

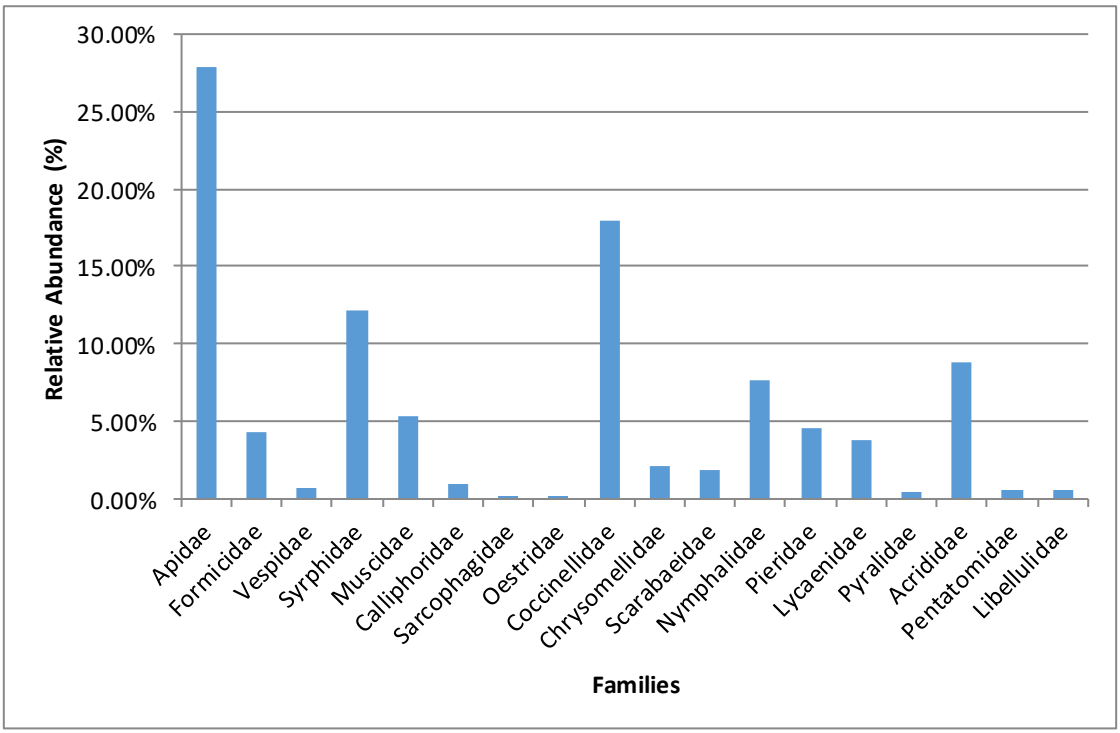

Figure 6. Families of insect with their relative abundance in 2021-22

Apis cerana was the most dominant species (12.35%) followed by *Apis mellifera* (9.50%) in year 2020-21. The second most abundant species was *Oxya hyla* (7.59%). Three species were found from family Syrphidae. Among them *Episyrphus bateatus* (7.49%) and *Eristalis sp* (4.80%) was most abundant species visiting mustard flowers. Seven species were found from family coccinellidae, among them *Chilocorus sp.* (5.37%) and *Coccinella septempunctata* (4.20%) were highly available in mustard plant. Butterfly species, *Gandaca harina* (3.62%), *Heliophorous sena* (3.39%), *Junonia atlites* (3.20%), *Danaus chrysippus* (2.63%), *Junonia almana* (0.62%), *Moduza sp.* (0.33%), *Melanitis sp.* (0.23%) and *Pieris oleracea* (0.18%) were found visiting mustard flowers which was less abundance compared to the bees in year 2020-21. Similarly, three species of wasp *Polites carnifex* (0.91%), *Polites sp.* (0.73%), *Delta conoideum* (0.41%) were found which was least abundant. *Musca domestica* (4.85%), *Camponotus sp.* (4.07%), *Phanogomphus lineatus* (1.46%), *Sympetrum semicinctum* (1.30%), *Cotinis sp*.(1.12%), *Monolepta signata* (0.80%), *Chinavia hilaris*(0.41%) were recorded from mustard field in year 2020-21 (Appendix.2).

In year 2021-22, *Apis cerana* was the most highly abundant species (12.49%) followed by *Apis mellifera* (9.12%). The second most abundant species was *Oxya hyla* (8.36%). Only two species were found from family Syrphidae i.e., *Episyrphus balteatus* (6.99%) and *Eristalis sp.* (5.62%). Nine species were found from family Coccinellidae. Among them *Chilocorus sp.* (5.16%) and *Coccinella septempunctata* (3.16%) were highly abundant species, whereas Butterfly species *Gandaca harina* (4.10%), *Heliophorous sena* (3.70%),

Junonia atlites (3.43%), *Danaus chrysippus* (3.13%), *Junonia almana* (1.09%) and *Pieris rapae* (0.39%) were also found visiting mustard flower. Only two species of wasp *Polites carnifex* (0.48%) and *Vespa sp.*(0.15%) were foundvisting mustard crop which was least abundant compared to *Apis cerana*.Similarly, *Musca domestica* (5.32%),*Camponotus sp.*(4.25%),*Cotinis sp*. (1.52%), *Monolepta signata* (1.67%), *Lucilia sericata* (0.91%), *Sympetrum semicinctum*(0.51%)were also recorded in year 2021-22 (Appendix. 3).

4.3 Species diversity and evenness index

Species diversity (H') and evenness of species (J) during 2020-21 were found to be 3.14487 and 0.83613 (Appendix 4). Similarly, in 2021-22 it was found 3.07032 and 0.84454 respectively (Appendix 5). It was found that, the value of diversity index during year 2020-21 was greater than that of year 2021-22. Since the value of evenness index in both years are nearly equal. It can be conformed that species are quite evenly distributed in both years (Figure 7).

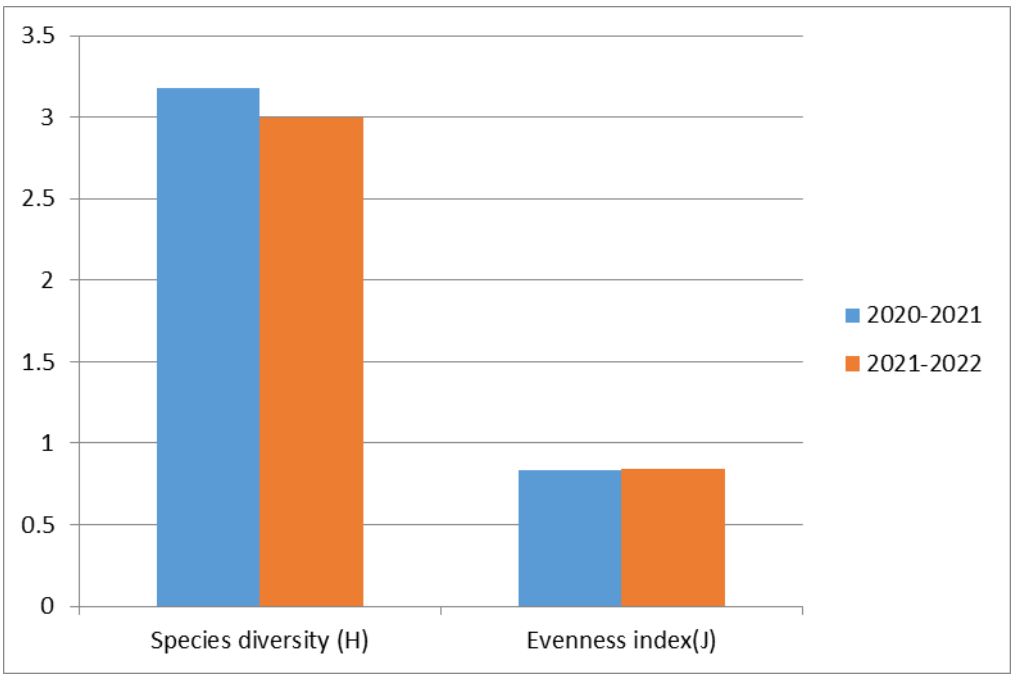

Figure 7. Species diversity (H') and Evenness index in two years (2020-21 and 2021-22).

4.4 Variation of insect on mustard plant in two years

Several numbers of insect species were recorded in mustard plants during the two years. Among them, *Apis cerana* was found in highest in number (882) followed by *Apis mellifera* (664), *Oxya hyla* (566), *Episyrphus bateatus* (517), *Anthophora urbana* (412) in both years. In year 2020-2021, *Acholla sp.* was least in number (3) while in 2021-22, *Sarcophaga sp*. was least in number (5).

Twenty nine similar species were recorded in both years. Some of them are- *Apis cerana, Apis mellifera, Oxya hyla,, Episyrphus bateatus, Anthophora urbana ,Chilocorus sp., Musa domestica, Eristalinus sp, Coccinella septempunctata, Camponotus sp., Gandaca harina, Heliophorous sena, Cycloneda munda, Menochilus sexmaculatus.* However, some of the species like *Eupeodes americanus, Polites sp., Delta conoideum, Moduza sp., Melanitis sp., Prantica aglea, Pieris oleracea, Campsomeriella sp., Cyclocephala sp. and Acholla sp.* were only found during 2020-21. Among them, the number of *Eupeodes americanus* was highest in number (51).Similarly, *Lucilia sericata, Pieris rapae, Phyllophaga sp., Illeis cincta, Propylea dissecta, Vespa sp., Cephenemyia sp.* and *Sarcophaga sp.* were only found in year 2021-22. Among these species, the number of *Lucilia sericata* (30) was highest in number.

4.5 Variation of insect's species according to the flowering stages

Variety of insect species was observed during different phases of mustard plant. Total 43 species were found in year 2020-21 and 38 species were recorded in 2021-22. All together 7 species in nonflowering stage, 43 in flowering stage and 22 species in late phase of flowering were observed in year 2020-21. Similarly, 5 species in non-flowering stages, 38 species in flowering stages and 18 species in late phase of flowering were observed in year 2021-22. *Apis cerana* was highest in number in flowering stages of both years followed by *Apis mellifera, Oxya hyla, Episyrphus bateatus and Anthophora urbana.*

Oxya hyla was found in highest number (12) in non-flowering stage with least in number *Menochilus sexmaculatus* (5). In both flowering and late stage of flowering *Apis cerana* was highly abundantin number (351) and (120). *Cyclocephala sp.* (5) was least in number in flowering stage and *Anemosella sp.* (2) was least in number in late stage of flowering in 2020-2021(Appendix 6). Similarly, in year 2021-2022, *Oxya hyla* was higher in number (12) in non-flowering with least in number *Chinavia hilaris* (5). *Apis cerana* (300) and (111) was highest in number in both flowering and late flowering stages. *Chinavia hilaris* (4) was least in number in flowering stage and *Junonia almana* (4) was least in number in late stage of flowering (Appendix 7).

Study showed that, 3,015 numbers of species were found in year 2020-21 and 2,327 were found in year 2021-22 from the flowering stage. Similarly, on late stage of flowering 799 species were observed in year 2020-21 and 799 were in year 2021-22. Least number of species found in non- flowering stage. Fifty five species were found in year 2020-21 and 36 species were found in year 2021-22 from the non-flowering stage of mustard plant. It shows that high numbers of insect species were observed from the flowering stage and least in non-flowering stage in both years on mustard plant (figure 8).

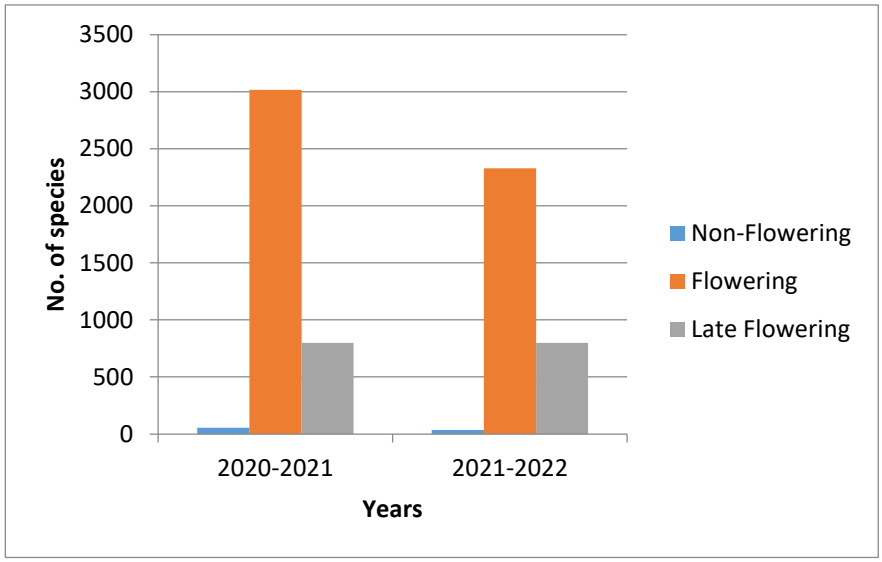

Figure 8.Insect species in different phases of flowering during (2020-21 and 2021-22).

5. DISCUSSION

The present study observed total 52 insect species from the mustard field in both years. Among them, the pollinator insects included 34 species representing 12 different families and five different insect orders (Appendix 1). Out of five orders, Hymenoptera (67%) was most abundant insect order visiting mustard flowers followed by coleoptera (37%), diptera (35%), lepidoptera (31%) and hemiptera (1%). In Hymenopterans, *Apis cerana* (25%) was highly available species followed by *Apis mellifera* (19%) and *Anthophora urbana* (12%). Among the families, apidae (56%) was highly abundant family followed by coccinellidae (32%)and syrphidae (26%).The results is similar to Duara and Borah (2020) which concluded total 21 species belonging to 4 orders (hymenoptera, lepidoptera, diptera and coleoptera) in mustard flowers. Three species of hymenopteran insects showed a high abundance i.e. *A. cerana* (19.43%), *A. dorsata* (18.46%) and *Trigona sp* (16.41%). Negi and Negi (2021) also recorded 13 insect species from 4 different orders hymenoptera, diptera, lepidoptera and coleoptera. Hymenoptera was most observed insect pollinator visiting on mustard crop. *A. mellifera* was the most abundant insect in mustard crop which is opposite to the present study.

Subedi and Subedi (2019) observed 16 species under five different orders and hymenopteran (36%) was the most abundant insect order visiting mustard flowers followed by diptera (34%), coleoptera (17%), lepidoptera (12%) and heteroptera (1%) which is similar with present study. Devi *et al*. (2017) recorded a total of 88 insects belonging to 63 genera under 31 families and nine orders were found to visit mustard flowers. Hymenoptera was the most abundant insect order. The present study resembles to this study withhymenoptera was high in number. Eight insect species belonging to three different orders i.e., hymenoptera, diptera and coleoptera were found visiting mustard flowers. Among them hymenoptera was highly abundant pollinators which was also concluded by Singh *et al*. (2018). Bashir *et al.* (2019) reported a total of 8,812 specimens of 154 species in 22 families and 2 orders (Diptera and Hymenoptera). Pollinators were broadly categorized into three major groups i.e., bees, wasps and flies. Bees comprised the highest proportion of the total pollinator speciesand were most abundant species followed by flies and wasps. This observation was quite similar to present results. Bees were most abundant species followed by beetles, flies and butterflies. Studies carried out by Rijal *et al.* (2017) showed that hymenopteran pollinators appeared in greater number and were the major pollinators found in visiting mustard flowers followed by diptera, coleoptera, lepidoptera, hemiptera and orthoptera in 2012/013. The increasing number of pollinators was observed in the year 2013/014 with similar trends which resembled to present study.

Bhowmik e*t al*. (2014) recorded 19 different insect species under four orders. Order lepidoptera and diptera shared maximum number of species followed by hymenoptera and Coleopteran.In this study, order Coleoptera was also reported to be high (17%) because of their predatory action on the aphids that are commonly found on mustard flower. This results opposite with present study as most species found from the order hymenoptera followed by coleoptera, diptera, lepidoptera and hemiptera. Kunjwal *et al*. (2014) observed a total of 30 species belonging to 4 orders (hymenoptera, diptera, lepidoptera, and coeloptera) and six families visiting mustard (*Brassica juncea)* flowers. Among them hymenoptera were the major insect pollinators which was similar to present study. Pudasaini *et al*. (2015) observed 21 species from six orders in which hymenopteran species were the most abundant insects visiting mustard flowers followed by diptera, lepidoptera, coleoptera, heteroptera and the lowest orthopteran which was resembled with present study.

Seven insect pollinators were found visited on the mustard flowers belonging to the orders diptera, hymenoptera and lepidoptera. Among the insect's order hymenoptera contributed major group of pollinators on *Brassica juncea* crop reported by Giri *et al.* (2018) which is similar to present study. Bajiya and Abrol (2017) observed the blooming crop of the *Brassica napus* was visited by 15 species ofinsects belonging to 4 orders and 7 families. Hymenopterans were the most dominant visitors of the insect pollinators. Among the hymenoptera *Apis mellifera* was highest in number of the visitors of mustard flowers followed by *Apis cerana*, *Apis dorsata* and *Apis florae* which is opposite to present study as *Apis cerana* was most abundant species followed by *Apis mellifera* and *Anthophora urban*a. Das *et al.* (2018) recorded a total of 13 insects belonging to order hymenoptera, diptera and lepidoptera visiting the *Brassica juncea.* Hymenopterans were the pre dominant floral visitorsfollowed by the diptera and lepidoptera. Among the hymenopterans, the honeybees (*Apis spp*.) were observed maximum representing 74.52% of the total pollinators. Among the honeybees, the Italian bee, *A. mellifera* (35.18%) was dominant sequentially followed by the Indian bee, *A. cerana indica* (23.11%) which revelsto present study that *Apis cerana* was highly abundant species followed by *Apis mellifera.*

Diversity of insect species were found to be more in year 2020-21($H^{'}$=3.14487) and less during year 2021-22 ($H^{'}$=3.07032). This found that year 2020-21 has more diverse species than year 2021-22. Since, the value of evenness index in both years, are nearly equal which shows insect's species are quite evenly distributed in both years. Maximum similar insect species were recorded in both years. Flowering stage has various number of species than late stage of flowering and non-flowering stage that is similar to Subedi and subedi (2019).

6. CONCLUSION AND RECOMMENDATIONS

6.1. CONCLUSION

Pollinator insects showed its valuable role in the crops production. Pollination plays an essential process for the propagation of sexually reproducing plants. The study of pollinator species was done in cultivated land on mustard plant at the Simarbana area in Itahari, Sunsari, Nepal. The direct observation method was done for the study. The present study showed that flowers of mustard are very attractive to a wide variety of insects. Altogether, 52 insect species with 22 different families and 7 different orders were recorded from the study sites in two years (2020-21 and 2021-22). Thirty-four insect pollinators belonging to 5 insect orders (hymenoptera, coleoptera, diptera, lepidoptera and hemiptera) and 12 families (apidae, syrphidae, muscidae, coccinellidae, formicidae, nymphalidae, pieridae, lycaenidae, vespidae, scoliidae, scarabaeidaeand pentatomidae) were visited in mustard plants during both years. Hymenopterans are the major insect pollinators found on mustard crops followed by coleopterans, dipterans and hemipterans were least abundant. Apidae was most abundant family followed by coccinellidae and syrphidae. *Apis cerana* was the most dominant species and *Apis mellifera* was second most abundant pollinators visited on mustard flowers followed by *Episyrphus bateatus* and *Anthophora urbana.* Present study recorded twenty-nine similar species. Some of them were (*Apis cerana, Apis mellifera, Oxya hyla, Episyrphus bateatus, Anthophora urbana, Chilocorus sp., Musa domestica, Eristalinus sp, Coccinella septempunctata, Camponotus sp., Gandaca harina, Heliophorous sena, Cycloneda munda, Menochilus sexmaculatus)* in both years. Species diversity ($H^{'}$) and evenness index of species (J) during 2020-21 were found to be higher than that of year 2021-22. Evenness index are nearly equal in both years. However, it shows that 2020-21 was most diverse in species in comparison to 2021-22. Study showed only cypermethrin insecticides used for the control of aphids on the mustard field. However, most of the farmers mainly focused on organic products rather than chemical products for the quality crop production.

6.2. RECOMMENDATIONS

Following future recommendation should be recommend,
The study based on different collecting technique like- Light trap, Malaise trap must be applied in order to find more species on mustard plant.

Integrated pest management (IPM) and organic farming should be highly promoted in order to minimize application of pesticides.

General public and policy-makers should play role in protection and conservation of insect pollinators.

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APPENDICES

Appendix 1. Description of genera with Diagnostic characters.

1. *Apis cerana*, Fabricius, 1793
Hymenoptera, Apidae
Branched plumose hairs on their bodies to assist in pollen collection, Has more prominent abdominal stripes.
Status –Pollinator insect (Thapa, 2015)

2. *Apis mellifera*, Linnaeus, 1758
Hymenoptera, Apidae
Light to dark brown body with pale and dark hairs in bands on abdomen, Distal abscissa of vein M in hind wing absent.
Status – Pollinator insect (Thapa, 2015)

3. *Episyrphus bateatus*, De Geer, 1776
Diptera, Syrphidae
Antenna orange yellow, basoflagellomere orange, darker dorsally, Abdomen parallel sided with mainly yellow, black pilose
Status –Pollinator insect (Negi and Negi, 2021)

4. *Anthophora urbana*, Cresson, 1878
Hymenoptera, Apidae
Clear wings usually held next to the body or overlapping the body, Thick black body with horizontal white stripes.
Status – Pollinator insect (Kunjwal *et al*., 2014)

5. Chilocorus sp.
Coleoptera, Coccinellidae
Abdominal postcoxal line not reaching posterior margin of abdominal sternites, Medium sized with plain orange- red in color.
Status – Pollinator insect (Saeed *et al*., 2016)

6. *Musca domestica*, Linnaeus, 1758
Diptera, Muscidae
Short antennae, a grey thorax with four darker longitudinal stripes, A grey or pale yellow abdomen with darker medium line
Status –Pollinator insect (Giri *et al.,* 2018)

7. *Eristalinus sp*.
Diptera, Syrphidae
The abdomen can vary in color from dark brown to orange, Body covered with fine yellow hairs and resemble as honeybees

Status - Pollinator insect (Devi *et al*., 2017)

8. *Coccinella septempunctata,* Linnaeus, 1758
Coleoptera, Coccinellidae
Elytra orange colored with 7-black spots, body is oval and has domed shape white or pale spots on either side of head
Status –Pollinator insect (Duara and Borah, 2020)

9. *Camponotus sp.*
Hymenoptera, Formicidae
Shiny gaster, dull surface of mandible, lack of erect hairs in the sides of head and cheeks, Small, bicolored carpenter ant with elbow-shaped antennae
Status –Pollinator insect (Choi and Jung, 2015)

10. *Gandaca harina,* Horsfield, 1829
Lepidoptera, Pieridae
Lime yellow butterfly with no markings on the wings, Small to moderate in size with light yellow color.
Status – Pollinator insect (Zapanta *et al*., 2016)

11. *Heliophorous sena,* Kollar, 1844
Lepidoptera, Lycaenidae
Small with metallic blue or dark brown color wings, Hind wings quite often carry delicate tail like prolongation
Status –Pollinator insect (Greeshma, 2010)

12. *Cycloneda munda,* Say, 1835
Coleoptera, Coccinellidae
Small and rounded in size with spotless red to orange wing covers, Pronotum black with a white border and two white lobes which extend back
Status –Pollinator insect (Saeed *et al.,* 2016)

13. *Menochilus sexmaculatus,* Fabricius, 1781
Coleoptera, Coccinellidae
Body is medium, rounded and dorsally glabrous, Elytra generally brownish yellow with black spots and decorated with transverse zigzag patches.
Status – Pollinator insect (Negi and Negi, 2021)

14. *Junonia atlites,* Linnaeus, 1763
Lepidoptera, Nymphalidae
Wings of upperside are grey with dark grayish- brown markings, Body is pale grayish buff above, with pink-black ocelli
Status – Pollinator insect (Devi *et al.,* 2017)

15. *Danaus chrysippus,* Linnaeus, 1758
Lepidoptera, Nymphalidae
The wings are orange, the upper side brighter than the underside, The body is black with many white spots.
Status –Pollinator insect (Duara and Borah, 2020)

16. *Coccinella tranversalis*, Fabricius, 1781
Coleoptera, Coccinellidae
Convex, rounded in size with bright orange or red in color, Elytra are orange with a black stripes down the middle and two roughly 'V' shaped markings on each wing cover.
Status –Predator (Bhowmik *et al*., 2014)

17. *Phanogomphus lineatus,* Selys, 1850
Odonata, Gomphidae
Head olive green with the thorax marked dark brown stripes, Abdomen is dark brown to black and marked along the top with line of elongate, triangular-shaped mark with color greenish to yellow.
Status – Predator (Tennessen, 2019)

18. *Eupeodes americanus,* Weidemann, 1830
Diptera, Syrphidae
Looks like a wasp or bee with big dark red metallic eyes, the body has yellow stripes with transparent and glossy wings
Status – Pollinator insect (Devi *et al*., 2017)

19. *Sympetrum semicinctum,* Say, 1839
Odonata, Libellulidae
Red-brownish or yellow-brownish with amber patches at the bases of the hind wings, Abdomen bright red, orange or yellowish in color.
Status –Predator (Tennessen, 2019)

20. *Cotinis sp.* Burmeister, 1842
Coleoptera, Scarabaeidae
Velvety green or orange with brownish highlights, elytra with area of metallic green and jet black.
Status – Pollinator insect (Dubey *et al.*, 2020)

21. *Polites carnifex*, Fabricius, 1775
Hymenoptera, Vespidae
Large wasp with yellow and black stripped, forewings are folded in half longitudinally their entire length.
Status – Pollinator insect (Thapa, 2015)

22. *Monolepta signata*, Olivier, 1808
Coleoptera, Chrysomellidae
Small in size white spotted beetle, body is domed, oval in dorsal view and often possess metallic luster
Status –Pest (Gangopadhyay and Haldar, 2016)

23. *Polites sp.*
Hymenoptera, Vespidae
Large, long and slender body with bilaterally divided between dull brown and dark coloration antennae, Abdomen with thick, mostly straight yellow bands.
Status –Pollinator insect (Thapa, 2015)

24. *Anemosella sp.* Casatt, 1969
Lepidoptera, Pyralidae
Body drab brown or grey in color, Front wings elongate with broader hind wings.
Status –Pest (Hochkirch *et al.*, 2000).

25. *Junonia almana*, Linnaeus, 1758
Lepidoptera, Nymphalidae
Color bright orange or brown with large spots on wings, Body more or less orange-brown pale beneath with dark brown antennae.
Status –Pollinator insect (Kunjwal *et al*., 2014)

26. *Coccinella hieroglyphica*, Linnaeus, 1758
Coleoptera, Coccinellidae
Head black with two small white patches, elytra is light brown with a pattern of black stripes, spots and patches.
Status – Pollinator insect (Saeed *et al*., 2016)

27. *Bombus sp.*
Hymenoptera, Apidae
Has a distinctive yellow and black striped pattern, Short, pale yellow hairs on their thorax and black hairs on heads, abdomens and legs
Status – Pollinator insect (Choi and Jung, 2015)

28. *Epilachan varivestis*, Dejean, 1837
Coleoptera, Coccinellidae
Oval in shape with creamy yellow color, Adult darken with age until they become an orange with black spots.
Status – Pest (Saeed *et al.*, 2016)

29. *Delta conoideum*, Gmelin, 1790
Hymenoptera, Vespidae

Eyes large, swollen, narrowly notched, Second segment of the metasoma is short with associated tergum bell –shaped.
Status – Pollinator insect (Thapa, 2015)

30. *Moduza sp.*
Lepidoptera, Nymphalidae
The upper side of wings bright reddish brown and centre of wings with white spots, hind wings with crenulated margins and underside whitish grey towards the base and row of dull reddish brown or black spot along the margins.
Status – Pollinator insect (Singh *et al*., 2020)

31. *Melanitis sp.*
Lepidoptera, Nymphalidae
Forewing with two large sub apical black spots each with a smaller spot, Antennae brown or grayish brown annulated with white at apex.
Status – Pollinator insect (Zapanta *et al.*, 2016)

32. *Nezara viridula,* Linnaeus, 1758
Hemiptera, Pentatomidae
Shield-shaped with overall dull green color, the partly green forewing cover and protect the hind wing.
Status – Pest (Baker, 2009)

33. *Prantica aglea,* Stoll, 1781
Lepidoptera, Nymphalidae
The both sides of wings is dark brownish-black in color with glassy markings, Head and thorax black spotted with white in color.
Status – Pollinator insect (Singh *et al*., 2020)

34. *Nebria pallipes*, Say, 1823
Coleoptera, Carabidae
Black shiny colored with slender orange legs, Front wings hard, covering the second pair of wing.
Status – Predator Scavengers (Spence, *et al*. 1976)

35. *Oulema sp.*
Coleoptera, Chrysomellidae
Metallic blue with brownish yellow legs, area behind head is reddish-brown.
Status –Pest (Baker, 2009)

36. *Pieris oleracea*, Harris, 1829
Lepidoptera, Pieridae
Medium-sized with pure white in color, Underside of hind wing and apex of forewing have veins edged with yellow-green or gray green.
Status – Pollinator insect (Duara and Borah, 2020)

37. *Eurydema ornata*, Linnaeus, 1758
Hemiptera, Pentatomidae
Usually red, black in color, Dark marks along the edge of corium.
Status – Pollinator insect (Subedi and Subedi, 2019)

38. *Campsomeriella sp.*
Hymenoptera, Scoliidae
The thorax covered in soft, ginger hairs, Body black with two smoky iridescent pair of wings.
Status – Pollinator insect (Devi *et al*., 2017)

39. *Aulacophora indica*, Gmelin, 1790
Coleoptera, Chrysomellidae
Dark area on the triangular piece at the base of the wing,Red oval with groove across the thorax.
Status – Pest (Dubey *et al.*, 2020)

40. *Cyclocephala sp.* Dejean, 1821
Coleoptera, Scarabaeidae
Prothorax often highly modified for burrowing with large coxae, Stout-bodied with dark brown bright metallic color.
Status – Pollinator insect (Souza *et al*., 2014)

41. *Acholla sp.*
Hemiptera, Reduviidae
Abdomen of female is much border than female, Front tibiae lack spines.
Status – Predator (Swanson, 2011)

42. *Lucilia sericata*, Meigen, 1826
Diptera, Calliphoridae
Metallic green and also copper green in color, Hairy backs, yellow mouthparts and red brown eyes.
Status –Pest (Dubey *et al.*, 2020)

43. *Pieris rapae*, Linnaeus, 1758
Lepidoptera, Pieridae
Small to medium size with white in color, Forewings have one or two dark spot.
Status – Pollinator insect (Choi and Jung, 2015)

44. *Tropidopola cylindrica,* Marschall, 1836
Orthoptera, Acrididae
Brownish in color, Body is long and slender.
Status –Pest (Atwal and Dhaliwal, 2009).

45. *Phyllophaga sp.*
Coleoptera, Scarabaeidae
Reddish brown in color without prominent markings, Body is oval with club lamellate antennae.
Status – Pest (Kathy, 2000)

46. *Illeis cincta,* Fabricius, 1781
Coleoptera, Coccinellidae
Elytra yellowish in color with fairly visible head, a pair of black spot can be found on the pronotum.
Status – Pollinator insect (Saeed et al., 2016)

47. *Propylea dissecta,* Mulsant, 1850
Coleoptera, Coccinellidae
Body small with brown head and black scutellum, elytra brownish with 4 black spot, 2 on each elytron, 1 anteriorly and 1 posteriorly.
Status – Pollinator insect (Choi and Jung, 2015)

48. *Vespa sp.*
Hymenoptera, Vespidae
Head wider, specifically above the mandibles and between the eyes, Banding on the abdomen is yellow and brown
Status – Pollinator insect (Thapa, 2015)

49. *Cephenemyia sp.*
Diptera, Oestridae
Large, gray-brown flies, often very accurate mimics of bumble bee.
Status – Pest (Atwal and Dhaliwal, 2009).

50. *Sarcophaga sp.*
Diptera, Sarcophagidae
Blackish stripes on the gray thorax, Medium to large size with checkered pattern of light and dark gray on the abdomen.
Status – Pest (Das *et al*., 2018)

51. *Oxya hyla,* Serville, 1831
Orthoptera, Acrididae

Body green and yellow in color, Short antennae and tympanum on each side of the first abdominal segment.
Status – Pest (Aryal *et al*., 2016)

52. *Chinavia hilaris,* Say, 1832
Hemiptera, Pentatomidae
Shield-shaped with fully developed wings, Solid light green with piercing and sucking mouthparts.
Status – Pest (Atwal and Dhaliwal, 2009).

Insect pollinators, predator and pest observed on mustard plant in year (2020-21 and 2021-22)

Pollinators

S.N	Species	Order	Family
1	*Apis cerana*	Hymenoptera	Apidae
2	*Apis mellifera*	Hymenoptera	Apidae
3	*Episyrphus bateatus*	Diptera	Syrphidae
4	*Anthophora urbana*	Hymenoptera	Apidae
5	*Chilocorus sp.*	Coleoptera	Coccinellidae
6	*Musa domestica*	Diptera	Muscidae
7	*Eristalinus sp.*	Diptera	Syrphidae
8	*Coccinella septempunctata*	Coleoptera	Coccinellidae
9	*Camponotus sp.*	Hymenoptera	Formicidae
10	*Gandaca harina*	Lepidoptera	Pieridae
11	*Heliophorous sena*	Lepidoptera	Lycaenidae
12	*Cycloneda munda*	Coleoptera	Coccinellidae
13	*Menochilus sexmaculatus*	Coleoptera	Coccinellidae
14	*Junonia atlites*	Lepidoptera	Nymphalidae
15	*Danaus chrysippus*	Lepidoptera	Nymphalidae
16	*Eupeodes americanus*	Diptera	Syrphidae
17	*Polites carnifex*	Hymenoptera	Vespidae
18	*Polites sp.*	Hymenoptera	Vespidae
19	*Junonia almana*	Lepidoptera	Nymphalidae
20	*Coccinella hieroglyphica*	Coleoptera	Coccinellidae
21	*Bombus sp.*	Hymenoptera	Apidae
22	*Delta conoideum*	Hymenoptera	Vespidae
23	*Moduza p.*	Lepidoptera	Nymphalidae
24	*Melanitis sp.*	Lepidoptera	Nymphalidae
25	*Prantica aglea*	Lepidoptera	Nymphalidae
26	*Cotinis sp.*	Coleoptera	Scarabaeidae
27	*Pieris oleracea*	Lepidoptera	Pieridae
28	*Eurydema ornata*	Hemiptera	Pentatomidae

29	*Campsomeriella sp.*	Hymenoptera	Scoliidae
30	*Pieris rapae*	Lepidoptera	Pieridae
31	*Illeis cincta*	Coleoptera	Coccinellidae
32	*Propylea dissecta*	Coleoptera	Coccinellidae
33	*Vespa sp.*	Hymenoptera	Vespidae
34	*Cyclocephala sp.*	Coleoptera	Scarabaeidae

Predator

S.N.	Species	Order	Family
1	*Phanogomphus lineatus*	Odonata	Gomphidae
2	*Sympetrum semicinctum*	Odonata	Libellulidae
3	*Nebria pallipes*	Coleoptera	Carabidae
4	*Coccinella tranversalis*	Coleoptera	Coccinellidae
5	*Acholla sp.*	Hemiptera	Reduviidae

Pest

S.N.	Species	Order	Family
1	*Monolepta signata*	Coleoptera	Chrysomellidae
2	*Anemosella sp.*	Lepidoptera	Pyralidae
3	*Nezara viridula*	Hemiptera	Pentatomidae
4	*Oulema sp.*	Coleoptera	Chrysomellidae
5	*Aulacophora indica*	Coleoptera	Chrysomellidae
6	*Epilachan varivestis*	Coleoptera	Coccinellidae
7	*Lucilia sericata*	Diptera	Calliphoridae
8	*Tropidopola cylindrica*	Orthoptera	Acrididae
9	*Cephenemyia sp.*	Diptera	Oestridae
10	*Sarcophaga sp.*	Diptera	Sarcophagidae
11	*Oxya hyla*	Orthoptera	Acrididae
12	*Chinavia hilaris*	Hemiptera	Pentatomidae
13	*Phyllophaga sp.*	Coleoptera	Scarabaeidae

Appendix 2. Diversity of insects and their relative abundance in 2020-2021

S.N	Species	Order	Family	Total no. Species	Relative abundance (%)
1	*Apis cerana* (Fabricius,1793)	Hymenoptera	Apidae	471	12.29
2	*Apis mellifera* (Linnaeus,1758)	Hymenoptera	Apidae	364	9.50
3	*Oxyahyla* (Serville, 1831)	Orthoptera	Acrididae	291	7.59
4	*Episyrphus bateatus* (De Geer,1776)	Diptera	Syrphidae	287	7.49
5	*Anthophora urbana* (Cresson, 1878)	Hymenoptera	Apidae	212	5.53
6	*Chilocorus sp.*	Coleoptera	Coccinellidae	206	5.37
7	*Musa domestica* (Linnaeus,1758)	Diptera	Muscidae	186	4.85
8	*Eristalinus sp.*	Diptera	Syrphidae	184	4.80
9	*Coccinella septempunctata* (Linnaeus,1758)	Coleoptera	Coccinellidae	161	4.20
10	*Camponotu sp.*	Hymenoptera	Formicidae	156	4.07
11	*Gandaca harina* (Horsfield,1829)	Lepidoptera	Pieridae	139	3.62
12	*Heliophorous sena* (Kollar,1844)	Lepidoptera	Lycaenidae	130	3.39
13	*Cycloneda munda* (Say, 1835)	Coleoptera	Coccinellidae	121	3.15
14	*Menochilus sexmaculatus* (Fabricius,1781)	Coleoptera	Coccinellidae	120	3.13
15	*Junonia atlites* (Linnaeus, 1763)	Lepidoptera	Nymphalidae	116	3.02
16	*Danaus chrysippus* (Linnaeus,1758)	Lepidoptera	Nymphalidae	101	2.63
17	*Coccinella tranversalis* (Fabricius,1781)	Coleoptera	Coccinellidae	67	1.74
18	*Phanogomphus lineatus* (Selys,1850)	Odonata	Gomphidae	56	1.46
19	*Eupeodes americanus* (Weidemann,1830)	Diptera	Syrphidae	51	1.33

20	*Sympetrum semicinctum* (Say,1839)	Odonata	Libellulidae	50	1.30
21	*Cotinis sp.*	Coleoptera	Scarabaeidae	43	1.12
22	*Polites carnifex* (Fabricius,1775)	Hymenoptera	Vespidae	35	0.91
23	*Monolepta signata* (Olivier,1808)	Coleoptera	Chrysomellidae	31	0.80
24	*Polites sp.*	Hymenoptera	Vespidae	28	0.73
25	*Anemosella sp.*	Lepidoptera	Pyralidae	25	0.65
26	*Junonia almana* (Linnaeus,1758)	Lepidoptera	Nymphalidae	24	0.62
27	*Coccinella hieroglyphica* (Linnaeus,1758)	Coleoptera	Coccinellidae	20	0.52
28	*Bombus sp.*	Hymenoptera	Apidae	19	0.49
29	*Epilachan varivestis* (Dejean,1837)	Coleoptera	Coccinellidae	17	0.44
30	*Chinavia hilaris* (Say,1832)	Hemiptera	Pentatomidae	16	0.41
31	*Delta conoideum* (Gmelin,1790)	Hymenoptera	Vespidae	16	0.41
32	*Moduza sp.*	Lepidoptera	Nymphalidae	13	0.33
33	*Melanitis sp.*	Lepidoptera	Nymphalidae	9	0.23
34	*Nezara viridula* (Linnaeus,1758	Hemiptera	Pentatomidae	9	0.23
35	*Prantica aglea* (Stoll,1781)	Lepidoptera	Nymphalidae	8	0.20
36	*Nebria pallipes* (Say,1823)	Coleoptera	Carabidae	8	0.20
37	*Oulema sp.*	Coleoptera	Chrysomellidae	8	0.20
38	*Pieris oleracea* (Harris,1829)	Lepidoptera	Pieridae	7	0.18
39	*Eurydema ornata* (Linnaeus,1758)	Hemiptera	Pentatomidae	7	0.18
40	*Campsomeriella sp.*	Hymenoptera	Scoliidae	6	0.15
41	*Aulacophora indica* (Gmelin,1790)	Coleoptera	Chrysomellidae	5	0.13
42	*Cyclocephala sp.*	Coleoptera	Scarabaeidae	5	0.13
43	*Acholla sp.*	Hemiptera	Reduviidae	3	0.07

Appendix 3. Diversity of insects and their relative abundance in 2021-2022.

S.N	Scientific Name	Order	Family	Total No. Species	Relative abundance (%)
1	*Apis cerana* (Fabricius,1793)	Hymenoptera	Apidae	411	12.49
2	*Apis mellifera* (Linnaeus,1758)	Hymenoptera	Apidae	300	9.12
3	*Oxya hyla* (Serville, 1831)	Orthoptera	Acrididae	275	8.36
4	*Episyrphus bateatus* (De Geer,1776)	Diptera	Syrphidae	230	6.99
5	*Anthophora urbana* (Cresson, 1878)	Hymenoptera	Apidae	200	6.08
6	*Eristalinus sp.*	Diptera	Syrphidae	185	5.62
7	*Musa domestica* (Linnaeus,1758)	Diptera	Muscidae	175	5.32
8	*Chilocorus sp.*	Coleoptera	Coccinellidae	170	5.16
9	*Camponotus sp.*	Hymenoptera	Formicidae	140	4.25
10	*Gandaca harina* (Horsfield,1829)	Lepidoptera	Pieridae	135	4.10
11	*Heliophorous sena* (Kollar,1844)	Lepidoptera	Lycaenidae	122	3.70
12	*Coccinella septempunctata* (Linnaeus,1758)	Coleoptera	Coccinellidae	120	3.64
13	*Junonia atlites* (Linnaeus, 1763)	Lepidoptera	Nymphalidae	113	3.43
14	*Menochilus sexmaculatus* (Fabricius,1781)	Coleoptera	Coccinellidae	112	3.40
15	*Danaus chrysippus* (Linnaeus,1758)	Lepidoptera	Nymphalidae	103	3.13
16	*Cycloneda munda* (Say, 1835)	Coleoptera	Coccinellidae	65	1.97
17	*Coccinella tranversalis* (Fabricius,1781)	Coleoptera	Coccinellidae	60	1.82
18	*Monolepta signata* (Olivier,1808)	Coleoptera	Chrysomellidae	55	1.67

19	*Cotinis sp.*	Coleoptera	Scarabaeidae	50	1.52
20	*Coccinella hieroglyphica* (Linnaeus,1758)	Coleoptera	Coccinellidae	40	1.21
21	*Junonia almana* (Linnaeus,1758)	Lepidoptera	Nymphalidae	36	1.09
22	*Lucilia sericata* (Meigen,1826)	Diptera	Calliphoridae	30	0.91
23	*Polites carnifex* (Fabricius,1775	Hymenoptera	Vespidae	16	0.48
24	*Sympetrum semicinctum* (Say,1839)	Odonata	Libellulidae	17	0.51
25	*Aulacophora indica* (Gmelin,1790)	Coleoptera	Chrysomellidae	15	0.45
26	*Pieris rapae* (Linnaeus,1758)	Lepidoptera	Pieridae	13	0.39
27	*Anemosella sp.*	Lepidoptera	Pyralidae	13	0.39
28	*Tropidopola cylindrica* (Marschall,1836)	Orthoptera	Acrididae	13	0.39
29	*Epilachan varivestis* (Dejean,1837)	Coleoptera	Coccinellidae	12	0.36
30	*Phyllophaga sp.*	Coleoptera	Scarabaeidae	11	0.33
31	*Chinavia hilaris* (Say,1832)	Hemiptera	Pentatomidae	9	0.27
32	*Nezara viridula* (Linnaeus,1758	Hemiptera	Pentatomidae	7	0.21
33	*Bombus sp.*	Hymenoptera	Apidae	9	0.27
34	*Illeis cincta* (Fabricius,1781)	Coleoptera	Coccinellidae	7	0.21
35	*Propylea dissecta* (Mulsant,1850)	Coleoptera	Coccinellidae	5	0.15
36	*Vespa sp.*	Hymenoptera	Vespidae	5	0.15
37	*Cephenemyia sp.*	Diptera	Oestridae	5	0.15
38	*Sarcophaga sp.*	Diptera	Sarcophagidae	5	0.15

Appendix 4. Shannon-Wiener diversity indices (H) and evenness index (J) of insects in 2020- 2021

S.N	Species	No.of species(Ni)	Pi	LnPi	Pi*LnPi
1	*Apis cerana*	471	0.1229444	-2.09602305	-0.257694298
2	*Apis mellifera*	364	0.09501436	-2.35372728	-0.223637883
3	*Oxya hyla*	291	0.07595928	-2.57760105	-0.195792719
4	*Episyrphus bateatus*	287	0.07491517	-2.59140114	-0.194135246
5	*Anthophora urbana*	212	0.05533803	-2.89429545	-0.160164614
6	*Chilocorus sp.*	206	0.05377186	-2.92300498	-0.157175418
7	*Musa domestica*	186	0.04855129	-3.02514049	-0.146874479
8	*Eristalinus sp.*	184	0.04802924	-3.03595028	-0.14581437
9	*Coccinella septempunctata*	161	0.04202558	-3.16947678	-0.133199102
10	*Camponotus sp.*	156	0.04072044	-3.20103591	-0.130347586
11	*Gandaca harina*	139	0.03628295	-3.31640597	-0.120329008
12	*Heliophorous sena*	130	0.0339337	-3.38333782	-0.114809166
13	*Cycloneda munda*	121	0.03158444	-3.45510462	-0.109127554
14	*Menochilus sexmaculatus*	120	0.03132341	-3.46340263	-0.108485595
15	*Junonia atlites*	116	0.0302793	-3.49730088	-0.105895824
16	*Danaus chrysippus*	101	0.02636387	-3.63575584	-0.095852608
17	*Coccinella tranversalis*	67	0.01748891	-4.04618317	-0.070763318
18	*Phanogomphus lineatus*	56	0.01461759	-4.22550163	-0.061766664
19	*Eupeodes americanus*	51	0.01331245	-4.31908939	-0.057497666
20	*Sympetrum semicinctum*	50	0.01305142	-4.33889052	-0.056628694
21	*Cotinis sp.*	43	0.01122422	-4.48970094	-0.050393406
22	*Polites carnifex*	35	0.009136	-4.69553263	-0.042898366
23	*Monolepta signata*	31	0.00809188	-4.81687936	-0.038977619
24	*polites sp.*	28	0.0073088	-4.91864881	-0.035949404
25	*Anemosella sp.*	25	0.00652571	-5.03196108	-0.032837125
26	*Junonia almana*	24	0.00626468	-5.07277669	-0.031779337
27	*Coccinella hieroglyphica*	20	0.00522057	-5.25506632	-0.027434437
28	*Bombus sp.*	19	0.00495954	-5.30634954	-0.026317056
29	*Epilachan varivestis*	17	0.00443748	-5.41777681	-0.024041296
30	*Chinavia hilaris*	16	0.00417646	-5.47840143	-0.022880298
31	*Delta conoideum*	16	0.00417646	-5.47840143	-0.022880298
32	*Moduza sp.*	13	0.00339337	-5.68604079	-0.01929484
33	*Melanitis sp.*	9	0.00234926	-6.05365657	-0.014221589
34	*Nezara viridula*	9	0.00234926	-6.05365657	-0.014221589
35	*Prantica aglea*	8	0.00208823	-6.17154861	-0.012887598
36	*Nebria pallipes*	8	0.00208823	-6.17154861	-0.012887598
37	*Oulema sp.*	8	0.00208823	-6.1714396	-0.012887371

38	*Pieris oleracea*	7	0.0018272	-6.304971	-0.011520438
39	*Eurydema ornata*	7	0.0018272	-6.304971	-0.011520438
40	*Campsomeriella sp.*	6	0.00156617	-6.45923068	-0.010116258
41	*Aulacophora indica*	5	0.00130514	-6.64155224	-0.008668171
42	*Cyclocephala sp.*	5	0.00130514	-6.64155224	-0.008668171
43	*Acholla sp.*	3	0.00078309	-7.15237786	-0.005600922
		3831			-3.144875439

Shannon-Weiner diversity index ($H^{'}$)	3.14487
Hmax	3.761200116
Eveness index (J)	0.836134719

Appendix 5. Shannon-Wiener diversity indices (H) and evenness index (J) of insects in 2021-2022

S.N	Species	No. of species (Ni)	Pi	LnPi	Pi*LnPi
1	*Apis cerana*	411	0.124962	-2.079745632	-0.259889162
2	*Apis mellifera*	300	0.0912131	-2.394556372	-0.218414993
3	*Oxya hyla*	275	0.083612	-2.481567749	-0.207488942
4	*Episyrphus bateatus*	230	0.0699301	-2.660259537	-0.186032135
5	*Anthophora urbana*	200	0.0608088	-2.80002148	-0.170265824
6	*Eristalinus sp.*	185	0.0562481	-2.877983021	-0.161881076
7	*Musa domestica*	175	0.0532077	-2.933552872	-0.156087489
8	*Chilocorussp.*	170	0.0516874	-2.962540409	-0.153126139
9	*Camponotus sp.*	140	0.0425661	-3.156696424	-0.134368349
10	*Gandaca harina*	135	0.0410459	-3.193064068	-0.131062222
11	*Heliophorous sena*	122	0.0370933	-3.294317801	-0.122197255
12	*Coccinella septempunctata*	120	0.0364853	-3.310847103	-0.120797097
13	*Junonia atlites*	113	0.0343569	-3.370951027	-0.115815587
14	*Menochilus sexmaculatus*	112	0.0340529	-3.379839975	-0.115093365
15	*Danaus chrysippus*	103	0.0313165	-3.463609858	-0.108468171
16	*Cycloneda munda*	65	0.0197628	-3.923951576	-0.07754845
17	*Coccinella tranversalis*	60	0.0182426	-4.003994284	-0.073043374
18	*Monolepta signata*	55	0.0167224	-4.091005661	-0.068411466
19	*Cotinis sp.*	50	0.0152022	-4.186315841	-0.063641165
20	*Coccinella hieroglyphica*	40	0.0121618	-4.409459392	-0.053626748
21	*Junonia almana*	36	0.0109456	-4.514819908	-0.049417305
22	*Lucilia sericata*	30	0.0091213	-4.697141465	-0.0428441
23	*Polites carnifex*	16	0.0048647	-5.325750124	-0.025908179
24	*Sympetrum semicinctum*	17	0.0051687	-5.265125502	-0.027214087
25	*Aulacophora indica*	15	0.0045607	-5.390288645	-0.024583256
26	*Pieris rapae*	13	0.0039526	-5.533389489	-0.021871105
27	*Anemosella sp.*	13	0.0039526	-5.533389489	-0.021871105
28	*Tropidopola cylindrica*	13	0.0039526	-5.533389489	-0.021871105
29	*Epilachan varivestis*	12	0.0036485	-5.613432196	-0.02048075
30	*Phyllophaga sp.*	11	0.0033445	-5.700443573	-0.019065029
31	*Chinavia hilaris*	9	0.0027364	-5.901114269	-0.016147774
32	*Nezara viridula*	7	0.0021283	-6.152428697	-0.013094254
33	*Bombus sp.*	9	0.0027364	-5.901114269	-0.016147774
34	*Illeis cincta*	7	0.0021283	-6.152428697	-0.013094254
35	*Propylea dissecta*	5	0.0015202	-6.488900934	-0.00986455
36	*Vespa sp.*	5	0.0015202	-6.488900934	-0.00986455

37	*Cephenemyia sp.*	5	0.0015202	-6.488900934	-0.00986455
38	*Sarcophaga sp.*	5	0.0015202	-6.488900934	-0.00986455
		3289			-3.070327287
	Shannon-Weiner diversity index (H')	3.070327			
	Hmax	3.637586			
	Eveness index (J)	0.844056196			

Appendix 6. Insect species in different phases of flowering during (2020-21)

S.N	Species	Non-flowering	Flowering	Late flowering
1.	*Apis cerana*	-	351	120
2.	*Apis mellifera*	-	267	97
3.	*Oxya hyla*	11	234	46
4.	*Nezara viridula*	-	9	-
5.	*Anthophora urbana*	-	147	65
6.	*Bombus sp.*		19	-
7.	*Camponotus sp.*	-	104	52
8.	*Campsomeriella sp.*		6	
9.	*Prantica aglea*	-	8	-
10.	*Junonia almana*	-	17	7
11.	*Melanitis sp.*	-	9	-
12.	*Moduza sp.*	-	13	-
13.	*Polites sp.*	-	28	-
14.	*Delta conoideum*	-	16	-
15.	*Polites carnifex*	-	27	8
16.	*Gandaca harina*	-	109	30
17.	*Eupeodes americanus*	-	51	-
18.	*Eristalinus sp.*	-	137	47
19.	*Musa domestica*	8	178	-
20.	*Pieris oleracea*	-	7	-
21.	*Junonia atlites*	-	89	27
22.	*Heliophorous sena*	7	100	23
23.	*Danaus chrysipuss*	-	83	18
24.	*Episyrphus bateatus*	7	216	64
25.	*Coccinella septempunctata*	-	133	28
26.	*Coccinella tranversalis*	-	51	16
27.	*Coccinella hieroglyphica*	-	20	-
28.	*Cycloneda munda*	-	96	25
29.	*Epilachan varivestis*	-	17	-
30.	*Menochilus sexmaculatus*	5	90	22
31.	*Chilocorus sp.*	-	150	56
32.	*Monolepta signata*	7	24	26
33.	*Phanogomphus lineatus*	-	45	11
34.	*Anemosella sp.*	-	23	2
35.	*Nebriapallipes*	-	8	-
36.	*Aulacophora indica*	-	5	-
37.	*Cyclocephala sp.*	-	5	-
38.	*Cotinis sp.*	-	34	9
39.	*Oulema sp.*	-	8	-
40.	*Sympetrum semicinctum*	-	50	-

41.	*Acholla sp.*	-	3	-
42.	*Chinavia hilaris*	9	16	-
43.	*Eurydema ornata*	-	7	-

Appendix 7.Insect species in different phases of flowering during (2021-22)

S.N	Species	Non- flowering	Flowering	Late flowering
1	*Apis cerana*	-	300	111
2	*Apis mellifera*	-	210	90
3	*Oxya hyla*	12	222	44
4	*Nezara viridula*	-	7	-
5	*Anthophora urbana*	-	140	60
6	*Bombus sp.*	-	9	-
7	*Camponotus sp.*	-	100	40
8	*Pieris rapae*	-	13	-
9	*Junonia almana*	-	32	4
10	*Vespa sp.*	-	5	-
11	*Delta conoideum*	-	5	-
12	*Polites carnifex*	-	16	-
13	*Cephenemia sp.*	-	5	-
14	*Sarcophaga sp.*	-	5	-
15	*Lucilia sericata*	-	30	-
16	*Eristalinus sp.*	-	100	85
17	*Musa domestica*	7	100	68
18	*Junonia atlites*		70	43
19	*Heliophorous sena*	-	104	18
20	*Danaus chrysipuss*	-	80	23
21	*Episyrphus bateatus*	7	185	38
22	*Coccinella septempunctata*	-	70	50
23	*Coccinella Tranversalis*	-	60	-
24	*Coccinella hieroglyphica*	5	17	18
25	*Cycloneda munda*	-	40	25
26	*Epilachan varivestis*	-	12	-
27	*Menochilus sexmaculatus*	-	90	22
28	*Monolepta signata*	-	55	-
29	*Anemosella sp.*	-	13	-
30	*Aulacophora indica*	-	15	-
31	*Phyllophaga sp.*	-	11	-
32	*Illeis cincta*	-	7	-
33	*Cotinis sp.*	-	30	20
34	*Propylea dissecta*	-	5	-
35	*Sympetrum*	-	17	-

	semicinctum			
36	*Tropidopola cylindrica*	-	13	-
37.	*Chilocorus sp.*	-	130	40
38.	*Chinavia hilaris*	5	4	-

PHOTO PLATES

Apis cerana

Apis mellifera

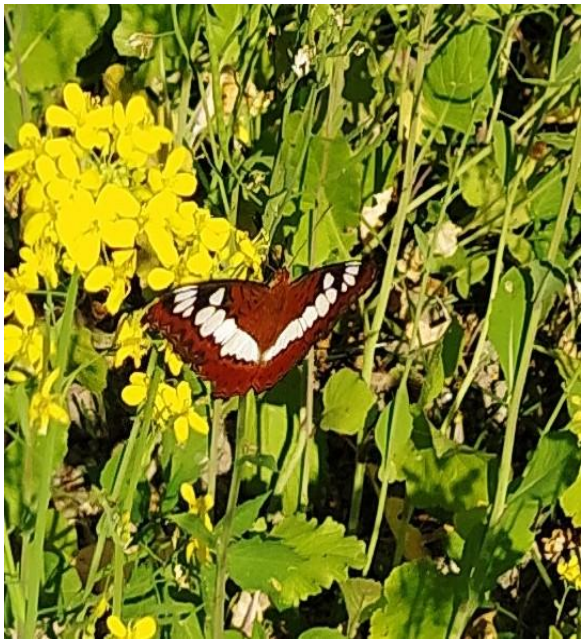
Delta conoideum

Anthophora urbana

Camponotus sp.

Pieris oleracea

Prantica aglea



Moduza sp

Junonia atlites

Gandaca harina

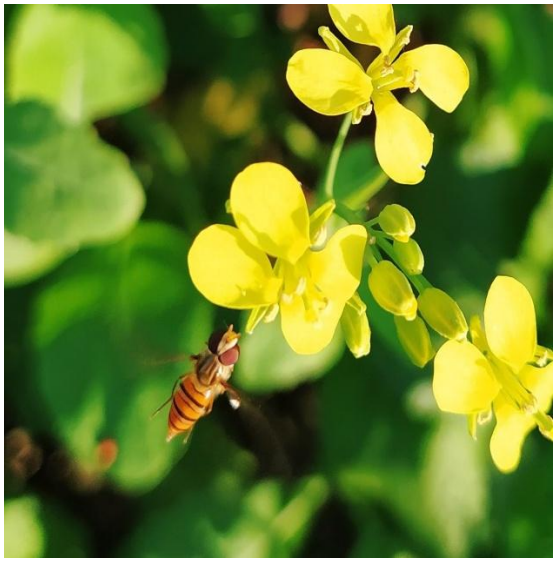
Junonia almana

Pieris rapae

Heliophorus sena

Danaus chrysipuss

Eristalinus sp.



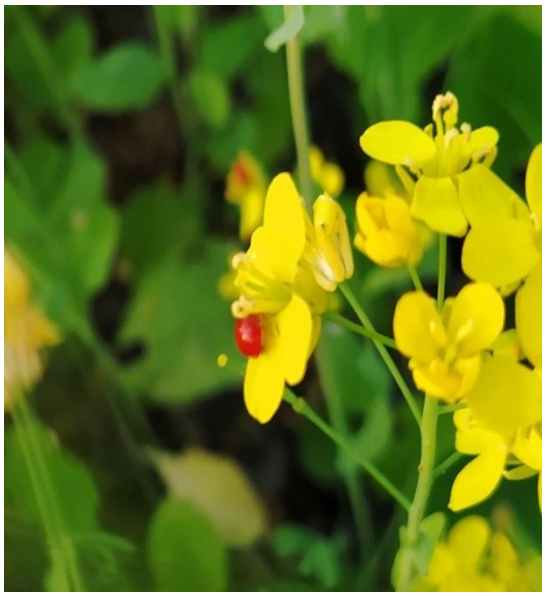
Episyrphus bateatus

Eupeodes americanus

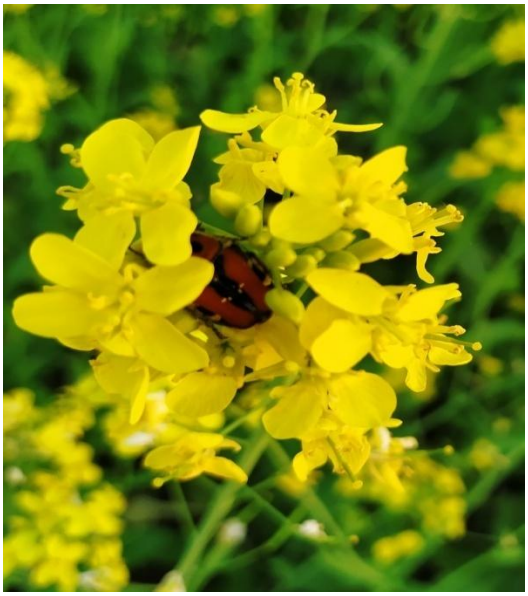
Musa domestica

Cycloneda munda

Propylea dissecta

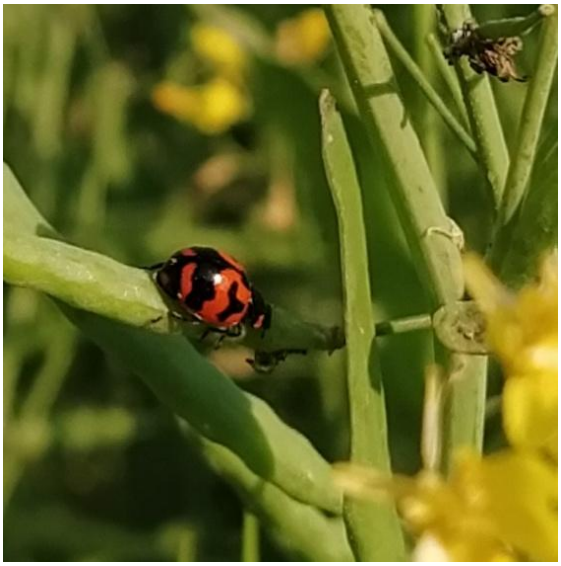


Chilocorous sp.



Cotinis sp

Coccinella septempunctata



Coccinella transversalis

Menochilus sexmaculatus

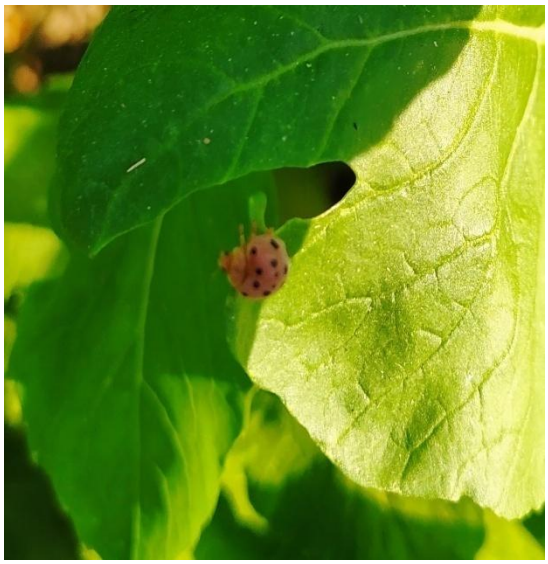
Illeis cincta

Coccinella hieroglyphica

Phyllophaga sp.

Aulacophora indica

Monolepta signata



Epilachan varivestis

Oxya hyla

Acholla sp.

Eurydema ornata

Phanogomphus lineatus

Sympetrum semicinctum

Study area

During field work

During field work

During laboratory work

Pinning and carding insects