DIVERSITY OF INSECT POLLINATORS AND THEIR ABUNDANCE ON *Brassica campestris* L. (MUSTARD CROPS) IN PANCHKHAL, KAVRE

Submitted by:

Ms. Punam Shrestha

T.U Registration No: 5-2-37-838-2013

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Amrit Campus

Tribhuvan University

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

Date: 13 July 2022

Punam

.....

Ms. Punam Shrestha

Examination Roll no. : 624/074

TRIBHUVAN UNIVERSITY

AMRIT CAMPUS

Coordinator
M. Sc. Program
Department of Zoology
Amrit Campus
IOST, Tribhuvan University

Ref. No. .....

Date.....

RECOMMENDATION

This is to recommend that the thesis entitled "**Diversity of Insect pollinators and their abundance on *Brassica campestris* L. (Mustard Crops)**" has been carried out by Mrs. Punam Shrestha for the partial fulfillment of a Master's Degree 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 work has not been submitted for any other degree in any institution(s).

Date: 13th July 2022

.....

Mr. Bimal Raj Shrestha
Supervisor
Teaching Assistant (Part-Time)
Department of Zoology
Amrit Campus
Tribhuvan University
Kathmandu, Nepal

ne No.: 4411637 Campus Chief, 4410408 Admin Off.
4414236 Hostel, 4421476 Examination
P.O.Box. No. 102
THAMEL, KATHMANDU, NEPAL
E-mail: amritcampus@ntc.net.np
contact@amritcampus.e
Website: amritcampus.edu.np

iii

TRIBHUVAN UNIVERSITY

AMRIT CAMPUS

Coordinator
M. Sc. Program
Department of Zoology
Amrit Campus
IOST, Tribhuvan University

Ref. No. .....

Date.....

LETTER OF APPROVAL

On the recommendation of supervisor Mr. Bimal Raj Shrestha, Teaching Assistant (Part-Time) this thesis entitled "**Diversity of Insect pollinators and their abundance on *Brassica campestris* L. (Mustard Crops)**" submitted by Mrs. Punam Shrestha is approved for the examination and submitted to Tribhuvan University in partial fulfillment of the requirement for Master's Degree of Science in Zoology with special paper in Entomology.

Date : 13th July 2022

.....

Mr. Barun Panthi
Coordinator
Assistant Professor
Department of Zoology
Amrit Campus
Tribhuvan University
Kathmandu, Nepal

phone No.: 4411637 Campus Chief, 4410408 Admin Off.
4414236 Hostel, 4421476 Examination
P.O.Box. No. 102
THAMEL, KATHMANDU, NEPAL
E-mail: amritcampus@ntc.ne
contact@amritcampu
Website: amritcampus.edu.n

Institute of Science and Technology

TRIBHUVAN UNIVERSITY
AMRIT CAMPUS

Coordinator
M.Sc. Program
Department of Zoology
Amrit Campus
IOST, Tribhuvan University

Ref. No. .....

CERTIFICARTE OF ACCEPTANCE

Date.....

This thesis work submitted by Ms. Punam Shrestha entitled **"Diversity of Insect pollinators and their abundance on *Brassica campestris* L. (Mustard Crops)"** has been accepted as partial fulfillment for the requirements of a Master's Degree of Science in Zoology with special paper Entomology.

EVALUATION COMMITTEE

.....

Supervisor
Mr. Bimal Raj Shrestha
Teaching Assistant (Part-Time)
Department of Zoology
Amrit Campus
Tribhuvan University
Kathmandu, Nepal

.....

Coordinator
Mr. Barun Panthi
Assistant Professor
Department of Zoology
Amrit Campus
Tribhuvan University
Kathmandu, Nepal

.....

Internal Examiner
Mrs. Babita Maharjan
Assistant Professor
Amrit Science Campus
Thamel, Kathmandu

.....

External Examiner
Mr. Ishan Gautam
Associate Professor
Natural History Museum
Swyambhu, Kathmandu

Date of Examination: 25th oct. 2022

Phone No.: 4411637 Campus Chief, 4410408 Admin Off.
4414236 Hostel, 4421476 Examination
P.O.Box. No. 102
THAMEL, KATHMANDU, NEPAL
E-mail: amritcampus@ntc.net.n
contact@amritcampus.
Website: amritcampus.edu.np

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Ms. Punam Shrestha

624/074

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Abstract

Insect pollination is the most crucial ecosystem service that insects give, resulting in ecosystem sustainability and continuity. The study was conducted to explore the diversity of insect pollinators and their abundance mustard crop; *Brassica campestris*in Panchkhal. The study was conducted in the flowering periods of the crops (November, 2019 - January, 2020). A total four sampling plots were as selected sampling sites with each size 10X10 m^2 were established with the inter-distance of 100m-200m between two consecutive plots. Insect diversity and individual counts wereconducted in two activation periods(10:00am to 12:00 pm, and 2:00 pm to 4:00 pm). The pollinator insects of the mustard crops- *B. compsestris*included 15 insect species belonging to four orders, Hymenoptera (38.28%), Diptera (32.75%), Coleoptera(17.93%) and Lepidoptera (11.49%). In terms of species richness of pollinators in both the mustard crop, Lepidopteransdominated the field. However, Hymenopterans were registered highest in context of relative abundance. The most prominent insect pollinators were*Apiscerena* from the order Hymenoptera (27.49%) whereas the insect pollinators recorded from Lepidoptera *Pieriscanidia,*and*Junonialemonias*dominated the fields. The peak foraging activities of most of insects were observed during day time. This study revealed that the Hymenopterans were the major pollinators followed by Lepidopterans. However, the pollinators would be increase if the disturbances like anthropogenic stresses have been controlled.

1. INTRODUCTION

1.1 Background

The varieties of life on earth which contributes directly and indirectly to welfare and existence of human beings on the earth by the provision of vital goods and services is biodiversity (Daily et al. 1997; Palmer et al. 2004). This can be termed "ecosystem services" and can be described as "the benefits to human welfare provided by organisms interacting with each other in ecosystems" (Hooper et al. 2005; Klein et al. 2007), and the "economic benefits that nature provides to people" (MEA, 2005). In recent times, both biodiversity and the ecosystem services it provides are under increasing pressure from human activities (Daily et al. 1997; Hooper et al. 2005; Cardinale et al. 2012). However, humans and biodiversity are not separate entities, and the maintenance of biodiversity and ecosystem services globally is increasingly dependent on maintaining biodiversity in landscapes dominated by humans (Fahrig et al. 2011).

Agricultural production forms one of the most important economic sectors where the quality of most crops is increased by pollination (Klein et al. 2007; Gallariet al. 2009). Pollination is an essential process in maintaining a healthy and bio- diverse ecosystem (Subedi and Subedi, 2019).It plays a key role in the maintenance of wild flower reproduction, the products if which support a wide range of invertebrates, birds and mammals. Pollination improves the yield of the crop. It also contributes to uniform and early pod setting (Abrol, 2007). Variety of organisms can acts as pollinators, including birds, bats, other mammals and insects (Willmeret al. 1994), with insects being the most common. Insect pollination helps in reproduction and persistence of many wild plants (Ollertonet al. 2011). Pollination is an important supporting ecosystem service required by the majority of flowering plants; it has been estimated that 87.5 % of angiosperms

require biotic pollination (Ollertonet al. 2011) and that 62 % of these flowering species are limited in reproduction by the amount of pollen they receive (Burd, 1994). Insects constitute one of the primary groups of pollinating agents, since the association between insects and flowers is well established. Pollination is an essential process for the propagation of sexually reproducing plants. It is the process by which pollens are transferred from the male reproductive part (anther) to the female reproductive organ of a plant (stigma), thereby enabling fertilization to take place.(Buchmann and Nabhan, 1996). There exists a strong relationship between pollinators and flower of the plant that they pollinate (Pratap et al. 2012).

Mustard (Brassica campestrisL.) belongs to Cruciferae (Brassicaceae)is a dominant winter season oilseed crop which occupies about 85% of total oilseed area in our country (Basnet, 2005). It is mostly grown after monsoon maize in upland and after early rice in lowland of Terai, inner Terai and mid hills (Ghimireet al. 2000). It is one of the important cash crop of Nepal which occupied 2,24,595 ha area, with the production of 2,45,866 mt and productivity of 0.78 mt/ha in 2017/2018, area increased to 2,60,307 ha, with production of 2,80,530mt and productivity of 1.08 mt/ha (MoAC, 2017/2018).

Mustard is economically important because of oil seed contents and some other plant parts like leaves which are edible and can be used as fodder crop. The oil extracted from their seeds is consumed by humans from centuries in the Asian continent. Seeds after oil extraction are changed to the shape of cake which is very nutritious and used to feed animals (Ramachandran et al. 2007). Mustard contains 44 to 46% oil and its meal has 38-40% protein having complete set of amino acids and low saturated fats (Das et al. 2009). This crop is important from income generation point of view and is prominent sources of fats, protein and vitamins 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). Similarly, 4.8% nitrogen, 2% phosphorus and 1.3% potash can be obtained from mustard oil cake (Prasai and Yadhav, 1999).

Mustard is a cross-pollinated crop and requires sufficient pollinating agents for better pollination and seed production. The mustard flower attracts a wide range of insect species (Stanley et al. 2013) and especially pollen and nectar-feeding insects due to its bilateral, bright yellow flowers (Abrol, 2007). Many insect species forage in the mustard field from seedling to harvesting stage of the crop. The foraging insects act as pest, predator, pollinator, and some has insignificant role. Various pollinating insect groups of mustard crops belong to the orders Hymenoptera, Diptera, Coleoptera, Lepidoptera, Thysanoptera, Hemiptera and Neuroptera (Mitraet al. 2008). Honeybees are most important pollinating insect and they have been utilized to provide managed pollination in mustard field (Sharma et al.2004, Klein et al.2007).

Brassica is an excellent research crop to study patterns of variation in pollinator behavior because it is mostly pollinated by insects and has a rapid life cycle, does not self-pollinate and require insects for cross pollination (Stewar, 2002). The structure of Brassica flowers is well adapted to generalist insect pollinators; it has colorful petals, large amounts of pollen, scent production and nectar production during the whole flowering period, which attracts insects to feed. So far, honeybees are considered as significant pollinators on Brassica crop, however a number of other insects also visit during flowering period of crop as reported by various workers from different parts of the country (Singh et al. 2004).

Numerous studies demonstrate that pollinators are disappearing globally (Descamps et al. 2014). Specifically, habitat loss, excessive use of chemical pesticides, anthropogenic risks, and the loss of bumblebee habitat are all contributing to the global decline in the number of butterflies and bumblebees (Van Swaay et al. 2010; Cameron et

al. 2011). However, due to overuse of chemical pesticides and outside meddling, pollinator populations in cultivated plants have been observed to be declining in Nepal (FAO 2011). Thus, preserving pollinator variety in the given environment necessitates comprehension of a distinct pattern of pollinator diversity as well as the different types of habitat. Despite research on its pollination requirements in other countries, knowledge on the specific pollinators of rapeseed crops is sparse in Nepal. Hence, the main of aim of this study is to estimate the diversity and abundance of pollinator insects of mustard crop in Panchkhal, Kavrepalanchok.

1.2 Objectives

1.2.1 General objective:

To explore the diversity and their relative abundance of insect pollinators in mustard crop (*Brassica camprestris*)

1.2.2 Specific objectives:

To determine the foragers activation period of insect pollinators

To investigate the abundance of insect pollinators in three flowering phase of *B.campestris*

1.3 Significance of study

The diversity and number of wild insect pollinators are essential for agricultural pollination, especially for crops that are insect pollinated. The improvement of ecological function through interspecific facilitation depends on high level of biodiversity. For food production and diversity of wild species, pollinators diversity must be preserved. Large scale agriculture has been reported to reduce the diversity and abundance of insect's pollen matters in many agricultural landscapes. In Nepal, knowledge of certain pollinators of mustard crops is limited, but their pollinator requirements are being studied in other countries. Therefore, this study was conducted to identify pollinators of mustard and their effect on crop production.

2. LITERATURE REVIEW

Insect pollination increased pollen deposition in canola/rapeseed crops leading to increased fruit set and seed production per plant, and decreased the variance of seed sets, and also enhanced better quality, uniform ripening and plant vigor (Klienet al., 2007).

During blooming season, Roy et al. (2014) observed 24 insect species belonging to 14 families under 6 orders in mustard field. They reported that four species were found as pollinator, 13 species as nectar collector and rest species were only visitors.

Langridge and Goodman (1975) reported that the oilseed crop was visited by many insect species. Which honeybees were major visitors contributed the most (32.9%), followed by hoverflies (30.7%), blowflies (22.9%), native bees (4.9%), and others (8.8%).

Oishi and Tsutsumi (2007) on honey bees (Apismellifera) mentioned that among several species of honeybee that are cultivated their products and pollination services most widely used species is honeybee, Apismellifera. These honeybees are found all landmasses except for the extreme poles.

Das and Jha (2018) observed that the pollinator population increased with flowering and after reaching peak period gradually declined. Apismeliifera was most predominant species representing 35.18% followed by Apiscerana constituting 23.11% of total insect visitors.

Crops' need on pollination varies substantially, with certain crops increasing yields by up to 100% while others only slightly increasing (Kamel et al. 2015). On the other side, animal pollination is necessary for 33% of global crop production and 70% of the major crop species. However, concerns have been raised regarding whether the pollination services they supplied are at jeopardy due to the decline in pollinator biodiversity (Garibaldi et al.2013). Land use change, agricultural intensification, climate

change, pesticide use, etc. are the main dangers to pollinators (Ghazoul 2005; Devi et al. 2017).

Diepenbrock (2000)found that mustard yield is dependent of fourimportant components i.e. plants per area, number of siliques per plant, number of seeds per silique, and seed weight. Seed number per area is determined during flowering and is regarded as a main factor for increasing yield.

Atmowidi et al. (2007) found 5,955 pollinator insects associated with B. rapa. They were belonged to 19 species and 4 orders: Hymenoptera (95%), Lepidoptera (2.17%), Coleoptera (2.07%) and Diptera (1%). Three species of flower-visiting insects showed a high abundance i.e. Apiscerana (43.1%), Ceratina sp. (37%), and A.dorsata (8.4%). Additionally, six species of Lepidoptera and one species of Coleoptera and Diptera visited mustard flowers.

Kumar and Naidu (2010) estimated about 80,000 species of insect pollinators are present worldwide. Among them 17, 533 species are bees' pollinators worldwide. Honeybees that they are exclusively visiting many flowers of the same species during a single trip, pick up pollen grains, hence considered reliable pollinators.

Bhowmiket al. (2014) studied diversity and abundance of insect pollinators of Brassica juncea and their influence on seed yield and quality. 19 different insect pollinators species under four orders were recorded. Among four orders, Lepidoptera and Diptera (Six and seven species) shared maximum number of species followed by Hymenoptera (four species) and Coleoptera (two species).

Kapil et al. (1971) found Apisflorea to be the main pollinators' insect species of mustard (Brassica juncea). They also found other species like A. dorsata, Andrena ilerda associated with the crops.

Pudasainiet al. (2015) carried out the study on the abundance and diversity of rapeseed insect flower visitors at Jutpani VDC, Chitwan district. The pollinator fauna of rapeseed included 21 species from six different insect orders. Hymenopterans (77.95%) were the most abundant insect visiting rapeseed followed by Dipterans (12.23%) and Lepidopterans (3.49%). Honey bees were the most dominant group of pollinators.

Panda et al. (1989) reported that mustard flowers were visited by seven species of insects, of which four species belonged to family Apidae, two to Anthophoridae and one species to Andrenidae. They reported that insect pollinated mustard crop had higher pod set (71.90%), average seed number per pod (10.80), 1000 seed weight (500gm), seed yield per ha (13.90 qt) and oil contents (36.40%) compared to the crops that was excluded from the pollinators.

Shakeel et al. (2019) studied the insect pollinators' diversity and their relative abundance in *Eruca sativa* Mill. (Arugula) and *Brassica rapa* L. (field mustard). They observed the insect pollinators belong to 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 the other three honey bee species of *A. cerana*, *A. florea*, and *A. dorsata* respectively.

Sharma and Abrol (2014) found that open pollination on mustard crop resulted in 1.80 times more yield compared to caged condition and crop pollinated by bees alone.

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. The impact of different mode of pollination found that significantly highest percent seed set was in open pollination followed by hand

pollination and the minimum seed set was observed in pollination exclusion during two years of survey (Devi et al. 2017).

Solimanet al. (2015) conducted a study on insect pollinator's diversity and their impact on yield production of Canola (Brassica napus) in Ismailia, Egypt. The result revealed that 21 species of insect pollinators belonging to 14 families under four orders visited canola flowers. The abundance of Hymenoptera insects reached the maximum of 67.90%, followed by Diptera 14.97%, Coleoptera 13.61% and Lepiodoptera 2.26% as average of both seasons.They also found that Open pollination increased the number of pods per plant, seeds per pod, weight of 1000 seeds, yield per plant, yield per feddan and seed germination, compared to close pollination.

Pudasaini and Thapa (2014) studied the foraging behavior of Apismellifera L. and Apiscerana F. in rapeseed flower under open and cage conditions in Chitwan, Nepal during 2012-2013. This study showed that both species of honeybee forage higher number of flower under open condition as compare to cage. The peak foraging hours for both species was around 12:00 pm to 14:00 pm. Seed set increased by 48.72% with Apiscerana F. and 45.73% with Apismellifera L. pollination as compared to the control. The highest seed yield was obtained from Apiscerana F. (1.11 mt/ha), followed by Apismellifera L. (0.88 mt/ha), hand (0.75 mt/ha), natural pollination (0.66 mt/ha) and control (0.13 mt/ha), respectively.

Prasad et al. (1989) reported that the plots which remained totally free from insect pollination had the lowest setting of siliqua (48.3%), which attained siliqua length (92.65mm) as compared to other treatments. The plots having free access to all the pollinators showed maximum siliqua setting (75.8%), which was closely followed by plots having honey bee (72.3%). Open pollinated plots had the maximum number of seeds per siliqua (10.58) and had the highest weight of 1000 dry seeds.

Verma and Joshi (1983) found that Apiscerena and other bees accounted for 58.7% of the total pollinators of mustard. Among honeybees, A. cerena contributed 49.9% followed by A. florea (27.57%) and A dorsata (22.43%).

Sihag and Khatkar (1999) observed that Apisdorsata initiated foraging on mustard flowers at 9 hour and reached peak at 12 hour and then the population declined. But in case of Apismellifera and Apisflorea started appearing on flowers around 10 hour and reached peak at 13 hour.

Mishra et al. (1988) revealed that percent pod setting, seed weight, seeds per pod andproportion of healthy seeds were significantly higher in open pollinated flowers then in the netcaged and muslin bagged ones.

Kumar et al. (1988) found that among all insects visiting some cultivators of cauliflower, Apiscerana was the most frequent visitor (38.75%) followed by Dipterans (29.74%) and other hymenoptera (11.86%). The least frequent visitor was Apismellifera.
According to Sharma et al. (2017) , higher insects visitors were trapped in fluorescent pan trap at the end of bloom (0.96 insect/trap) as compared to full bloom (0.65insects/trap0 and at onset of bloom (0.40 insects/trap) due to lack of flora at the end of bloom and insects got attracted towards fluorescent pan trap and sink in to. Hymenoptera, diptera, Lepidoptera and coleopteran were major insects pollinators. Apismellifera were abundant species.

83 insects from 10 different groups were registered. 57% from total number of collected number of insects were hymenopterans i.e. honey bee (13.8%), wild bee (42.3%), bumble bee (0.9%). The second place was occupied with the group of Anthomyias (19.8%), followed by flower flies and ichneumons among which the numerous are syrphid flies (Naumkin and Velkova, 2013).

According to Klein et al. (2003), there are favorable correlations between the diversity and activity of pollinators at the landscape level and the richness and availability of floral resources. The results of an experiment using a randomized complete design (RCBD) to evaluate the variety of pollinators and their impacts on rapeseed show that hymenopterans, primarily honeybees, were the dominating pollinators.

3. MATERIALS AND METHODS

3.1 Study Area

The study was conducted in Panchkhal-6 (27° 39' 0" N and 85° 37' 0" E), Kavre, Bagmati Province, Nepal. The study site is located in the mid-hills, a subtropical climatic zone of Nepal which is 40 km east of Kathmandu valley. The altitude ranges of the study sites vary from 920m to 1538m. The maximum temperature in summer exceeds 32°C and the average winter temperature is about 16°C. The total area of the Panchkhal is 103 sq. km. Major vegetation of the study site comprises *Shorearobusta, Pinus spp. Dalbergiasissoo,* etc.

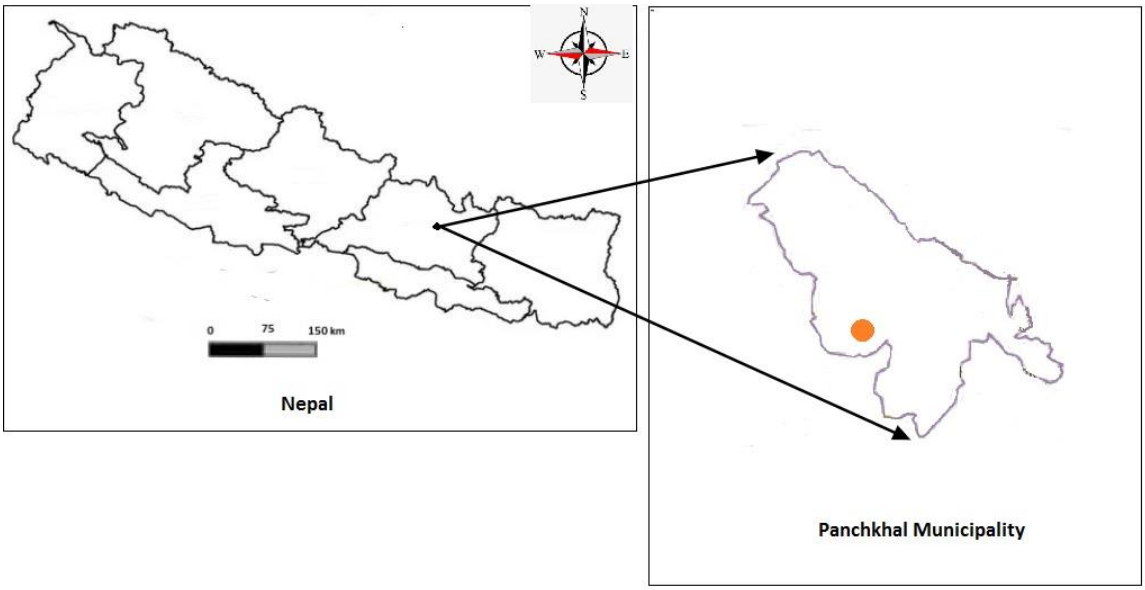

Figure 1: Map of study area

3.2 Materials

Insect trapping net	polythene bag	tracing paper
measuring tape	brush	entomological pins
killing jar	microscope	entomological box
ethyl alcohol		

3.3 Sampling periods and Preparation of plots

The sampling of the insect pollinators was done during November, 2019 to January 2020. To study the activation period of the insect pollinators, surveys were conducted two times of a day; Morning(10-12 am) and afternoon (2-4 pm) on weekly basis during the whole flowering period. During the month of November, flower visiting insect pollinators were recorded for the study of abundance of pollinators in early phase; December for peak phase and January for the late phase of flowering. Altogether four sampling plots were established in the geographical feasible field site with the inter-distance of 100m-200m between two consecutive plots. The sizes of each plot were prepared approx. 10*10 m^2.

3.4 Pollinators collection, preservation, and identification

The data were recorded till the end of flowering season. At flowering stage of the crops different pollinators' insect visiting the flowers were visually observed. During three different phases of mustard blooming i.e. early phase (about 10% flowering), peak phase (almost 100% flowering) and late phase (about 10% flowering remaining) diversity of insects were observed on weekly basis. Butterflies were caught by using sweep net and were kept in envelope made by tracing paper.Other insects were captured like Hymenoptera, Coleoptera, Diptera and Lepidoptera and were killed with the help of killing jar and preserved with the 70% ethyl alcohol. Collected specimens were labeled and kept in insect collection box.

Abundance of the insect pollinator were recorded through visible observation along with capturing by insect net.

3.5 Data analysis

A. Relative abundance (%)

Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area. It was used to show the family-wise and order-wise composition of pollinator insects.

Relative abundance (%) = (n/N) * 100

Where,

n = Number of each individual

N = Total number of individual

B. Shannon-Weiner diversity index (H) and Evenness index (J)

The diversity of pollinator insect species was calculated using Shannon-Wiener diversity index (H), given by the equation, $H = -\sum pi * \ln(pi)$

Where,

pi = ni/N, ni is the number of individuals of the species and $N = \sum ni$

ln = the natural log

$\sum$ = the sum of calculations

To find the evenness of the species evenness index (J) given by, J =H/Hmax was calculated.

where,

$H = -\sum pi * \ln (pi)$

Hmax = ln (n) , n is the total species richness.

4. RESULTS

4.1Diversity and relative abundance of insect pollinators:

A total of 4058 pollinator insects associated with mustard crop was recorded. The present study recorded 15 insect species that belongs to the four orders i.e. Hymenoptera, Lepidoptera, Coleoptera andDiptera and they were belonged to nine families i.e. apidae, bombidae, pieridae, coccinellidae, syrphidae, muscidae, nymphalidae, and lycaenidae. Hymenopteran were the most abundant order on mustard crop.

The insect pollinators collected from the crop included two families of Hymenoptera: Apidae and Bombicidae. Apidae was the dominant pollinator followed by Bombidae. Similarly, insects pollinators from Diptera were of Syrphidae and Muscidae families. Syrphidaeshowed higher number than Muscidae.Nymphalidae, LycaenidaeandPieridae from Lepidoptera and Coccinellidaefrom coleopteran were also present. Hymenoptera and Diptera mainly visited the flowers for nectar purpose and pollen collection. Lepidopteran were visited for nectar purpose while coleopteran for pollen collection.

4.1.1 Species diversity index

The Shannon-winner diversity index (H) was 2.350 which indicates high diversity of pollinator insects in Mustard field.

Table 1: Diversity of insect pollinator on flower of *B. compestris*

S.N	Order	Family	Scientific name	Foraging source	Relative abundance (%)
1.	Hymenoptera	Apidae	*Apiscerena*	pollen and nectar	27.49
2.	Hymenoptera	Apidae	*Apismellifera*	Pollen and nectar	9.98
3.	Hymenoptera	Bombidae	*Bombus sp.*	Pollen and nectar	0.81
4.	Coleoptera	Coccinellidae	*Coccinella `undecimpunctuta*	Casual visitor	7.88
5.	Coleoptera	Coccinellidae	*Coccinellaseptumpunctata*	Casual visitor	9.44
6.	Diptera	Sryphidae	*Eristalis sp.*	Pollen and nectar	18.63
7.	Diptera	Sryphidae	*Episyrphusbalteatus*	Pollen and nectar	11.53
8.	Diptera	Muscidae	*Muscadomestica*	Pollen and nectar	2.83
9.	Lepidoptera	Nymphalidae	*Aglaiscashmiriensis*	Pollen and nectar	1.47
10.	Lepidoptera	Pieridae	*Pieriscanidia*	Nectar	2.31
11.	Lepidoptera	Nymphalidae	*Vanessa cardui*	Nectar	1.94
12.	Lepidoptera	Pieridae	*Eurenahecabe*	Casual visitor	1.57
13.	Lepidoptera	Nymphalidae	*Neptishylas*	Casual visitor	1.35
14.	Lepidoptera	Lycaenidae	*Lampidesbecticus*	Nectar	1.08
15.	Lepidoptera	Nymphalidae	*Junonialemonias*	Nectar	2.31

In terms of species richness of pollinators in the mustard crop, Lepidopterans dominated the field followed by Hymenopterans and Dipterans. A total of 15 species belonging to four orders; Lepidoptera (7: 47%), Hymenoptera (3: 20%), Diptera (3:20%) and Coleoptera (2: 13%) (Table-1, Figure--2).From the Lepidoptera order, four species from the family Nymphalidae namely *Aglaiscashmiriensis*, *Vanessa cardui*, *Neptishylas* and*Junonialemonias*and two species from the family Pieridae viz. *Pieriscanidia* and *Eurenahecabe* were found greater in the crop field. The species *Apiscerena. A. mellifera*, and *Bombusspp*. were found which were from Apidae family of Hymenoptera. Additionally, from Diptera order three species from two families :Muscidae(*Muscadomestica*) and Sryphidae (*Eristalis spp*. and *Episyrphusbalteatus*) were observed. Likeas, two species from coleopteran family: Coccinellida (*Coccinellaundecimpunctata* and *C. septumpuntata*) were recorded during the total field visit.

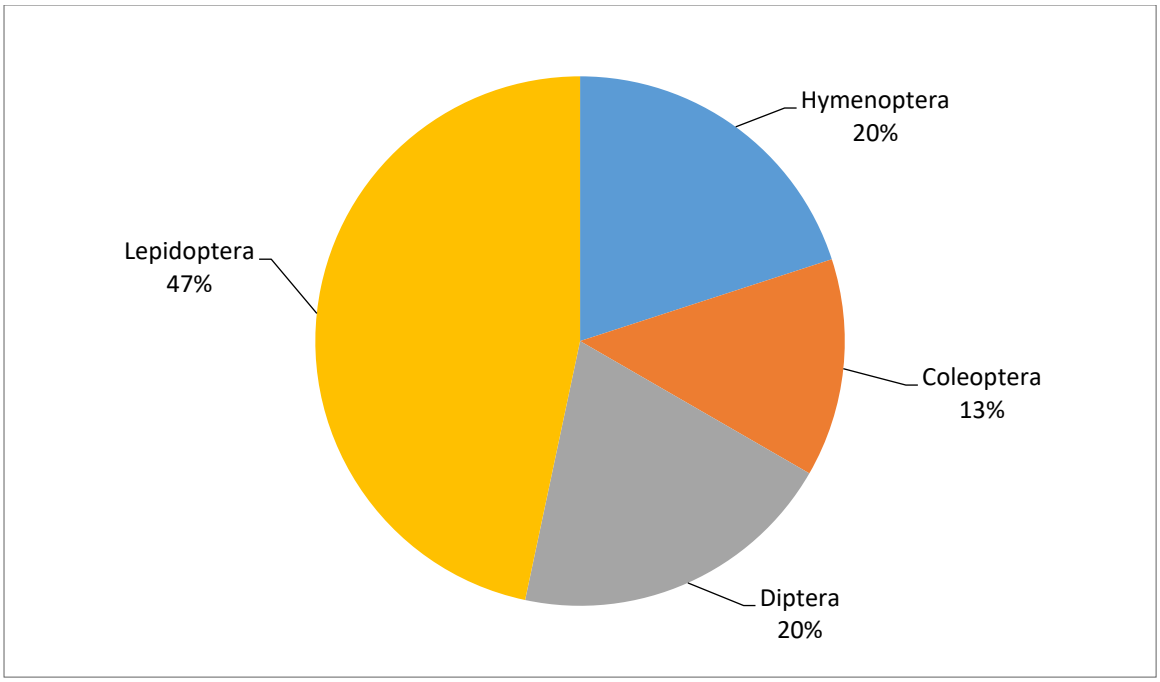

Fig.2- Insect pollinators richness on *B. compestris*

The percent relative abundance of pollinators on *B. compestris* is presented in chart below (fig-3). The recorded Hymenoptera (38.28%)and Diptera (32.28%) shared highest relative abundance which was significantly higher than Coleoptera 17.93% and Lepidoptera 11.49%.

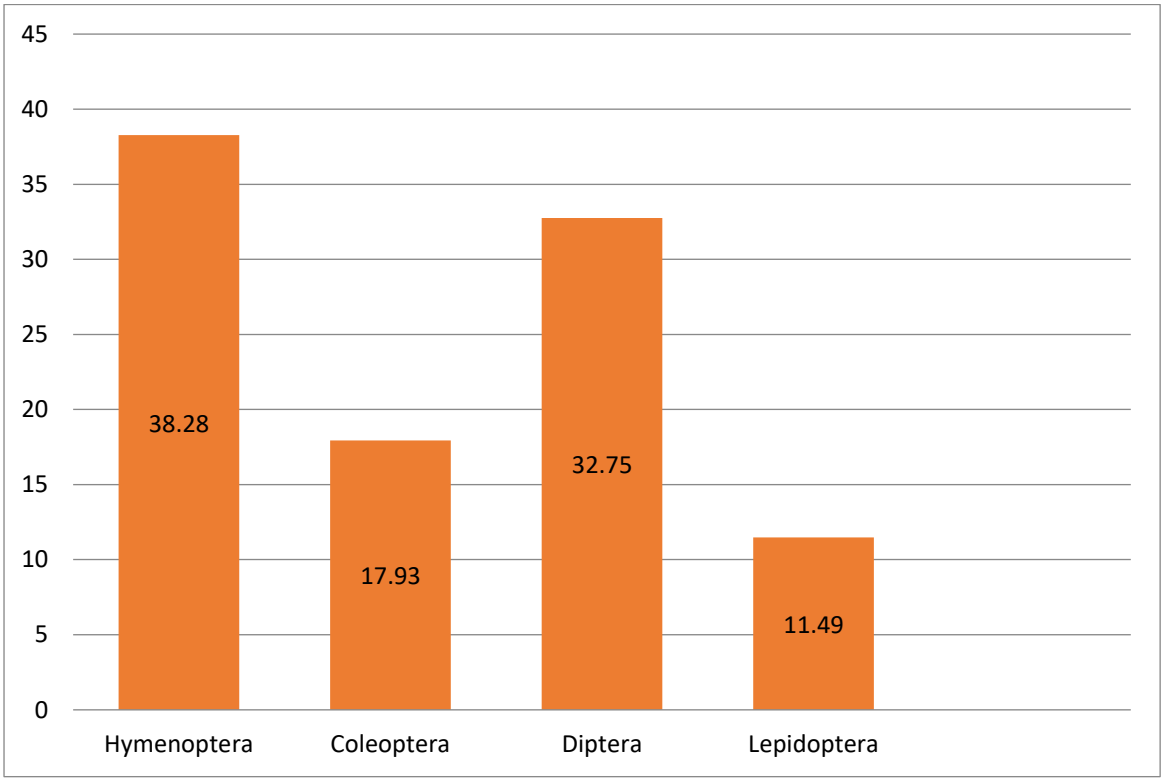

Fig.3- Order-wise composition of insect pollinators

4.2 Relative abundance at two activation periods

Abundance of hymenoptera during different day times on mustard crop is shown in the fig.4. Their abundance was significantly lower (37.48%) in the morning time. However, their abundance slightly increased (38.02%) in the afternoon on flowering plants of mustard.

Regarding coleopteranpollinator's similar observation was recorded. Lower abundance (16.96%) was recorded in morning time while high abundance (18.9%) was recorded in afternoon.

The abundance of lepidopteron pollinators is presented in chart below. It shows that the abundance was comparatively high (11.73%) in the morning but during the afternoon time their abundance was low (11.26%) comparatively.

The abundance of dipteran during afternoon was lower than that of morning time. The relative abundance of diptera was found to be 33.8% at morning and at afternoon it was found to be 31.7%.

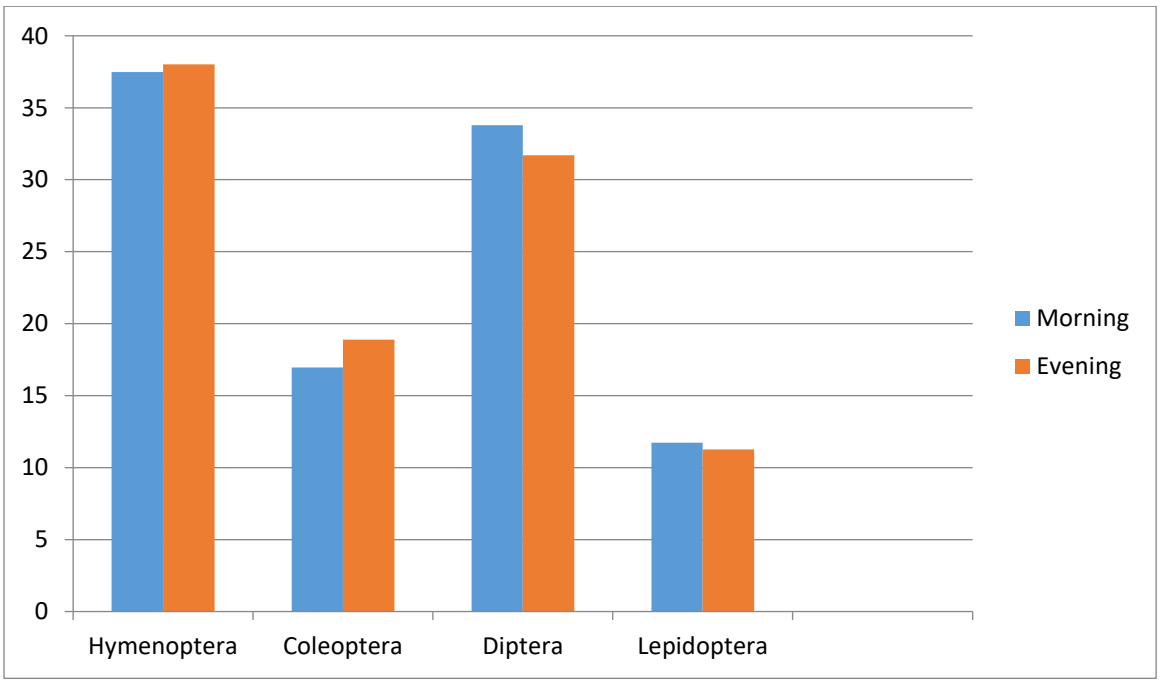

Fig.4- Order-wise abundance of pollinators at two activation periods

4.3 Foraging source of Pollinators insects

Among the recorded 15 species, seven species were found foraging on both pollen and nectar of mustard flowers. Of them, Hymenopteran species were the most common followed by Dipterans. Pollen and nectar feeding insects includes *Apiscerana, Apismelifera, Bombus sp., Eristalis sp., Episyrphusbalteatus, Muscadomestica a*nd Ag*laiscashmiriensis. Four species* were found foraging on nectar it mostly includes butterfly species like *Pieriscanidia, Vanessa cardui, Junonialemonias*and L*ampiidesboeticus*. The rest four species were recorded as casual visitor of the mustard flowers and it includes *Coccinellaundecimpunctuta, Coccinellaseptumpunctata, Neptishylas*, and*Euremahecabe.*

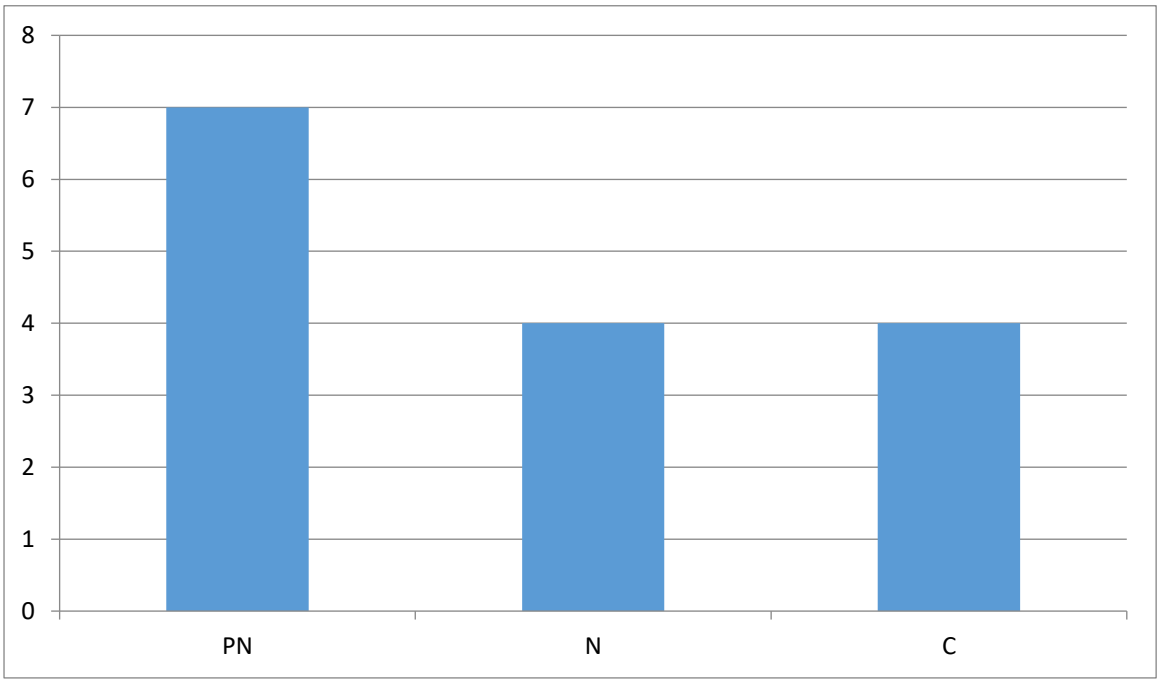

Fig.5-Foraging source of pollinators on*B. compestris*

4.4 Relative abundance of pollinator insects in three flowering phases of *B.compestris*

A significant difference in the abundance of pollinator insects was observed during different phases of flowering. The highest abundance of insects were found during peak phase(48.92%) of flowering followed by early phase (28.54%) and least in late phase (22.55%) of flowering. Among 15 species of insect pollinators, seven species of pollinators were found in all three phases of flowering. Nine species were recorded in the early phases whereas seven species were recorded in late phase.

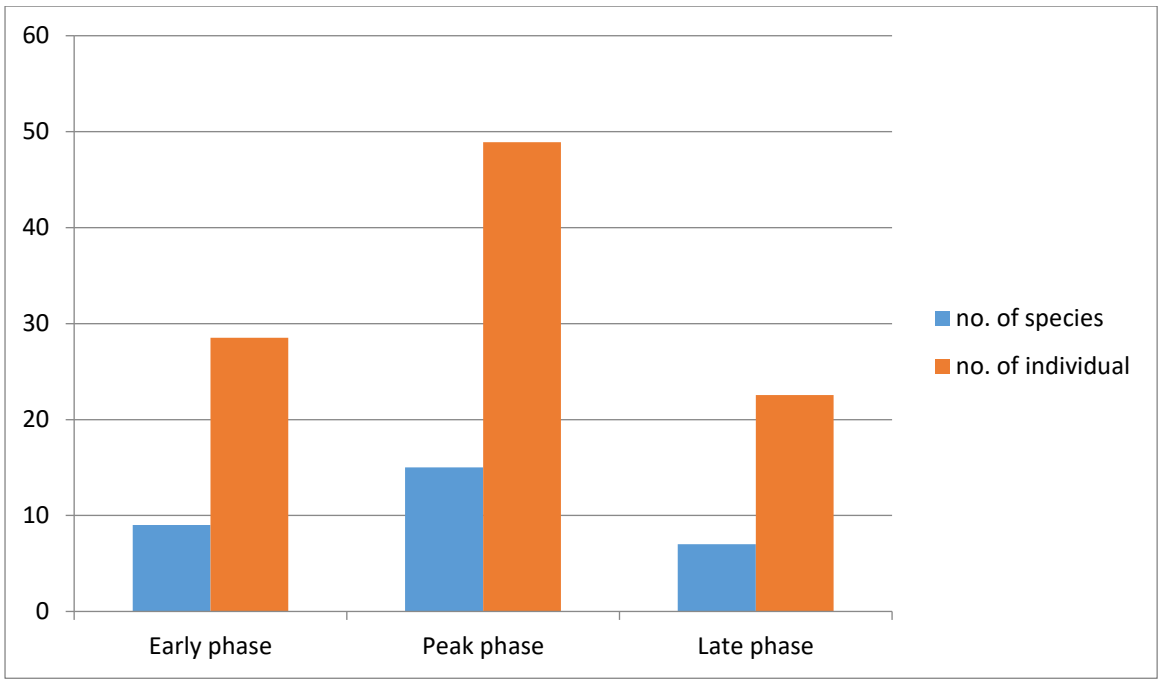

Fig.6- Relative abundance of pollinators at three phases of flowering

5. DISCUSSION

An essential function of the insect is pollination, which enables the production of many edible crops (Das et al. 2018). As a result, the quality and quantity of the yield properties of cruciferous crops are greatly influenced by insect pollination (Sihaj 2017). This study showed that the insect pollinators took part in the pollination of the mustard crop actively. Insect pollinators belonging to four orders (Hymenoptera, Lepidoptera, Diptera, and Coleoptera) were identified. Hymenoptera, one of these groups, was thought to be the main insect pollinator (Subedi and Subedi 2019). In terms of species richness, Lepidoptera-order species are the most frequently encountered, followed by Hymenoptera, which contribute the second-highest richness in the environment.

As opposed to what we found, Rijal et al. (2017) and Das and Jha (2018) reported greater species richness from the order Hymenoptera that were present in *B. campestris*. Lepidoptera have a high diversity in our results, possibly as a result of their brief visits and preference for floral nectar as a food source (Jauker et al. 2012). Consequently, they are occasionally regarded as the crops' secondary pollinators (Akthar et al. 2018). Additionally, Shakeel et al. 2019 found that some Lepidopteran pollinators show a preference for certain colors since it may have a significant impact on their frequent visits (Reverte et al. 2016).

Dhakal (2003) observed 16 species of pollinator insects of mustard under five different orders. Among 16 species hymenopteran (36%) was the most abundant insect order visiting mustard flowers followed by Diptera (34%), Coleoptera (17%), Lepidoptera (12%) and the lowest Heteroptera (1%).Goswami and Khan (2014) also recorded six familes of Hymenoptera and Apidae being most abundant, Syrphidae was the most dominant among the true flies. Devi et al. (2017) also 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. High temperature in the afternoon increases the secretion of nectar which attracts more insect pollinators. Higher abundance of pollinators was also recorded in afternoon in earlier studies on sunflower

(Ali et al. 2015) observed abundance of pollinators on mustard was less in the morning while it increased in the afternoon. This may be due to the increase of temperature in the afternoon timing or amount of nectar secretion. Flowers nectar secretion has great relation with temperature.

Similarly Kamel et al. (2015) observed 21 species of insect pollinators visiting canola, *B. napus* flowers. Bhowmik et al. (2014) recorded 19 different insect species under four orders. Among them, order Lepidoptera and Diptera shared maximum number of species followed by Hymenoptera and Coleoptera, of them, Hymenopteran species were reported to be common with significantly active throughout the day, followed by Coeloptera, Diptera and Lepidoptera. In this study, Order Coleoptera was also reported to be quite high (17%) and it was probably because of their predatory action on the aphids that are commonly found on mustard flower. Nine families of insect pollinators were recorded and among them family Apidae was the most abundant, followed by Syrphidae. These findings are similar to those recorded by Pudasaini et al. (2015) where they recorded seven families of Hymenoptera and Apidae was dominant family.

Among the recorded 16 species most of them also appear as major pollinator insects of mustard. These include honeybees, flies and butterflies. The yellow colour of the flower with shallow placement of visible nectar mostly attracts bees, flies and butterflies (Ali et al., 2011). Similarly, Shakeel and Inayatullah (2013) recorded nine species of pollinator insects in canola, among which *A.mellifera, A. florea, A. dorsata,* and *A. cerana* were the major pollinators those findings were similar to present study. Butterflies species like *Aglaiscashmiriensis, Pieriscanidia, Vanessa cardui,*

*Junonialemonias, Lampiidesboeticus, Neptishylas*and*Euremahecabe* were present in less abundance. These findings are similar tothose reported by early Bhowmik et al. (2014) and Pudasaini et al. (2015).

This study revealed the significant differences in number of visits in the mustard crops during morning and day times. In general, the number of visitors belong to Hymenoptera were observed more during early afternoon day time (11 am-1pm)where decreased no. of pollinators was obtained in morning time (8-10 am) followed by late afternoon day time (2-4 pm). However, the case is not same in some visitorsof the order Lepidoptera such as *Aglaiscashmerinsis, Pierislemonias, Pontiadaplidice.Neptishylas, Vanessa cardui, V. indica*and *Teriashecabe*) and Diptera (*Muscadomestica*) on *B. rapa*. These species were actively visited during the morning time with high population number and decreased at early afternoon and relatively much less in late afternoon. Likewise, *B. campestris* also offered the visitors belong to Lepidoptera in morning time of the day. The result was coincided with the result obtained by Shakeel et al. (2019) and Mehdi et al. (2020). Lepidopterans like butterflies are very sensitive to different factors of disturbance. During the field periods we observed the maximum anthropogenic stress during the day time on both the study sites, which directly shortened the foraging periods of the butterflies. This might be the possible reason of observing high number of butterflies during morning time.

Different pollinators are attracted to the mustard flowers because of sugar content and the morphology of the flower. Hymenopterans were mainly attracted to the mustard flower for nectar collection. Most bees collect nectar which provides energy and pollen, which supplies the protein for larval growth. Other insects also visit flowers for collecting pollen and nectar as pollen and nectar are essential resources for bees for survival.

Mustard field harbored many species of insects that collected nectar and pollen. Among the recorded 16 species, seven species were found foraging on both pollen and nectar of mustard flowers. Among them Hymenopterans species were the most common followed by Dipterans. The open field attracted bees in higher number, which were beneficial for both nectar and pollen collectors (Rijal et al., 2017). Roy et al. (2014) found that among six species of hymenopterans, four species were found as pollen and nectar foragers and two species as only nectar foragers. All Dipterans and Lepidopterans were found as only nectar foragers and others like Coleoptera, Odonata and Hemiptera species as causal visitors of mustard flowers. Roy et al. (2014) argued the peak foraging activity of the members of Hymenoptera, Coleoptera, Diptera and Hemiptera at 2 p.m and that of Lepidopterans were found during 12 p.m. Maximum honey bee activity was recorded in the 12-14 hr as it provides more floral rewards in terms of pollen which is regarded as source of protein. A diurnal rhythm of honey bee visits is by change in climatic conditions. Bee visits commenced only if the threshold level of temperature and light intensity is surpassed (Sihag, 1984).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Fifteenpollinator insect species visited mustard flower belonging to five orders (Hymenoptera, Diptera, Lepidoptera, Coleoptera and Heteroptera) and nine families ((Apidae, Bombidae, Syrphidae, Muscidae, Nymphalidae, Pieridae, Lycaenidae, and Coccinellidae).. Hymenoptera was the most abundant order followed by Diptera.Apidae was most abundant family followed by Syrphidae. *Apiscerana* was the most dominant species and *Eristalis sp.* was second most abundant in mustard flower.

Among the recorded 15 species, seven species were found foraging on both pollen and nectar of mustard flowers. Of them, Hymenopteran species were the most common followed by Dipterans. Pollen and nectar feeding insects includes *Apiscerana, Apismelifera, Bombus sp., Eristalis sp., Episyrphusbalteatus, Muscadomestica* and *Aglaiscashmiriensis*. Four species were found foraging on nectar it mostly includes butterfly species like *Pieriscanidia, Vanessa cardui, Junonialemonias* and *Lampiidesboeticus*. The rest four species were recorded as casual visitor of the mustard flowers and it includes *Coccinellaundecimpunctuta, Coccinellaseptumpunctata, Neptishylas, Euremahecabe.*

The peak foraging activities of the members of Hymenoptera and Coleoptera were observed during afternoon . Butterflies were active in the morning than at the day time. Coelopterans foraging activities remain fairly constant throughout day, whereas Dipteran and Heteropteran species foraging became active at morning time than the day time.

There was significant difference in the abundance of pollinator insects during different phases of flowering. Among three phases of flowering i.e. early phase, peak phase and late phase, highest abundance of insects were found during the peak phase followed by early and late phase. *A.cerena, A.mellifera, C.septumpunctata, C.*

undecimpunctata, *Eristalis sp*., *Pieriscanidia*, and *Neptishylas* were found in all three phases as a common species. Whereas,*Junonialemonia* and *Muscadomestica* were also recorded during the early phase. Similarly, all 15 species of pollinators were found during the peak phase of flowering.

Finally, a decrease in species diversity could endanger agriculture plant pollination and seed output. Though the report of insect pollinators of mustard crops from Panchkhal, Kavre was a preliminary attempt, it will undoubtedly aid the research. Pollinators and pollination crops in the area will be used as a baseline data for future employees. Hence, for conservation and pollinator protection, pollinator-friendly agricultural techniques should be used. To increase mustard production and productivity, insect pollinators must be managed.

6.2 Recommendation

In most terrestrial ecosystems, pollinators serve a significant functional role and provide a critical ecosystem service. The bulk of the world's angiosperms rely on insects, primarily bees, for pollination. Many interrelated species and processes in both wild and farmed ecosystems might collapse without this service. Some of the recommendations are:

1. Other widely cultivated crop species must also be evaluated for the role of insect pollination to seed or fruit set.

2. To calculate the contribution of oil content, germination percentage, and chlorophyll content to the quality and market value of mustard.

3. From the farmer's perspective, an awareness program about the necessity and conservation of pollinator insects should be implemented.

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APPENDIX

Appendix 1 : Abundance of the insect pollinators species in the two sampling periods

Order	Family	Species	10am-12pm	2pm-4pm
Hymenoptera	Apidae	*Apiscerena*	475	600
Hymenoptera	Apidae	*Apismellifera*	185	200
Hymenoptera	Bombidae	*Bombus sp.*	10	15
Coleoptera	Coccinellidae	*Coccinellaundecimpunctuta*	140	185
Coleoptera	Coccinellidae	*Coccinellaseptumpunctata*	165	233
Diptera	Sryphidae	*Eristalis sp.*	357	389
Diptera	Sryphidae	*Episyrphusbalteatus*	204	244
Diptera	Muscidae	*Muscadomestica*	47	68
Lepidoptera	Nymphalidae	*Aglaiscashmiriensis*	28	32
Lepidoptera	Pieridae	*Pieriscanidia*	39	55
Lepidoptera	Nymphalidae	*Vanessa cardui*	37	42
Lepidoptera	Pieridae	*Eurenahecabe*	31	33
Lepidoptera	Nymphalidae	*Neptishylas*	26	29
Lepidoptera	Lycaenidae	*Lampidesbecticus*	24	27
Lepidoptera	Nymphalidae	*Junonialemonias*	20	24

Photos

Fig: *Coccianellaundecimpunctata*

Fig: *Eristalis sp.*

Fig: *Apiscerena*

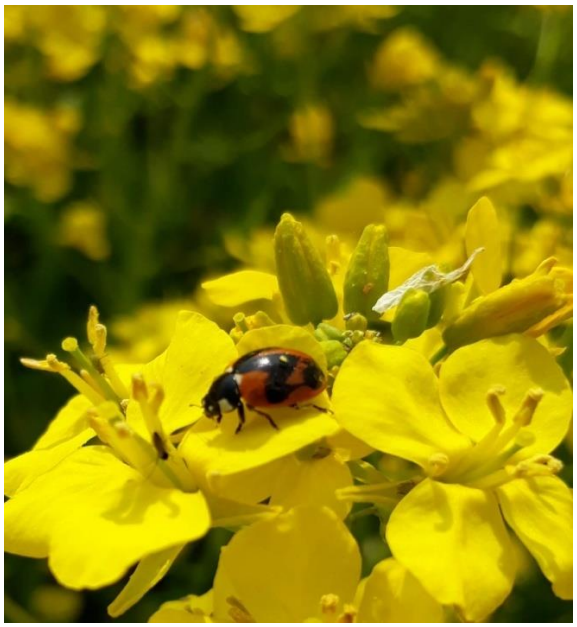

Fig: *Coccinellaseptumpunctata*

Fig: *Musca domestica*

Fig:*Pieris canidia*

Fig: *Aglaiscaschmirensis*

Fig: *Junonialemonias*