INSECT PESTS OF CITRUS FRUITS AND THEIR MANAGEMENT PRACTICES IN SAHAJPUR, KAILALI, NEPAL

Submitted by

SITA RAM AWASTHI

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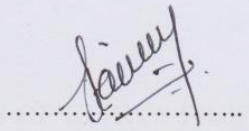
DECLARATION

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



Sita Ram Awasthi

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CENTRAL DEPARTMENT OF ZOOLOGY
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RECOMMENDATION

This is to recommend that the thesis entitled **"INSECT PESTS OF CITRUS FRUITS AND THEIR MANAGEMENT PRACTICES IN SAHAJPUR, KAILALI, NEPAL"** has been carried out by Mr. Sita Ram Awasthi for the partial fulfillment of Master's Degree of Science in Zoology with special paper Entomology. This is his original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

.....

Dr. Prem Bahadur Budha

Associate Professor

Supervisor

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

Date: 01 Feb 2021

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01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

LETTER OF APPROVAL

On the recommendation of supervisor Dr. Prem Bahadur Budha, Associate Professor, Central Department of Zoology, Tribhuvan University" this thesis submitted by Mr. Sita Ram Awasthi entitled **"INSECT PESTS OF CITRUS FRUITS AND THEIR MANAGEMENT PRACTICES IN SAHAJPUR, KAILALI, NEPAL"** is approved for the examination in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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Prof. Dr. Tej Bahadur Thapa

Head of Department

Central Department of Zoology

Tribhuvan University

Kirtipur, Kathmandu, Nepal

Date: - 01 Feb 2021

TRIBHUVAN UNIVERSITY
01-4331896
CENTRAL DEPARTMENT OF ZOOLOGY
Kirtipur, Kathmandu, Nepal.

Ref.No.:

Central Department of Zoology T.U., Kirtipur

CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Mr. Sita Ram Awasthi entitled **"INSECT PESTS OF CITRUS FRUITS AND THEIR MANAGEMENT PRACTICES IN SAHAJPUR, KAILALI, NEPAL"** has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

EVALUATION COMMITTEE

Supervisor	Head of Department
Dr. Prem Bahadur Budha	Prof. Dr. Tej Bahadur Thapa
Associate Professor	Central Department of Zoology
Central Department of Zoology	Tribhuvan University
Tribhuvan University	Kiritpur, Kathmandu, Nepal
Kiritpur, Kathmandu, Nepal	

External examiner

Internal Examiner

Date of Examination: 04 Feb. 2021

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Abbreviated form	Details of Abbreviations
Asl	Above sea level
CTV	Citrus tristeza virus
FAO	Food and agriculture organization.
MoAC	Ministry of agriculture and co-operatives.
SD	Standard deviation.
SE	Standard error.
Spp.	Species.
GDP	Gross domestic product
MT	Million ton
GSB	Green sting bug
SL	Soluble liquid
GPS	Global positioning system
CLM	Citrus leaf minor

ABSTRACT

The study was conducted in Sahajpur, Kailali, Far Western Nepal from September 2018 to February 2019. One hundred Citrus plants were selected randomly from both commercial (30%) and non-commercial (70%) cultivated sites of the study area. Insects were collected by Hand-picking, yellow pan trap, and beating method. By using questionnaire method and informal discussion with farmers the pest management status was assessed in the study area. The study recorded 10 citrus insect pests species belonging to three insect orders and nine families. Among them, Hemiptera (74%) was the most abundant order followed by Lepidoptera (21%) and Diptera (5%) was least abundant. Aphididae (44.65%) was the most abundant family followed by Gracillarirdae (10.23%) and Tephritidae (4.65%) was least abundant. The Shannon-Winner diversity index was calculated to be 2.132, with Pielou's species evenness as 0.926. The study found that 60% insects were minor pests and 40% pest were major pests of citrus. Insect pests are responsible for variety of damages ranging from moderate to severe resulting in yield loss. The highest abundance was found on the month of November (92 ± 2.42) followed by in month of January (86± 0.86) and the lowest abundance was recorded in month of September (44 ± 0.23). The study reveals that infestation rate gradually increases from September to December and gradually decreases thereafter. Highest damage percentage was observed in December (18%) and lowest in September (5%). There was positive correlation between abundance of insect pest and damage percentage. Majority of the farmers (33%) used chemical pesticides, 28% adopted mix methods, 27% used Cultural methods and 12% used bio-pesticides for the control of insect pests. It was found that majority of farmers did not adopt safety precaution during pesticides application due to the lack of awareness and knowledge of pesticide handling.

1. INTRODUCTION

1.1 Background

Citrus are flowering plants in the family Rutaceae originated from the tropical and subtropical regions of South East Asia (Gmitter and Hu 1990). It comprises a number of crops such as orange (*Citrus sinensis*), lemon (*Citrus lemon*), grapefruits (*Citrus paradisi*), pomelos (*Citrus maxima* or *Citrus grandis*), lime (*Citrus aurantifolia*) and mandarin (*Citrus reticulata*). The taxonomy and systematics of the genus are complex and the precise number of natural species is unclear, as many of the species are clonally propagated hybrids. There is genetic evidence that even some wild, true-breeding species are of hybrid origin. Cultivated Citrus may be derived from as few as four ancestral species. Natural and cultivated origin hybrids include commercially important fruit such as the oranges, grapefruits, lemons, limes and tangerines (Pinchas and Goldschmidt 1996). The present day citrus is delectable, juicy, and seedless and is of great nutritional significance as well. Additionally, it possesses enormous therapeutic qualities (Chaudhry et al. 1992).

Citrus fruits rank first in terms of world fruit production and international trade value (Norberg 2008, UNCTAD 2009). This crop possess great adaptability to some favorable various climatic conditions and hence grown equally both in tropical and subtropical regions as well as parts of the temperate regions of the world. Citrus is the world's principal fruit crop, with about 60 million megatons grown annually (FAO 2015). Brazil and China are largest producers of citrus worldwide followed by USA, India, Mexico and Spain (Anon 2012). Among various citrus produced, sweet oranges are the major ones contributing to approximately 70% of the output. The citrus fruit industry is becoming more global in scope due to technological advances in fruit transport and storage. The market is assisting to a change in consumption patterns, particularly in the form of an increasing focus on the quality and the value-added aspects of the product (UNCTAD 1996).

1.1.1 Citrus production in Nepal

Due to unique topography and climatic condition of Nepal, it is possible to grow many kinds of citrus fruits. It is one of the most important and popular fruit crops of Nepal covering 49% of total fruit growing area (MoAC 2009, FDD 2008). Citrus farming traditional practices since ancient period. However commercial cultivation of citrus in

Nepal started only after 1970 (NCRP 2010, Roistacher 1996). Predominantly citrus cultivated districts lies in mid-hill area (altitude range of 800 m to 2100 m) (Lama 1988). Taplejung, Sankhuwashabha, Solukhumbu, Dolakha, Sindhupalchok, Kalikot, Bajura, Bajhang and Darchula are mountainous citrus producing districts. Similarly, three terai districts viz., Chitwan, Nawalparasi and Kailali also produce citrus in significant amount due to sub- tropical climate in the region. In context of Far-western region, every region produces citrus fruits except Kanchanpur.

According to NARC (2000), Citrus contributes 14% to the total agricultural gross domestic product. Mainly, three citrus species i.e. Mandarin (*Citrus reticulata*), Sweet Orange (*Citrus sinensis*) and Lime (*Citrus aurantifolia*) were grown commercially and have great potential for export (Gurung 2003). At present, citrus is being cultivated in about 60 districts of Nepal (Acharya 2016). It is grown in an area of 46,328 ha with only 26,759 ha productive area which accounts total production of 2,39,773 Mt and the productivity is 8.96 Mt/ha (MoALD 2017). Citrus Fruit contributes 22.37 % of total fruit production in Nepal. Among them, Mandarin orange is dominant which shares about 67% of the total citrus production in the country. At present major mandarin producing districts of Nepal are Illam, Panchthar, Terathum, Dhankuta, Bhojpur, Sindhuli, Ramechap, Kavrepalanchok, Dhanding, Gorkha, Lamjung, Tanahun, Kaski, Shayanja, Gulmi, Arghakhanchi, Dailakh, Dadeldhura, Baitadi and Darchula (Shah 1971). Much of the oranges are transported and sold in other towns and cities within and outside the country. A report indicate that worth of USD 14371000.00 value (fruits and juice) was being exported annually (MoAC 2008). Only a small portion of the produced oranges is locally consumed.

Like most fruits, citrus are a low-caloric food, a good source of carbohydrates and fiber, is low in sodium, fats and is an excellent source of vitamin C. The fruits are however, also appreciated for its biologically active, anti-nutrient compounds or phytochemicals (Huang et al. 2007). Citrus phytochemicals have potential antioxidant, anti- cancer, and cholesterol-lowering ability (Tian et al. 2001).

1.1.2 Insect pests of citrus fruits

Fruit pests inflict up to 80% loss of citrus yield due to *Pseudocercospora angolensis* around Arbaminch of southeast region of Ethiopia (Yesuf 2013). Among the citrus, sweet orange is susceptible to postharvest diseases, in which, the extent of damage range from

25.5 to 43.8% (Oviasogie et al. 2015). Now a day citrus production are decline worldwide by different citrus insect pests belonging to various orders associated with the flowers, shoots and roots of citrus and colonize on different parts of citrus tree (Browning 1999) either directly damaging or serve as vectors of diseases.

Fruit flies are the most destructive insect pests of many crops including citrus species. The major citrus pest fruit fly species are Mediterranean fruit fly (*Ceratitus capitata*) and Oriental fruit fly (*Bactocera dorsalis*). Mediterranean fruit fly was distributed mainly in European, African and North and South American countries where as oriental fruit flies have been found in most Asian countries including Nepal (Thomos 1999). Similarly Citrus green stink bug (*Rhynchocoris humeralis*) was one of the major insect pest responsible for premature fruit drop in citrus (Pandey and Rana 1993). Other citrus pest species were Citrus psylla (*Diaphorina citri*), Citrus leaf miner (*Phyllocnistis citrella*), Lemon butterfly (*Papilio demoleus*), Fruit sucking moths (*Otheris fullonica, Achaea janata* L.), Citrus Aphid (*Toxoptera citricida*).

The insect pests like Red scale, leaf miner, Orange dog, woolly whitefly, false codling moth, thrips, aphids and bud mites have been identified so far as the main pests of citrus in many fruit growing parts of Ethiopia (Yosef et al. 2014). Among the insects, woolly whiteflies are the newly introduced alien invasive pests of citrus across many parts of Ethiopia. The pest sucks the saps of phloem, causing the leaf to wilt and drop when the population of the insect starts increasing. The droplets of the insects collect dust and provide a favorable environment for the growth of sooty mold (Getu 2007).

This studies identified several arthropods as key pests of the crop in Alabama including citrus whitefly, *Dialeurodes citri* (Ashmead) (Hemiptera: Aleyrodidae), purple scale, *Lepidosaphes beckii* (Newman) (Hemiptera: Diaspididae), Glover scale, *L. gloveri* (Packard) (Hemiptera: Diaspididae), citrus red mite, *Panonychus citri* (McGregor) (Acari: Tetranychidae), and citrusrust mite, *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae). The first published studies on life history and control of pests of Alabama satsuma mandarin were conducted in the early part of the last century (Dozier 1924, English and Turnipseed 1933, 1940). After these early publications, commercial production of satsuma mandarins in Alabama was largely abandoned due to severe freezes. The recent expansion of commercial satsuma production in the state has called for a renewed attention to pest management.

A recent comprehensive survey of Alabama satsuma orchards identified at least 28 arthropod pest species (Fadamiro et al. 2007, 2008). These included 24 insect species from five orders: Hemiptera (18 species), Hymenoptera (1 species), Lepidoptera (2 species), Orthoptera (2 species), and Thysanoptera (1 species). In addition, four species of pest mites were identified. Seven species were identified as major pests of satsuma in Alabama including citrus whitefly, *Dialeurodes citri* (Ashmead) (Hemiptera: Aleyrodidae), purple scale, *Lepidosaphes beckii* (Newman) (Hemiptera: Diaspididae), Glover scale, *L. gloveri* (Packard) (Hemiptera: Diaspididae), citrus red mite, *Panonychus citri* (McGregor) (Acari: Tetranychidae) and citrus rust mite, *Phyllocoptruta oleivora* (Ashmead) (Acari: Eriophyidae), citrus leaf miner, *Phyllocnistis citrella*, Stainton (Lepidoptera: Gracillariidae), and leaffooted bug, *Leptoglossus zonatus*. (Hemiptera: Coreidae). The minor (secondary) pests include citrus mealybug, *Planoccocus citri* (Risso), black citrus aphid, *Toxoptera auranti* (Fonscolombe), green citrus aphid, *Aphis spiraecola* Patch, cotton aphid, *Aphis gossypii* Glover, flower thrips, *Frankliniella bispinosa* Morgan, Brown stink bug, *Euschistus servus* Say, green stink bug, *Acrosternum hilare* Say,and red imported fire ant, *Solenopsis invicta* Buren, *Orangedog, Papilio cresphontes* (Cramer), Citrus snow scale, *Unaspis citri* (Comstock), Cottony cushion scale, *Icerya purchasi* Maskell (Fadamiro et al. 2007, 2008). Most of the arthropod pests identified by Fadamiro et al. (2007, 2008) had first been identified in Alabama in the early 1900s (English and Turnipseed 1933, 1940).

Beside these insect pests, other factors also cause the loss of citrus fruits production. The decline of production and productivity of citrus are many types of fungal, bacterial, viral, nematode, to several biotic and abiotic factors Mekbib et al. (2006). Another disease like gummosis also causes a yield loss of 10 to 30% throughout the world due to use of susceptible rootstocks and application of excessive irrigation water (Al-Sadi et al. 2014). Similarly, citrus nematode cause damage to over 50 species of citrus can cause up to 43.3% of yield loss Irshad et al. (2012).

1.1.3 Management practices of citrus pests

In many sites in Florida, growers tried applying insecticides as an effort to mitigate the impact of the citrus leaf miner, although they soon recognized that the tactic was expensive and often ineffective (Heppner 1993). Chemical control alone was not a viable management strategy for the citrus leaf miner over the long term. This was due to concerns about resistance to pesticides, disruption of biological control of other citrus

pests, concerns about pesticide residues on food and in the ground water, negative impacts on worker safety, and impacts on non-target organisms in the environment (Tan and Huang 1996). Classical biological control was expected to provide substantial control of the citrus leaf miner in Florida, particularly in mature orchards. However, they soon learned that surprisingly little was known about many of the species reported as natural enemies of the citrus leaf miner in Southeast Asia (Mafi and Ohbayashi 2006). For many species, there is not even a specific name. Few details were found about the host range of these parasitoids or their ability to be facultative hyperparasitoids, information which was crucial for classical biological control programs (Heppner 1993). Furthermore, in most new environments, the citrus leaf miner has also accrued new natural enemies, including parasitoids that moved onto the citrus leaf miner from unknown hosts (Ujiye 2000). The long term impact of these natural enemies remains to be resolved.

Although traditional pest control, through pesticides use is effective but causes damage to the population dynamics of useful invertebrates (Pekar 1998, Tahir et al. 2010, Mukhtar et al. 2013). Insecticides contain toxic chemicals which have adverse impacts on agro-ecosystem and human health (Bukhari et al. 2012). Many pests have developed resistance against pesticides due to their excessive use (Khuhro et al. 2012, Rogers and Dewdney 2012). Efforts are being made to conserve natural predators in agro ecosystems by using practices that do not damage population of natural predators (Sunderland and Samu 2000). Several techniques like reduce tillage practice (Tahir et al. 2012), organic farming, mulching, intercropping (Sunderland and Samu 2000) and preservation of over-wintering sites (Landis et al. 2000) have been used to increase the diversity and abundance of natural predators in agro-ecosystems. Use of natural predators as biological control agents is a part of integrated pest management technique (Amalin et al. 2001). Natural predators like ladybeetles (Michaud et al. 2002), lacewing *Chrysoperlacarnea* (Rosenheim et al. 1993) and spiders (Nyffeler and Benz 1987, Sunderland and Samu 2000, Tahir and Butt 2009) are effective bio-control agents for several pests in agro-ecosystems (Hodge1999, Ghavami 2008). Knowledge of the type of disease and insect pests is essential for appropriate monitoring leading to a devising of effective management strategies. However, the available information on the type of diseases, insect pests and weeds pose serious threats to production of citrus in the irrigation schemes as very limited.

Farmers were practicing the use of pheromone traps, application of chemical measures and field sanitation of attacked fruit fly, as management options (Jaisawal et al. 1997).

Different citrus pests were controlled and managed by applying different techniques such as integrated pest managements as well as chemical method. Systemic insecticides have been used against the citrus leaf miner and several general predators, such as spiders, ants, and lacewings were used as biological predators to suppressing the population of the citrus leaf miner. Similarly different predators were used to control the different major and minor pests of citrus such as *Ageniaspis citricola*, *Closterocerus cinctipennis*, *Horismenus fraternus*, *Pnigalio minio* have been reported as successful parasitoids and have the potential to play an integral role in biological control (Michaud 2002, Lacey and Shapiro-Ilan 2008). In recent year, biological control methods were practiced in Nepal. Wasp species (i.e. *Anastatus* sp, *Trissolcus letisculus* and *Ooencyrtus utitheisee*) were parasitized citrus green sting bug eggs and reduced the population of bug. Increasing of wasp population and distribution of parasitized egg would be the effective measure for the control of citrus green sting bug. Rearing, conservation and augmentative release of these parasitoids can be useful for biological control of citrus green stink bug (Pandey and Rana 1993).

1.2. Objectives

The general objective was to document insect pests of citrus fruits and their management practices in Sahajpur, Kailali. The specific objectives of the study are to;

i. explore the diversity of insect pests of citrus fruits.

ii. identify the destructive insect pests of citrus fruits and the timing of heavy infestation along with damage patterns.

iii. document local knowledge for the management of destructive pests species and health hazard.

1.3 Significance of the study

Citrus was one of the most important and popular fruits of Nepal. The Far western region was commercially known for three citrus species, mandarin, sweet orange and lime. Citrus fruits were affected by different pests and cause significant loss of quantity and quality of citrus in different citrus growing area of Nepal (FAO 2015). The research was be helpful to recognize pests species occurring in the study area and understand the level of damage pattern to different citrus fruits. This understanding will provided baseline data for developing future strategies to control different pests in different phases of citrus fruits to enhance the quality and quantity of citrus production. Sahajpur, Kailali is one of the important citrus growing area of mid hill agro-ecological area of Nepal where pests identifications was not made. The result obtained could be useful as a baseline for further

research on control of insect pests in the affected areas, which might be of great benefit to both the farmers as well as the entire nation economically.

1.3.1 Research Questions

i. What are the insect pests of the citrus fruits in Sahajpur?
ii. What are the damage patterns of different insect pests and destructive pests responsible for yield loss?
iii. What are the management practices applied by farmers?

2. LITERATURE REVIEW

Citrus fruit production is affected by several biotic and abiotic factors. Among the factors, insect pests are the serious one. More than 250 species of insect are known to damage citrus throughout the world. Among them, fruit sucking bugs, fruit flies, green sting bug, lemon butterfly, stem borer, aphids are very serious pests as they cause massive fruit drop and farmers are facing heavy economic loss in Nepal (Shrestha et al. 2008). Farmers practices chemical, botanical, biological, cultural methods to control pests. Out of them, traditional pest control through use is effective but causes damage to the population dynamics of useful invertebrates. Insecticides contain toxic chemicals which have adverse impacts on agroecosystem and human health (Bukhari et al. 2012).

2.1 Diversity and abundance of insect pest in citrus fruits

Dahal (2020) Studied on the production and trade scenario of citrus in Nepal and result showed the increasing trend of area, productive area, and production of citrus fruits under study i.e. Mandarins, Sweet orange and lime and their decreasing productivity during the study period from 1999/2000 to 2017/18. It is grown in an area of 46,328 ha with only 26,759 ha productive area which accounts total production of 2,39,773 Mt and the productivity is 8.96 Mt/ha.

Shrestha (2006) studied on fruit fly surveillance in Nepal. He reported six species of fruit flies are the major pests of citrus fruits. NCRP (2006) reported Chinese fruit fly (*Bactrocera minax*) as main cause for the massive fruit drop in eastern Nepal. Fruit flies notoriously deplete vegetables and tree-fruits qualitatively and quantitatively (Adhikari et al. 2018). Fruit flies, *Bactrocera cucurbitae*, *B. tau*, *B. dorsalis*, *B. zonata*, *B. scutellaris*, and *B. minax* are predominantly occurring flies in horticultural ecosystem and infesting fruits in Nepal. NPPO-Nepal is aware of the fruit fly pestilence in potentially tradable horticulture fruits of the country, and is making update on the country status of fruit flies through a regular surveillance (Sharma et al. 2015). In Nepal five other species of fruit fly were identified in the training of fruit fly identification which was conducted by Plant Protection Directorate, Hariharbhawan, Lalitpur (Gautam et al. 2015) at NARC Entomology Division, Khumaltar and the species are preserved in Plant Protection Laboratory, Hariharbhawan. *B. nigrofemoralis* (White & Tsuruta) *B. latifrons* (Hendel), *B. aritfacies* (Perkins), *B. tuberculata* (Bezzi) and *D. ciliates* (Loew). The groups of horticultural crops most affected by fruit fly problems were cucurbit fruits (79%)

followed by tree fruits (14%) and solanaceous fruits (6%) Adhikari et al. (2018). G.C. (2001) recorded 42-68% bitter gourds losses due to fruit flies invasion. Chinese citrus fly (*B. minax*) is a very serious insect causing sweet oranges losses as high as 97 % by the end of harvesting season in the eastern middle mountain regions of Nepal (NCRP 2012) and it is moving towards the central parts of the country (Adhikari et al. 2018).

Singh (1998) reviewed on status of citrus decline in India. He concluded that citrus decline was caused by mainly infestation of insect pests (citrus blackfly, psylla, aphid, bark eating caterpillar, trunk borer) infestation of nematode, virus and virus like diseases (Tristeza, psorosis, crinky leaf, infectious varlegation and greening) and the prominent factors responsible for citrus decline was bacterial canker.

Tennant (2009) studied on diseases and pests of citrus (*citrus* spp.) and reported larvae of coleopterans (*Exophthalmus* and *pachnaeus* spp.) causing root damage similarly aphid and psyllid species serves as vector for citrus tristeza virus (CTV) and huanglongbing as well as lepidopterans (*Papiliodemoleus*) feed on the young leaves resulting loss of photosynthetic leaf area and slowed growth of the plant. The serious damage on citrus fruits of all Ructaceae family by caterpillar of citrus butterfly (*Papilio demoleus* Linnaeus) in Andhra Pradesh, India during July to December Gopal et al. (2013).

Tena and Garcia-Mari (2011) carried out a research on current situation of citrus pests and diseases in the Mediterranean basin and they determine the present situation of the citrus pests and diseases in different countries of the Mediterranean basin. California red scale (*Aonidiella aurantii*), the medfly (*Ceratitis capitata*) and the aphids (*Aphis spiraecola*) and (*Aphis gossypii*) as main citrus pests. Finally, the fungi *Phytophtora* spp. and *Penicillium* spp. were considered the most important diseases.

Uygum and satar, 2008 studied the current situation of citrus pests and their control methods in Turkey where they found 89 pests, 34 diseases, 16 nematodes, and 15 weed species until 2007. Among these species, 17 pests, 8 diseases, 1 nematode, and 10 weeds are economically important and control measures should be taken. In this presentation, they explained on how the IPM tactics are used for suppressing the key pests, diseases, and weeds and how to prevent the potential species reached to economic levels.

2.2 Pest management practices

Deka et al. (2016) carried out a research work on survey and surveillance of insect pests of citrus and their enemies in Assam. They recorded about 12 species of insects and mites

pests and many species of natural enemies in khasi mandarin ecosystem in Assam. Very severe incidence of trunk borer (*Anoplophora versteegi*), citrus leaf miner (*Phyllocnists citrella*) and citrus butterfly (*Papilio* spp.) were observed in most of the orchards. Among natural enemies, different species of spider, coccinellids, non-stinging wasps, mantids and chrysopids were the main predators observed. Aubert (1987) worked on *Trioza erytreae* del Guercio and *Diaphorina citri* Kuwayama (Homoptera: Psylloidea), the two vector of citrus greening diseases, biological aspects and possible control strategies and concluded natural enemies to control Asian citrus psyllid nymphs are commonly generalist predators including ladybeetles, Syrphid flies, lacewings and spiders. Citrus crop insect pests management with adhesive cages under integrated pest management program conducted and they recorded *Papilio demoleus* and *Citrus psylla* as major insect of citrus crops which causes severe loss to the grower. They used adhesive cages or insect traps as primary control measures and found that international stick traps (IPST) were more effective than jackson trap (JT) Arya and Dubey (2013).Chattopadhya and Ladaniya (2015) published a prospectus entitle insect pests and diseases of kinnow and their management. They describe eight species of Kinnow mandarin pests and their integrated pest management (IPM) strategies.

Hussain et al. (2017) carried out work on a case study of insect pest complex of citrus and their management at Keren, Eritrea and a note on their natural enemies and recorded woolly whitefly (*Aleurothrixus* sp.), cottony cushion scale (*Icerya purchase*), citrus leaf miner (*Phyllocnistis* sp.), diaspine black scale (*Parlatoria* sp.) and brown scale (*Coccus* sp.). To control the high incidence of *Aleurothrixus* sp. and *Icerya purchase*, field evaluation of locally prepared botanicals (5% neem seed kernel extract, 5% balanites Kernel extract) and imidacloprid 17.8% SL were carried out and they were effectiveness in managing the pests at three weeks post-foliar spray and surprisingly no natural enemy was observed.

IPM comprises combination of culture, biological and chemical control of the insect pests (Gogi et al. 2014). Cultural controls are the oldest methods that have been used to manage pest populations. Cultural practices such as crop rotation, filed sanitation, early showing, tillage and use of resistant varieties considerably contribute to the reduction of pest infestation. Early sowing in the season reduce *Aphis craccivora* infestation in cowpea (Jackai et al. 1985). Pheromones traps are widely used for monitoring, mass trapping and mating disruption of many insects. Prassannakumar et al. (2009) found that red

pheromone traps were effective for trapping male moth pest of vegetables and fruits in Karnataka, India.

Sticky traps are an alternative tool for the monitoring of the insects which are one of the cheaper and almost equal effective for small insects especially aphids (Sarwar 2014). Yellow traps have been found very effective for trapping aphids. Saljoqi and Emden (2003) by using a yellow sticky plastic sheet traps reported a remarkable reduction in aphid (*Myzus periscae*) and other aphid species population in the research conducted in Peshawar, Pakistan.

(Lacoq et al.1983) described cultural practices like, field sanitation, crop rotation and mulching give better protection against aphid pests in growth and fruit setting periods in muskmelon. Cue-lure traps have been used for monitoring and mass trapping of the Melon Fruit Flies in Bitter Gourd (Pawer et al. 1991, Permallou et al. 1998, Seawooruthun et al. 1998, Jaiswal et al. 1997) reported that integrated control with pheromone traps, field sanitation and bagging of individual fruits proved very effective against *Bactrocera cucurbitae* in Nepal. Methyl eugenol and cue-lure traps have been reported to attract males from mid-July to mid-November (Ramsamy et al. 1987, Zaman 1995, Liu and Lin1993). The sex attractant cue-lure traps are more effective than the food attractant lure traps for monitoring the *Bactrocera cucurbitae* and *B. dorsalis* in Bitter Gourd and citrus fruits respectively (Pawer et al. 1991).

Bagging of the fruits is a tedious task for big commercial orchards (Kapoor 1993). The destruction of Bitter Gourd and fruits can be prevented by bagging fruits and using Fruit Fly traps and pheromone traps however field sanitation also prevents their recurrence. Fang (1989a, 1989b) stated that bagging of fruits of Bitter Gourd (*Momordica charantia*) in Taiwan at the stage of 3 to 4 cm fruits length with 2 layers of paper bags every 2-3 days against *Bactrocera cucurbitae* greatly promoted fruit quality and the yields and net income increased by 45% to 58% respectively. Sanitation i.e. manual destruction of infested twigs and fruits and bait trapping with Cue lure pheromone works wonder for Fruit Fly control (Kapoor 1993). Nasiruddin and Karim (1992) reported that the hand picking is less effective but necessary because the female Fruit Fly lay eggs and the larvae hatch inside fruit, so it is essential to look for available measures in the field sanitation.

2.3 Chemical control

Shrestha (2011) worked on productivity improvement of citrus fruits through effective fruit drop management techniques in the mid and far western development region of Nepal and reported green sting bug as major factor of citrus fruit drop. To control green sting bug spraying insecticides Roger or Phoskill @ 2ml/l water in first and second nymphal stage is effective. Fruits and vegetable producers around the world rely heavily on the use of chemical pesticides for pest control. Although pesticides do not directly contribute to agricultural yields, there is evidence to suggest that intensive use of pesticides has significantly increased agricultural production (Brethour and Weersink 2001). Halder and Rai (2018) reported that the acetamiprid pesticide was highly effective for the control of *Myzus periscae*, *Aphis craccivora* and *Lipaphis erysimi* in Uttar Pradesh, India.

An experiment conducted by Kafle (2015) for the management of Turnip aphid (*Lipaphis erysimi*) in Lamjung, Nepal reported that Dimethoate (Rogor 30 EC) was highly effective for the control of pest. Khan et al. (2011) studied efficacy of imidacloprid and thiamethoxam against *M. persicae*. Both the foliar insecticides significantly reduced *M. persicae* infestation. Haider et al. (2007) evaluated the toxicity of various synthetic pyrethroids and organophosphorus insecticides to *M. persicae* by direct spray and leaf-dip method in the laboratory. Among the synthetic pyrethroids, alpha-cypermerthin was the most toxic insecticide and profenofos was the most toxic organophosphorus insecticide. A survey in Dhading and Sindhuli districts revealed only a few farmers were using chemical such as Folido, Metacid (now banned), Malathion, Roger and Thiodin (now banned) to control citrus sting bug (Manandhar et al. 2002). Further, spraying of Metasystox was found effective to control citrus sting bug (Tiwari and Thapa 2010).

Sen et al. (2018) concluded that chemical pesticides imidacloprid, thiamethoxam and diafenthiuron were effective against *Lipaphis erysimi* at Nadia, West Bengal, India. Chiranjeevi et al. (2002) evaluated imidacloprid, lambda-cyhalothrin, monocrotophos and cypermethrin against *M. persicae* and found that imidacloprid was proved to be the most effective insecticide.

2.4 Botanical control

Hikal et al. (2017) concluded that Botanical insecticides affect only target insects, not destroy beneficial natural enemies and provide residue-free food and safe environment,

therefore recommend using botanical insecticides as an integrated insect management program which can greatly reduce the use of synthetic insecticides. In this, we review the use of plant compounds (essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids) having anti-insect effects and their importance as an alternative to the chemical compounds used in the elimination of insects in different ways, namely repellents, feeding deterrents/antifeedants, toxicants, growth retardants, chemosterilants, and attractants. Botanical insecticides are naturally occurring extracted or derived from plants or minerals are considered to be the best alternative to synthetic pesticides. They are also called natural insecticides. Botanical pesticide of Neem and tobacco were found effective to control aphids, thrips and white flies in the research carried by (Kunbhar et al. 2018) in Tandojam, Sindh, Pakistan. Ara et al. (2015) carried out study to assess the larvicidal efficacies of some indigenous plant seed extracts against Epilachna beetle, *Epilachna vigintioctopunctata* in the laboratory of the Department of Entomology, HSTU, Dinajpur, Bangladesh. Neupane (1999) reported that the water extracts of green leaves of Neem, chinaberry, malabar nut and Indian privet were found effective in controlling insect pest have been demonstrated as antifeedent, growth inhibitors, chemo sterilanta and repellents, could repel over 120 species of insects Budhathoki et al. (1993). (Butterworth and Morgan 1968, Leuschner 1972). Sing and Srivastava (1985) found that alcohol extract of Neem oil reduced oviposition of fruit fly completely. Khalid (2009) found that both Neem seed water and Neem oil extract at 10,000 ppm adversely affected the settling of Melon Fruit Fly. Rajapaske and Ratnasekera (2007) studied management of insect pest in commercial agricultural and concluded that the use of Neem based product with predatory ants gave excellent control of Fruit Fly.

2.5 Biological control

Biological control is the use of natural enemies of insect pests to suppress target pest populations. It is an important component of integrated pest management. Natural enemies of insect pests include predators, parasitoids and pathogens. Pathogenic micro-organisms include bacteria, fungi and virus. Common predatory insects are ladybug, lacewings and praying mantids Deka et al. (2017).Biological control involves the use of one or more types of beneficial organisms, to reduce the numbers of another type of organism (van Lenteren 2011) or alternatively the use by humans of parasitoid, predator, pathogen, antagonist or competitor populations to suppress a pest

population, thereby making the pest less abundant and damaging than it would be in the absence of these organisms (Hoddle 2004, van Driesche et al. 2008).

Maharjan et al. (2016) concluded that *C. septumpunctata* is an effective predator for the control of different aphid species in an experiment conducted in laboratory of Entomology Division, Nepal Agricultural Research Council (NARC), Khumaltar. *Coleomegilla maculate* is the most widely recognized predatory insect of aphids in United States (Sanda and Sunusi 2014).

Citrus is attacked by a number of insect pests in Pakistan. The list includes citrus psylla *Diaphorina citri*, leaf miner *Phyllocnistis citrella*, white fly *Aleurocanthus woglumi* scale insect*Aonidiella aurantii*, mealy bug *Planococcuscitri*, fruit flies *Bactrocera zonata* and *B.dorsalis* and butter fly *Papiliode moleus*. Lemon butterfly is one of the destructive pests of citrus fruits managing by different biological agents include the yellow wasp (*Polistes hebreus* F.), praying mantis (*Creobrator gemmatus*) and spider Gopal et al. (2013). At present farmers rely on pesticide sprayings in orchards to control pests and diseases. These practices have not only worsened the pest status overtime but also have created the risks of pesticide residues in produce. The need of the time therefore is to shift from the present pesticide based plant protection to integrated pest management based on bio-ecological principles to reduce the use of pesticides in crops particularly in horticulture. In the paper, status of key pests of citrus in Pakistan is reviewed and possibilities of their management by non-chemical measures have been discussed (Mahmood et al. 2014).

There is a long history of attempts to use parasitoids for the biological control of fruit flies. Clausen (1978) reviewed the classical biological control methods in the world for controlling fruit flies.

Citrus psylla has become a very serious pest in all citrus growing areas of Pakistan. It attacks all parts of the plant above ground affecting plant yield. Insect feeds on plant sap and under high populations plant start dying (Halbert and Nunez 2004). In Pakistan CIBC (Anon 1969) conducted surveys for natural enemies of *D. citri* and recorded some species of parasitoids including *Tetrastichus* spp. *Tetrastichodes* spp., *Psyllaephagus* spp., *Aphycoide* spp. and *Achrysochari* spp.

The citrus leaf miner is mainly a pest of *citrus* spp. damages by mining the inner under side of young citrus leaves. Larval feeding results in leaf deformation and leaf drop. It is

widely distributed in Asia and is also found in Australia, Florida, in USA, Honduras in Central America, Cyprus, Italy, Spain, and Turkey in Europe (Anon 1995). In survey conducted in 1960s in Pakistan CABI recorded *Ceratoneuromyia*sp. And *Cirrospilu* spp. parasitizing larvae (Mohyuddin 1981). About 39 species of parasitoids have been reported from citrus leaf miner from Southeast Asia, Japan, Australia, and USA (Heppner 1993, Evans 1999, Lo and Chiu 1988, Schauff et al. 1998).

The mealy bugs and scale insects suck the plant sap and highly infested plants become weak, shoots dry and thus indirectly affects the plant yield. The mealy bugs secrete honey dew which deposits on leaves and twigs. It is highly polyphagous species and more than 100 plants have been reported as its hosts in Pakistan. It is one of the major pests of citrus. In Pakistan farmers mostly dust insecticide powder on soil around tree trunks or put sticky bands on tree trunks to check the climbing of nymphs on tree. In India the researchers such as Lakra et al. (1980) and Sandhu et al. (1981) and in Pakistan Rahman and Latif (1944) studied the effectiveness of various types of bands put around tree trunks for checking the climbing of the bug nymphs on trees.

Aonidiella spp. are common pests of *Citurs* spp. in the plains. They suck the plant sap and highly infested plants become weak and the shoots dry and indirectly affect the plant yield. Biological control of *A. aurantii* has been quoted as one of successful example of biological control of insect pests worldwide. In California and other countries a number of predators and parasitoids were obtained from the oriental region including Pakistan, India and China (Clausen 1978).

Different way to biological control of Lemon butterfly are Larval parasitoids (*Erycia nymphalidophaga* Baron off, *Cantheconidea furcellata* (Wolff), Pupal parasitoid (*Brachymeria* sp. *Pteromalus puparum* Linnaeus from Thailand, and an encyrtid egg parasitoid and a chalcidoid parasitoid have been reported from Jamaica. A number of parasitoids including *Apanteles* spp. including *Apanteles papilionis*, *Bracon hebetor* and egg parasitoids (*Ooencyrtus malayensis* Ferriere ,*Tetrastichus* sp.) from India (Clausen 1978). Predators including predatory pentatomids, reduviid bugs, birds, spiders, sphecid wasps and chameleons have also been reported from Thailand (Clausen 1978). In Pakistan the parasitoids *Pteromalu s*pp. *Pteromalus bengalensis* and *Bugnetia musca* are known attacking butterfly larvae (Anon 1969).

3. MATERIALS AND METHODS

3.1 Study Area

The study area was Sahajpur of Chure Rural Municipality in Kailali district (Figure 1). It lies in upper tropical region and altitude is 824 m asl. It extended approximately from the latitude of 29º N and longitude of 80.59º E. Kailali district has high possibilities of agricultural commercialization because of suitable climate, favourable soil. District Agriculture Development Office (DADO) has identified, Sahajpur, Nigali and Khairala as citrus growing pocket area.

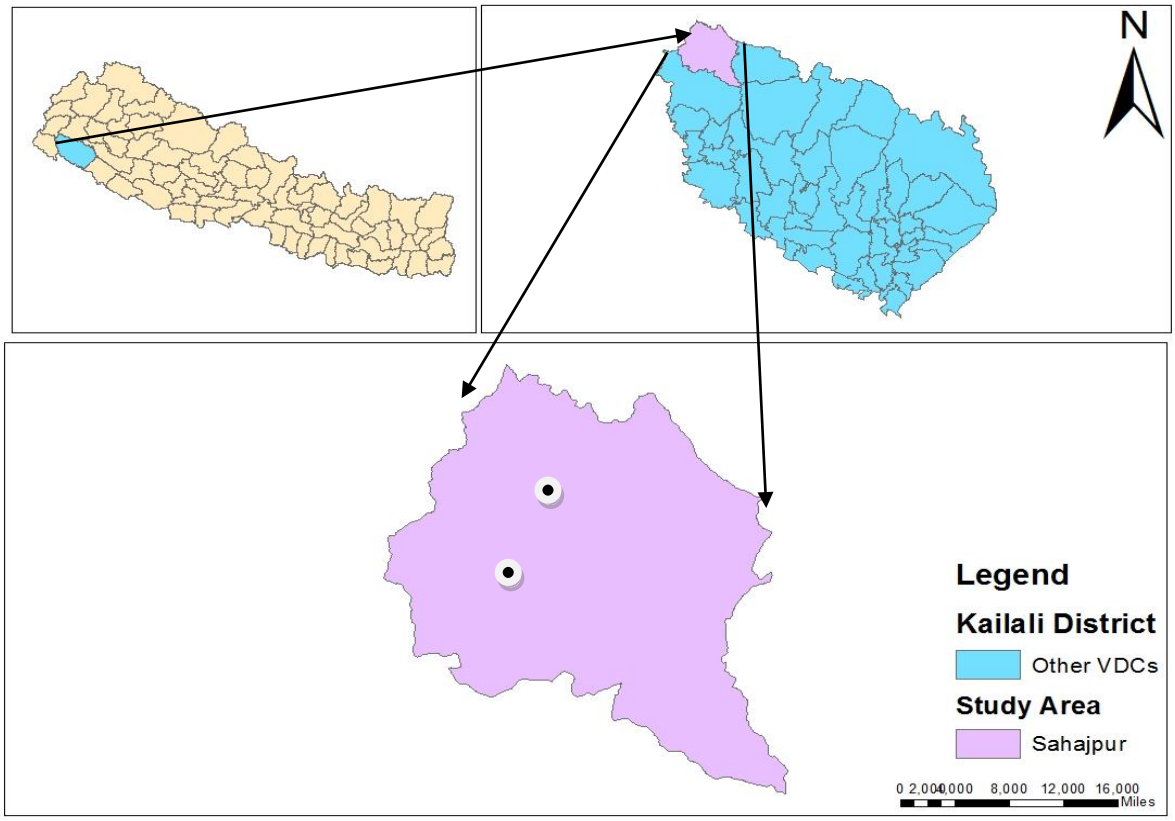

Figure: 1 Map of study area, Sahajpur, Kailali.

3.2. Sampling Methods

3.2.1. Collection of pests

Insect pest species were collected for six months from September to February. For collection of pests, randomly 100 citrus plants were selected from both commercial (30%) and non-commercial (70%) cultivated sites of the study area. Pests were collected twice a month during study period. Hand-picking method and yellow pan trap were adopted including beating method for collection of pests. Trapped pests were collected by camel

hair (10A) brush and preserved in 70 % alcohol. Hand picking method was applied using feather weight forceps. Insects that cause less than 5 % damage were not considered as pests. For listing out major and minor pests of citrus damage pattern and yield loss were observed. The insects which cause damage between 5-10% were considered as minor pests and those that cause damage above 10% were considered as major pests (Paul Navarajan 2007). The yield loss was assessed using questionnaire survey and calculated using following formula.

Yield loss = Total damage parts/ Total parts × 100 %

3.3.2. Questionnaire survey

For the assessment of yield loss and pest management, questionnaire method and informal discussion with farmers was made and the pest management status was assessed in the study area. The people perception about the pest management practices and health hazards were documented.

3.3.3. Identification of specimens

Species were identified by using standard keys (Borror and De Long 1964, Richards and Davies 1977 and Sharma et al. 2015). Further specimen were identified by help of entomologist of Crop Protection Laboratory, Sundarpur, Kanchanpur and Agriculture Knowledge Center, Kanchanpur. The collected specimens were deposited at the Museum of Central Department of Zoology (Entomology), T.U. Kirtipur, Kathmandu, Nepal. Identified species and their short description are given in Appendix II.

3.3.4 Data Analysis

The primary data were managed in excel software and later transferred to statistics software for further analysis. Following statistical tools were performed to analyze the data.

Relative abundance is the percent composition of an organism of a particular kind relative to the total number of organisms in the area. Relative abundance was used to show the family wise and order wise composition of identified insect pest.

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

Where, n= Number of each individual

N= Total number of individual

Shannon-Wiener diversity index was used to calculate the species diversity.

$H = \Sigma (pi) * (\ln pi)$……. (Shannon Wiener, 1949)

Where, H= Shannon- Wiener diversity index

N= Important value for each species is the number of individual in each; the abundance of each species.

N= Total important value, total number of individual observed.

Correlation was performed to find relation between insect pest abundance with damage percentage.

4. RESULTS

4.1 Diversity of insect pests of citrus fruits

During the study, a total of 430 individuals were captured from the both commercial and non-commercial cultivated sites of the study area. Citrus pests preliminarily belonged to major three orders: Hemiptera, Lepidoptera and Diptera. The order Hemiptera (74%) was the most abundant order followed by Lepidoptera (21%) and Diptera (5%) was least abundant (Figure 2).

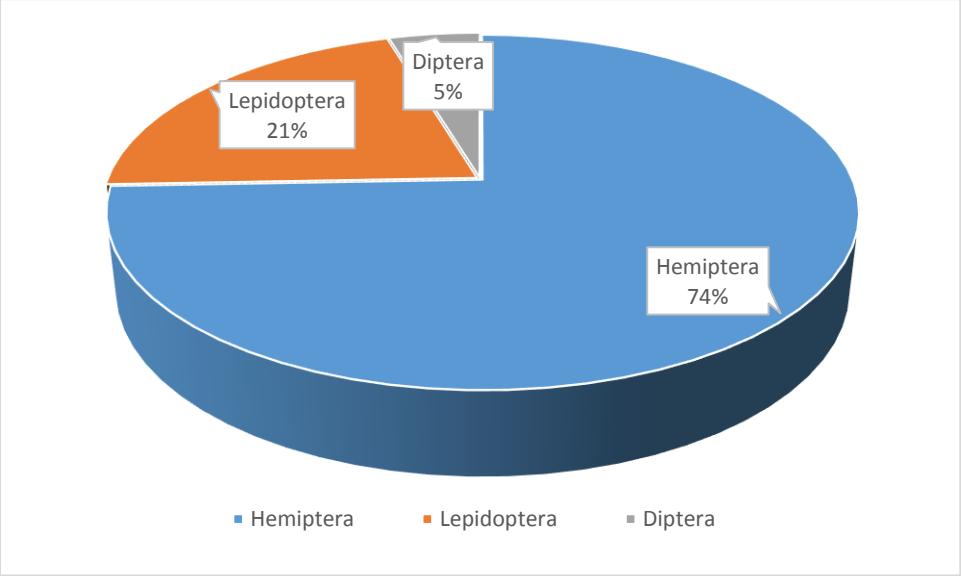

Figure: 2 Order wise composition of Citrus pests in study area

Out of 430 individuals, 10 genera of insect pests belonging to nine families and three orders were identified. Among the various families, Aphididae (44.65%) was the most abundant family followed by Gracillarirdae (10.23%) and Pentatomidae (8.83%). The least abundant family was Tephritidae (4.65%) followed by Erebidae (4.88%) and Papilionidae (5.81%) (Figure 3).

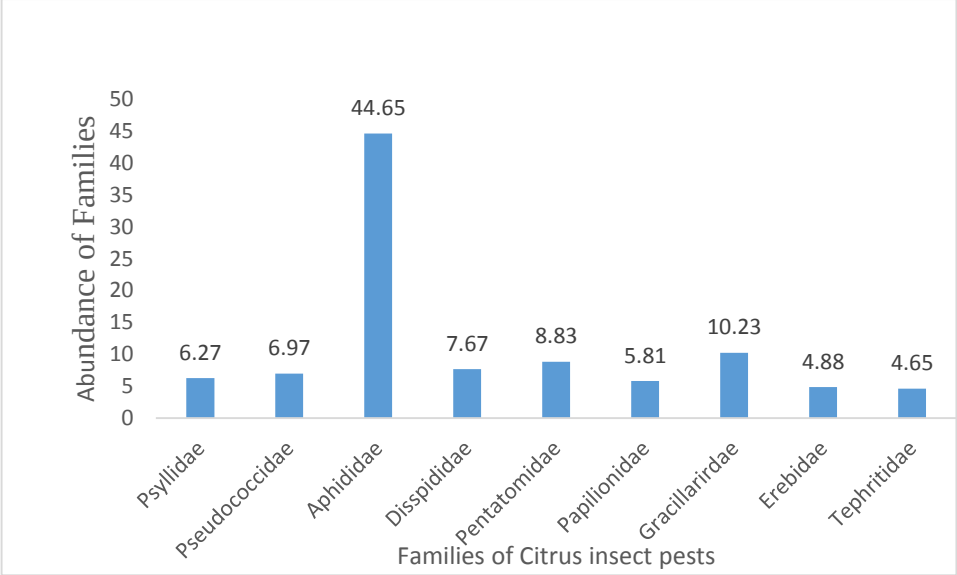

Figure: 3 Family wise compositions of Citrus pests in study area

4.1.1. Relative abundance of citrus pest species

Diaphorina citri, Planoccus citri, Toxoptera aurantii, Toxoptera citricidus, Aonidiella aurantii, Rhychocoris humeralis belonging to the order Hemiptera; *Papilio demoleus, Phyllocnistis citrella* and *Eudocima* sp. belonging the order Lepidoptera and *Bactrocera dorsalis* to the order Diptera.

Table: 1 Diversity and relative abundance of citrus pest species

Common Name	Scientific Name	Order	Family	Abundance	Relative abundance (%)
Citrus Psylla	*Diaphorina citri*	Hemiptera	Psyllidae	27	6.27
Mealy Bug	*Planoccus citri*	Hemiptera	Pseudococcidae	30	6.97
Black Citrus Aphid	*Toxoptera aurantii*	Hemiptera	Aphididae	89	20.69
Citrus Aphid	*Toxoptera citricidus*	Hemiptera	Aphididae	103	23.95
Red Scale	*Aonidiella aurantii*	Hemiptera	Disspididae	33	7.67
Citrus Green Sting Bug	*Rhychocoris humeralis*	Hemiptera	Pentatomidae	38	8.83
Citrus Lemon Butterfly	*Papilio demoleus*	Lepidoptera	Papilionidae	25	5.81
Citrus leaf Miner	*Phyllocnistis citrella*	Lepidoptera	Gracillarirdae	44	10.23
Fruit Sucking Moth	*Eudocima* sp.	Lepidoptera	Erebidae	21	4.88
Fruit Fly	*Bactrocera dorsalis*	Diptera	Tephritidae	20	4.65

The Shannon-Winner diversity index (H) was calculated to be 2.132 which indicates high diversity of citrus insect pests, with Pielou's species evenness (J) was calculated to be 0.926 (Appendix I).

4.2. Destructive insect pests of Citrus fruits

Destructive insect pests were categorized into major and minor pests based on the nature of damage done by them. The study found that 60% insects were minor pests and 40% pest were major pests of citrus (Table 2 and Figure 4).

Table: 2 Destructive insect pests of Citrus fruits

Order	**Family**	**Genus**	**Species**	**Status**	
				Major	**Minor**
Hemiptera	5	6	6	2	4
Lepidoptera	3	3	2	1	2
Diptera	1	1	1	1	0
Total	9	10	9	4	6

The study shows that species like *Toxoptera citricidus* (Hemiptera), *Rhychocoris humeralis* (Hemiptera), *Papilio demoleus* (Lepidoptera) and *Bactrocera dorsalis* (Diptera) were destructive (major) insect pests of Citrus whereas *Diaphorina citri* (Hemiptera), *Planoccus citri* (Hemiptera), *Toxoptera aurantii* (Hemiptera), *Aonidiella aurantii* (Hemiptera), *Phyllocnistis citrella* (Lepidoptera), *Eudocima* sp. (Lepidoptera) were considered as Non-destructive (minor) insect pests.

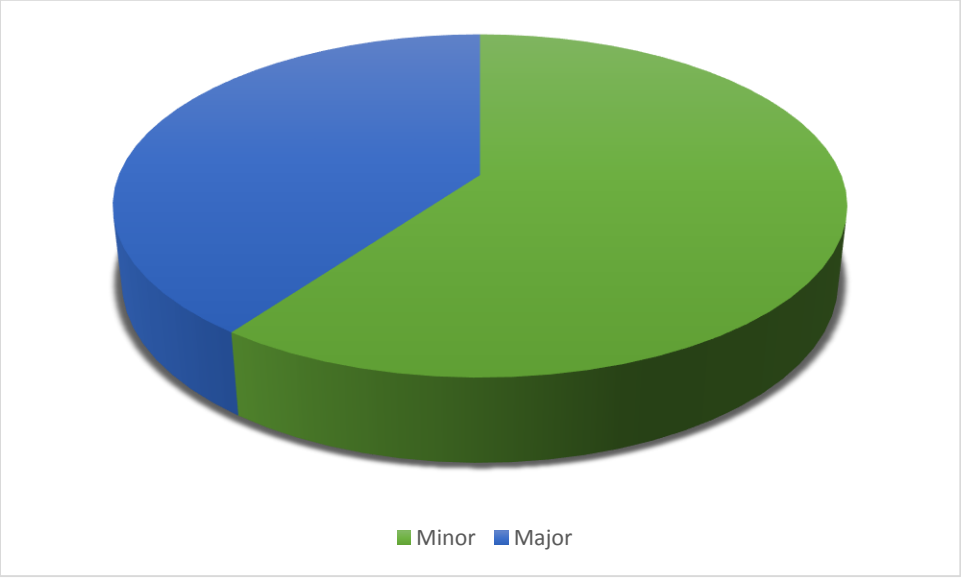

Figure: 4 Major and minor pests of Citrus fruits

4.2.1 Insect pests damage pattern observed in the field

Insect pests were responsible for variety of damages ranging from moderate to severe. Although several abiotic factors plays a major role in damage pattern in several species. In present study, insects pest were responsible for damage throughout season feeding almost all parts of plants. The specific damage pattern of Insect pests are listed in Table 3.

Table: 3 Damage pattern of Citrus by insect pests

Species	**Damage pattern**
Diaphorina citri	Leaves and Stem
Planoccus citri	Root, Foliage and Fruits
Toxoptera aurantii	Bud and Leaves
Toxoptera citricidus	Foliage and Flowers
Aonidiella aurantii	Stem, Fruits and Leaves
Rhychocoris humeralis	Fruits and twings
Papilio demoleus	Light Green tender leaves
Phyllocnistis citrella	Lower and Upper Surface of Leaves
Eudocima sp.	Fruits
Bactrocera dorsalis	Fruits

4.2.2 Monthly abundance of insect pests of citrus fruits

Statistically, a significant difference was observed in abundance of insect pest on citrus. The higher abundance was found on the month of November (92 ± 2.42) followed by in month of January (86± 0.86). The lowest abundance was recorded in month of September (44 ± 0.23) (Figure 5).

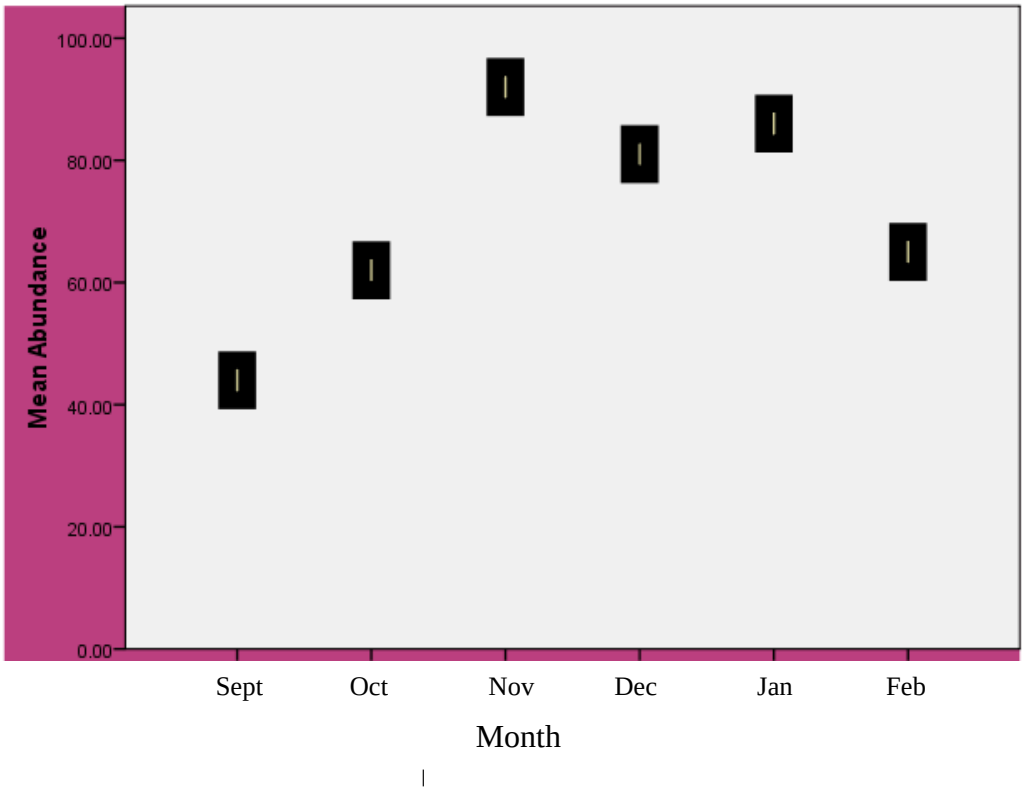

Figure: 5 Abundance of Citrus pest on different month

4.2.3. Infestation on different months

Time of heavy infestation was obtained with the help of questionnaire survey from respondents and direct observation. It was obtained with the yield loss experience by respondents throughout season. The study reveals that infestation rate gradually increases from September to December and gradually decreases thereafter. Highest damage percentage was observed in December (18%) and lowest in September (5%).

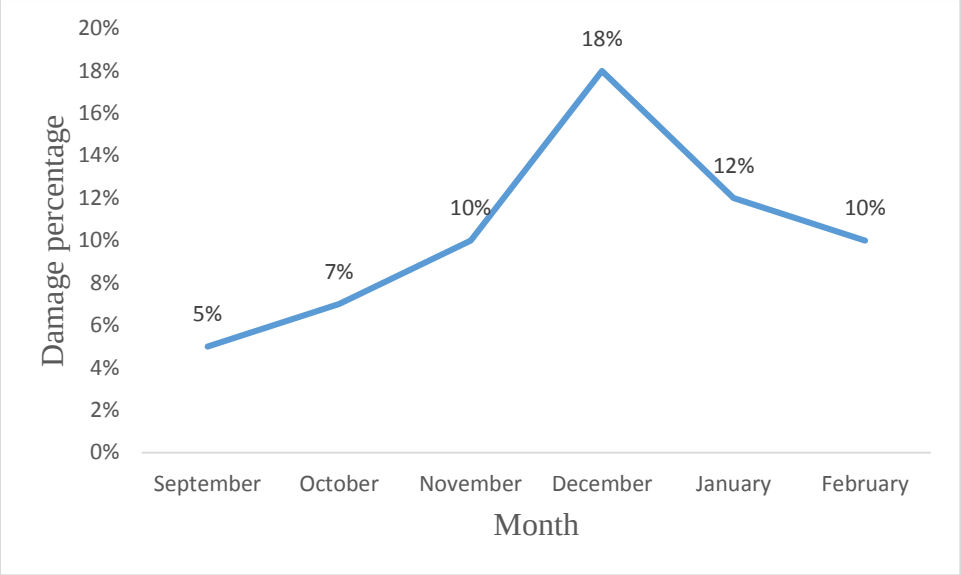

Figure: 6 Infestation on different months

4.2.4. Relationship between Insect pest abundance and Damage percentage

There was positive correlation between abundance of insect pest and damage percentage. The Pearson correlation matrix showed that damage percentage increases as pest abundance increases on different months.

Table: 4 Correlation between abundance of insect pests and damage percentage

Variables	Abundance of insect pests	Damage percentage
Abundance of insect pests	1	0.674**
Damage percentage	0.674**	1

**** Correlation is significant at 0.01 level**

4.3. Pest management practices

The study found that most of the farmers grow citrus for household consumption. Only few famers grows citrus commercially. By using questionnaire method and informal discussion with farmers, the pest management status was assessed in the study area (AppendixIII). The total number of respondent were 60. Out of which 65% were male and 35% were female. Pest management practices followed by the farmers include use of chemical pesticides, bio-pesticides, tillage, crop sanitation and hand picking of insect pests. It was found that farmers seldom use traditional as well as the newly commercialized bio-pesticides as practice of insect pests management. Moreover, they preferred to use chemicals pesticides. The study found that 33% farmers use chemical pesticides and 28% farmers adopted mixed methods, 27% farmers use cultural methods

and 12% farmers adopt bio-pesticides to control pests in their field. Many of them had knowledge about IPM but they do not practice in their field because according to them, IPM requires a lot of labor, time and pesticides are cheaper.

Table: 5 Methods of pest management adopted by farmers

Methods	**No of Respondents**
Chemical	20
Cultural	16
Bio pesticides	7
Mix	17
Total	60

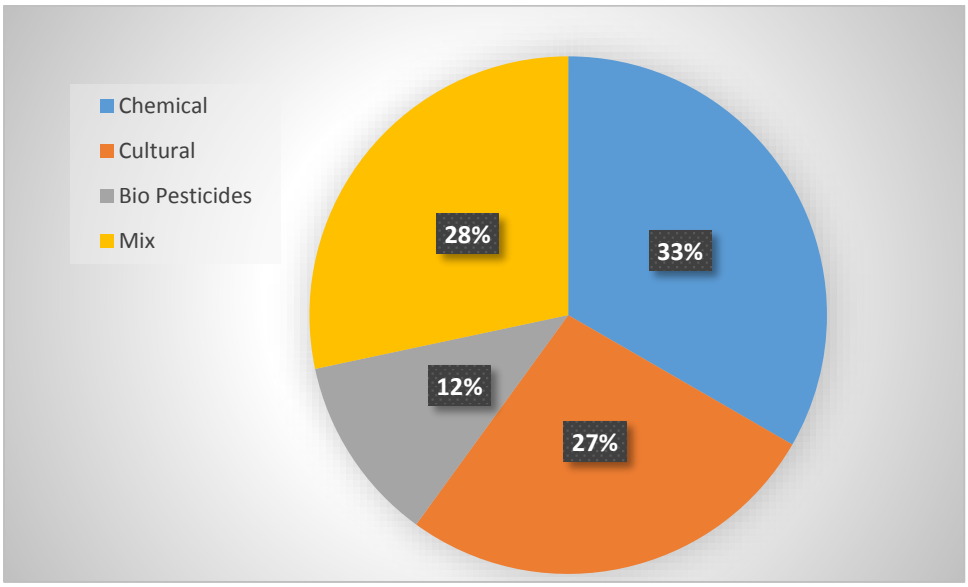

Figure: 7 Methods of pest management adopted by the farmers

4.3.1 Chemical pesticides used for the control of pests

The study found that 33% farmers use chemical pesticides to control insect pests in citrus. Most of the famers used chemical pesticides to control the insect pests and disease. Only few farmers used chemical pesticide to increase productivity. Chemical pesticides used in the study area were: Dichlorovus, Dimethoate, Malathion, Alphamethrin, Imidacloropri, Mancozeb, and Cypermethrin. Most of the citrus were sprayed with Nuvan, and cypermethin to control aphid and biting insect caterpillars. Dimethoate was used to control caterpillars and whiteflies. Imidacloropid was mostly pesticide used to kill insect pests of citrus.

Table: 6 Chemical pesticides used for the control of pests in study area Shajpur

Trade Name	Common Name	Pesticide group	WHO Class	Physical State
DD-76	Dichlorovous	Organophosphate	IB	Liquid
Nuvan	Dichlorovous	Organophosphate	IB	Liquid
Rogarplus	Dimethoate	Organophosphate	II	Liquid
Malathion50%EC	Malathion	Organophosphate	III	Liquid
Surya M-45	Mancozeb	Fungicide	U	Solid
Stop 10 EC	Alphamethrin	Synthetic Pyrethroid	II	Liquid
Stop 10 EC	Cypermethrin	Synthetic Pyrethroid	II	Liquid
Gaucho, Admire, Marathon	Imidacloroprid	Nicotinoid	II	Solid/Liquid

Note: IB= highly hazardous, II= moderately hazardous III= slightly hazardous, U= Unhazardous

4.3.2. Cultural method used for the control of pests

The study found that 27% farmers use cultural methods to control insect pests of citrus fruits in the study area. The different cultural methods followed by the farmers in study area are ploughing, racking, hoeing, pruning, and destruction of weed hosts and buried. Most of the farmers do buried, hoeing and destruction of weeds to control pests.

Table: 7 Cultural methods used in study area

Cultural Methods	Target Pest
Ploughing	Caterpillar, fruit flies
Racking and hoeing	Fruit flies
Pruning	Mealy bugs and aphids
Destruction of weed hosts	Citrus fruit sucking moth
Buried	Fruit flies

4.3.3. Bio- pesticides used for the control of pests

The 28% farmers use bio-pesticides to control insect pests of citrus fruits in the study area. Most of the farmers prepared bio-pesticides by themselves and only few farmers purchased bio-pesticide such as Derisom, and Neem oil from the market. While preparing local bio-pesticides, they use mixture of animal urine, neem leaves (*Azadirachta indica*), titepaati leaves (*Artemisia vulgaris*), banmara (*Eupatorium* spp.) and bakaina (*Melia azadarach*). Besides use of bio-pesticides, farmers also reported use of ash, soapy water, garlic and animal urine to control insect pests and diseases. Among them, mostly used was ash followed by animal urine and soap water.

Table: 8 Bio-pesticides used in study area

Botanical Pesticides	Target Pest
Neem oil	Aphids, caterpillar of lemon butterfly and citrus leaf miner
Banmara leaves	Aphids and Mealy bugs
Titepati leaves	Caterpillars, aphids, GSB and other fruit sucking pests
Derison	Scale insects, thrips,and whiteflies
Animal urine	Green sting bug and aphids
Carcass	Green stink bug
Ash	Beetle and aphids

4.3.4. Equipment used for the application of pesticides

Farmers used different types of appliances such as sprayers, hand compression, hand sprayer, broom, brushes and duster for applying pesticides in the field. Among them hand compression sprayer was mostly used. In the absence of a sprayer, locally made brooms are used. Similarly, in the absence of a duster, pesticide dust is spread over plants and soil surface by hand.

4.3.5. Farmers perception on pesticides

Most of the respondent reported that the use of chemical pesticides and chemical fertilizer in the citrus has increased the production. Majority of farmers 40% used pesticides to control pest, 33% used pesticides to increase productivity and 27% used pesticides to control disease. According to them, local bio-pesticides are time consuming, nuisance to prepare and readymade bio-pesticides are expensive and not as effective as chemical pesticides. This forced them to use chemical pesticides as chemical pesticides are cheaper and easily available at market. Majority of the farmers are unaware of pesticide types, level of poisoning, safety precautions and potential hazards on health and environment. Most of the respondents about 60% have the knowledge of adverse health hazards of pesticides and 40% did not have knowledge about adverse health hazards of pesticides (Figure 8).

Table: 9 Reason of using pesticide by farmers

Reasons	No. of Respondents
Control Pest	24
Increase Production	20
Control Disease	16
Total	60

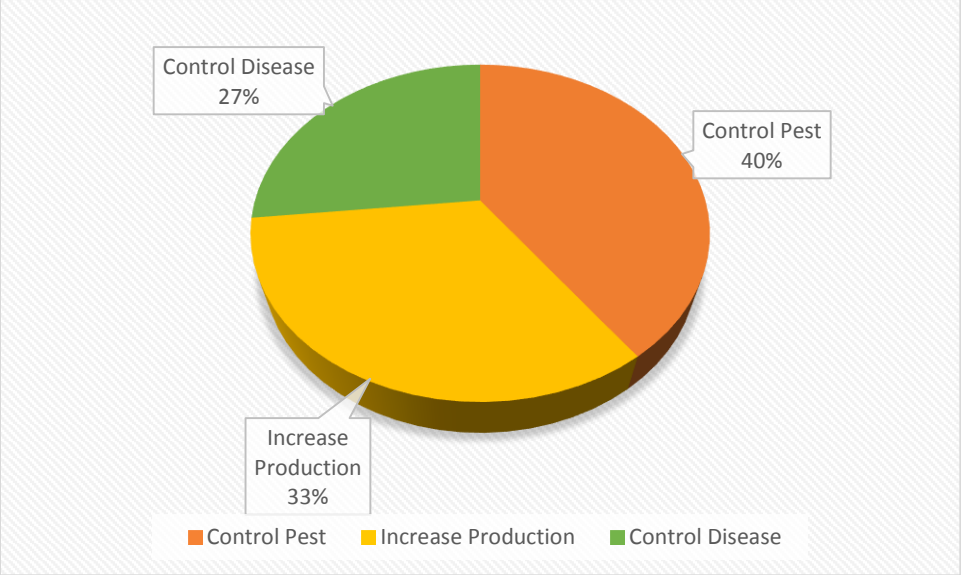

Figure: 8 Reasons of using pesticides by the farmers

4.3.6 Protective measures adopted during use of pesticides

Very few farmers used protective clothing or other safety measures during insecticide application. The study found that 21.21% of total respondents did not use any safety measures at all, 84% of the respondents covered their mouth with masks and piece of clothes. 44% of them used gloves while applying and mixing pesticides. No farmer used glasses or other form of protective devices to protect their eyes during pesticide application. This may put them in the risk of acute and chronic health hazards due to the inhalation, ingestion and contamination of pesticides. The reason for not using protective measures was lack of knowledge and not having the habit of wearing. Due to unsafe practices, fruit growers are more vulnerable to expose with toxic pesticides and are in higher health risks as there has been use of pesticides with too little or no protection. Most of the respondents maintain personal hygiene after pesticide spray. 63% of them change their clothes and 37% did not change their clothes right after using pesticides.

Table: 10 Use of personal protective equipment and maintenance of hygiene

Items	**Yes %**	**No %**
Gloves	44	56
Mask	84	16
Shoes	85	15
Hat	25	75
Glasses	-	100
Change clothes	63	37
Wash hand and feet	75	25

4.3.7 Disposal techniques

Most of the farmers (50.5%) did not dispose pesticides bare container properly. They throw the pesticide containers anywhere they like. 20.5% buried in the fields and 15% disposed by burning. 14% of the respondents throw them in dumping sites.

4.3.8 Health hazards experienced by the farmers while using pesticides

In this survey, 44% respondent replied that they did not experience any health effect, 35% experienced headache and nausea. Similarly, 21% experienced skin problems like itching, skin rashes, burn and allergy.

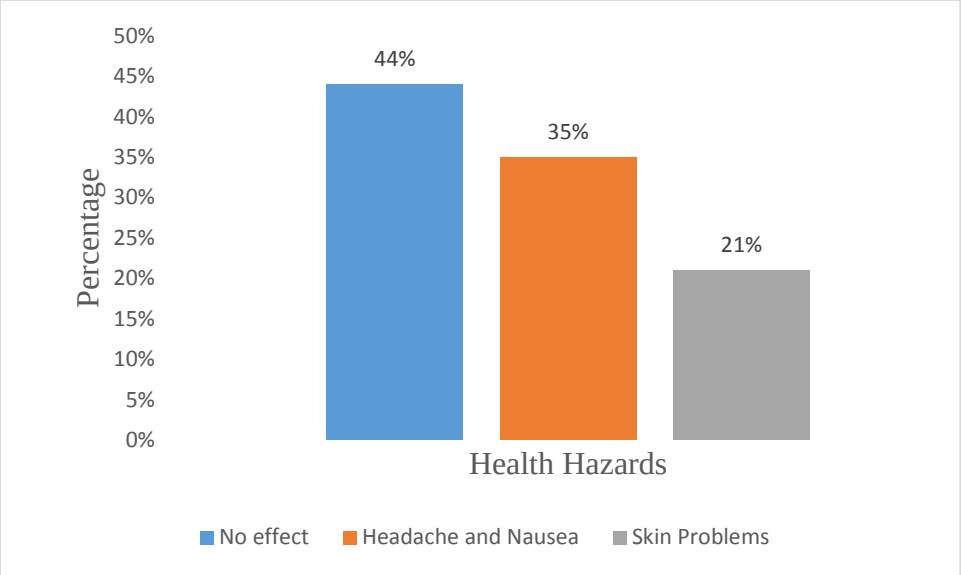

Figure: 9 Health hazards experienced by the farmers

5. DISCUSSION

5.1. Abundance and diversity of insect pests

The present study found 10 citrus insect pests species belonging to nine families (Psyllidae, Pseudococcidae, Aphididae, Disspididae, Pentatomidae, Papilionidae, Gracillarirdae, Erebidae, Tephritidae). The results of this findings are in conformity with the findings of Chattopadhya and Ladaniya (2015) who describe eight species of Kinnow mandarin in Assam.

Family Aphididae of the order Hemiptera was most abundant followed by Lepidoptera and Diptera was least abundant. The study result shows resemblance with study result of Bhat and Ahangar (2018) who had reported family Aphididae as the most abundant insect pest family in the research conducted on vegetable crops and fruit in Kashmir valley, India.

In this study two species of aphids namely *T. citricida* and *T. aurantii* were found from citrus cultivated area of Sahajpur, Kailali as a vector of CTV. The number of *T. citricida* was found more than *T. aurantii*. Similarly, Regmi and Lama (1992) reported two species of aphid *T. citricida* and *T. aurantii* from the horticulture farm of Pokhara and Sanothimi (Bhaktapur) among which *T. citricida* was considered as a major vector for the transmission of the CTV. Likewise, similar species of aphids were recorded for the transmission of CTV in horticulture farms at Lamjung, Nepal (Ghimire 2000) which caused the huge loss of citrus production in Sahajpur, Kailali.

Fruit flies and aphids were also the major problem in the study area. They causes huge loss productivity in citrus fruits. Similar result was observed by Adhakari et al. (2015). Among different pest problems of these horticultural crops. Fruit fly is an important insect pest in Nepal Adhakari (2015). In Nepal various insect pests of citrus have been reported in various location, citrus aphid, fruit fly, green sting bug, bark borer and lemon butterfly as key insect pests (Paneru and Giri 2011).

The species diversity index of insect pests found in study area was 2.132, which indicates high diversity of citrus insect pests and species evenness was calculated to be 0.926.

5.2. Destructive insect pests of Citrus fruits

In this study 60% insect pests were minor pests and 40% were major pest of citrus. Major insect pests of Citrus were *Toxoptera citricidus, Rhychocoris humeralis, Papilio demoleus*

and *Bactrocera dorsalis.* Minor insect pests were *Diaphorina citri, Planoccus citri, Toxoptera aurantii, Aonidiella aurantii, Phyllocnistis citrella, Eudocima* sp. This findings are similar to results of Thomos (1999) who concluded that the major citrus pest fruit fly species were Mediterranean fruit fly (*Ceratitus capitata*) and Oriental fruit fly (*Bactocera dorsalis*). Mediterranean fruit fly were distributed mainly in European, African and North and South American countries where as oriental fruit flies have been found in most Asian countries including Nepal (Thomos 1999). The insect pests like red scale, leaf miner, Mediterranean fruit fly, thrips, aphids have been identified so far as the main pests of citrus in many fruit growing parts of Ethiopia (Yosef et al. 2014).

On the basis of survey, Green sting bug, Fruit fly and citrus (*Toxoptera citricidus*) are the major pests. These citrus pest causes the major fruit drop in Sahajpur. Similarly, Shrestha R.L. (2012) recorded these three species in Kailali which causes huge loss of citrus production. Green sting bug were observed in the citrus orchad and loss around 20% in western region (Shrestha et al. 2008), whereas fruit fly is serious in eastern development region and western development region and eastern loss as 90% (NCRP 2006).

Insect pests are responsible for variety of damages ranging from moderate to severe. Although several abiotic factors plays a major role in damage pattern in several species. In present study, insects pest were responsible for damage throughout season feeding almost all parts of plants. Insect species belonging to various orders were associated with the flower, shoot and root of citrus and colonize on different parts of tree causing huge impact on production and life of citrus tree (Browning 1999).

The abundance of insect pests was significantly different in different months. The higher abundance of pests were found on the month of November followed by month of January and the lowest abundance was recorded in month of September. It may be due to the fact that November was the ripening season for Citrus. The study reveals that infestation rate gradually increases from September to December and gradually decreases thereafter. Highest damage percentage was observed in December and lowest in September. Occurrence of pests depends on host sustability and climatic condition, therefore occurrence and infestation of pest differ in different months due to variation of management practices in the study area (Khan and Talukder 2017).

Fruit flies and aphids were also the major problem in the study area. They causes huge loss productivity in citrus fruits. Same result observed by Adhakari et al. (2015). Among

different pest problems of these horticultural crops. Fruit fly is an important insect pest in Nepal Adhakari (2015). Farmers are practices the use of pheromone traps, application of chemical measure and field sanitation of attacked fruits, as management option. Jaisawal et al. (1997). Same as in the study area citrus cultivating farmers are also practices pheromones and chemical methods to control fruit fly. In last five years even mandarin fruits are being damaged (about 15%) by the fruit flies (NCPP 2012). The fruit fly trap (Pheromones trap) was found very useful in terms of minimizing damage caused by fruit fly and farmer also liked this technology very much (Jaisawal et al. 1997).

5.3 Pest management practices

For the management of insect pests on citrus fruits, pest management practices followed by the farmers include use of chemical method, cultural, bio-pesticides, biological and other. It was found that farmers seldom use traditional as well as the newly commercialized biopesticides as practice of insect pest management. Moreover, they preferred to use chemicals pesticides. The study found that 33% farmers used chemical pesticides, 28% of farmer adopted mixed methods, 27% farmers used cultural methods, and 12% used bio pesticides for control of insect pests in their field. High dependence on chemical pesticides in vegetable and fruit production was also reported in the Chitwan districts of Nepal (Rijal et al. 2018) in which the majority of the farmers (80%) used chemical pesticides solely to control insect pests in their vegetable and fruit crops. Only 16% of the farmers used other methods (biological, cultural, and mechanical) for insect pest control. Farmers used chemical pesticides to control the pest, to control disease as well as to increase productivity.

Different types of chemical pesticides used in the study area were Dichlorovous, Dimethoate, Malathion, Mancozeb, Alphamethrin, Cypermethrin and Imidacloroprid. Majority of pesticides belong to Organophosphates group. Pesticide often used in the field fall under the category of moderately hazardous group (Group II) according to the WHO classification of hazard. Use of highly hazardous pesticide Dichlorovous was also found in the field. Use of similar chemical pesticides were reported by (Koirala et al. 2010) on citrus growing area of Tanahun, Kavre, Dhading and Gorkh of Nepal.

This study found that 12% of farmers used biopesticdes to control insect pests. Most of them prepare biopesticides by locally available plants and animal urine. Only few of them purchase biopestiicdes from the shop. Majority of them used animal urine and ash as the

alternative methods of pesticides in this area. Similar findings was reported by (Ghimire, 2016) in Nawalparasi districts of Nepal. Adoption of safety precaution during and after pesticide application is very important to prevent harmful impact of pesticides. The various safety measures could be use of mask, gloves, use of long sleeved clothes, glass, shoes, hat, etc. During this study it was found that very few farmers used protective clothing or other safety measures during insecticide application. The reason for not using protective measures were lack of knowledge, not having easy access of safety measure equipment and not having the habit of wearing. This may put them in the risk of acute and chronic health hazards like cancer, birth defects, reproductive problems, tumors, and damage of liver, kidney and neural organs (Sharma et al. 2012). In many developing countries like Nepal, most pesticides are associated with adverse effects on human health and environment due to inappropriate use and handling of pesticides by inadequately trained farm workers (Naidoo et al. 2010). Various studies in Nepal reported the huge use of chemical pesticides in vegetable and fruit growing areas have raised problem of health risks (Atreya 2007). Similar result observed from (NCRP 2004) spraying of contact insecticides in common practices to control citrus green sting bug. Increasing of wasp population and distribution of prasitized egg would be the effective measure for the control of citrus green sting bug (Manandhar et al. 2002). In the study area farmer were practicing hanging of carcass in plant that attract citrus green sting bug and collect and destroy them.

Acute health problems experienced by the farmers in the study were: skin rashes, itching dizziness, nausea, difficulty of breathing, headache, eye irritation, blurred vision and irritation of nose and throat. They use home remedies such turmeric water, oil massage, salt water gargle and eating mint (*Mentha* sp.) to cure the acute symptoms of pesticides infection as described by Thapa 2014. Majority of farmers had poor knowledge about pesticides use and its bad impact on non-target organisms due to the misuse of pesticides. Lack of knowledge about pesticide, its composition and its formulation made more misuse of pesticides. Misuse of insecticides is common in Nepal. Unregistered and illegal products, open air sales, sales of banned products, cases of decanting and reweighing, fake pest control products using counterfeit labels, sales of expired products with modified expiry dates were among the misuse cases that have been reported in Nepal (Sharma et al. 2012). Palikhe (2002) reported that misuse and overuse of pesticides particularly among commercial farmers pose a health risk to the public and have

numerous cases caused serious poisoning. There are numerous reports on pesticide residues in food in Nepal. A recent survey conducted by Department of Food Technology and Quality Control (DFTQC) indicated that Nepalese people are at alarming threat of pesticides in their diets. Pesticide pollution not only affects human health, but also other ecological assets, such as soil surface and ground water, micro and macro flora and fauna (Pimental 2005).

Integrated Pest Management is the best method for long term pest control as it is eco-friendly, lowers cost, guarantees yield and contributes to the sustainability of agriculture. During this study we did not found anyone practicing IPM in their fields because they did not have knowledge of integrated pest management. Maximum percentage of people (54.56%) had the education of primary level only. This could be the reason for the low level of knowledge of IPM and safety precaution while applying pesticides. Also they have not received any training programs of IPM. So, government should provide training and awareness programs regarding integrated pest management in this region to reduce the application of chemical pesticides.

6. CONCLUSION AND RECOMMNEDATION

6.1 Conclusion

This study found 10 insect species belonging to nine families under three orders. Hemiptera (74%) was the most abundant order followed by Lepidopterans (21%) and Dipterans (5%) was least abundant.

The highest abundance of insect pest was from the family Aphididae (44.65%) whereas Tephritidae (4.65%) was least abundant. In this study 60% insect pests were minor pests and 40% were major pest of citrus. Insects pest were responsible for damage throughout season feeding almost all parts of plants. A significant difference was observed in abundance of insect pest on citrus. The higher abundance was found on the month of November (92 ± 2.42) followed by in month of January (86± 0.86). The lowest abundance was recorded in month of September (44 ±). The present study reveals that infestation rate gradually increases from September to December and gradually decreases thereafter

Highest damage percentage was observed in December (18%) and lowest in September (5%). There was positive correlation between abundance of insect pest and damage percentage. Majority of the farmers (33%) use chemical pesticides, 28% adopted mix methods, 27% used Cultural methods and 12% used bio-pesticides for the control of insect pests. It was found that majority of farmers did not adopt safety precaution during pesticides application due to the lack of awareness and knowledge of pesticide handling. Therefore, it is urgent to provide training on integrated pest management, training on pesticides handling, disposal and dissemination of alternative technology through field demonstration to reduce the chemical risks in future.

6.2 Recommendation

On the basis of the present study following points are recommended:

- Detailed study of insect pests in citrus cultivated area in Shajpur, Kailali is needed to control the insect pests.
- Training should be provided to the farmers on integrated pest management to reduce the application of insecticide.

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APPENDICES

APPENDIX: I Shannon-Weiner Diversity Index (H) and evenness index (J) of Citrus insect pests

Scientific Name	**Ni**	**Pi**	**LnPi**	PI*LnPi
Diaphorina citri	27	0.063	-2.76	-0.174
Planoccus citri	30	0.07	-2.66	-0.186
Toxoptera aurantii	89	0.21	-1.56	-0.328
Toxoptera cidricida	103	0.24	-1.43	-0.343
Aonidiella aurantii	33	0.077	-2.56	-0.197
Rhynchocoris humeralis	38	0.088	-2.43	-0.214
Papilio demoleus	25	0.058	-2.85	-0.165
Phyllocnistis citrella	44	0.102	-2.28	-0.233
Eudocima sp.	21	0.049	-3.02	-0.144
Bactrocera dorsalis	20	0.047	-3.06	-0.144
Shannon Weiner Diversity Index (H)				2.132
H_{max}				2.302
Eveness Index(J)				0.926

APPENDIX: II

Identified insect pests in study area:

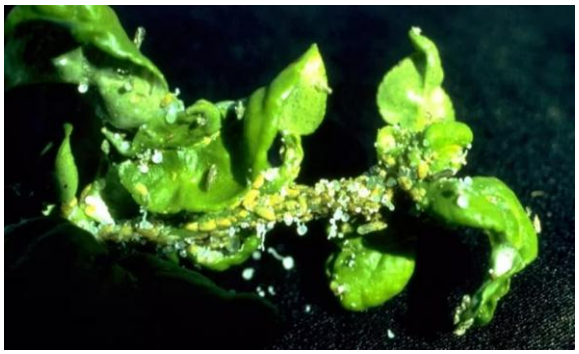
<table>
<tr>
<td>1. Diaphorina citri, Kuwayama (Photo Plate: 1)

Common name: Asian citrus psyllid

Order: Hemiptera

Family: Psyllidae

Collected host plant: mandarin

Diagnostic characters: The adults are 4 mm long with mottled brown body. The head is light brown. Forewing is broadest in the apical half, mottled and with brown band extending around the periphery of the outer half of wing. Antennae have black tips with two small segments.</td>
<td> 
 
Affected part and adult (Diaphorina citri)</td>
</tr>
<tr>
<td>2. Planoccus citri, Risso

Common name: Citrus mealy bug

Order: Hemiptera

Family: Pseudococcidae

Collected host plant: mandarin, lime

Diagnostic characters: Adult size 4.5 mm and white to light brown in colour, with brown legs and 8 segmented antennae. Their oval body contain slightly longer pair of filaments present at the rare end of their body.</td>
<td> 
 
Adult and colony of (Planoccus citri)</td>
</tr>
</table>

3. *Toxoptera aurantii*, Boyer Common name: Black citrus aphid Order: Hemiptera Family: Aphididae Collected host plant: mandarin, lime Diagnostic characters: On the alate form only the third segments of *T. aurantii* are transparent or light colored. The pterostigma sector of the fore wings is distinctly dark to black colour in *T. aurantii*Median vein is always once branched in *T. aurantii.*	 Adult (*Toxoptera aurantii*)
4. *Toxoptera citricidus*, Kirkaldy Common name: Brown citrus aphid Order: Hemiptera Family: Aphididae Collected host plant: mandarin, lime Diagnostic characters: For both alate and apterygote aphids *T. citricida* approximately 10% larger and anal segment possesses large number of hair like filamentous structure than that of *T. aurantii*.On the alate forms only the third antennal segments for *T. citricida* are distinctly and entirely black. The pterostigma sector of the fore wings of *T. citricida* is light transparent brown. Median vein is always once branched in *T. aurantii* but is branched twice in *T. citricida*.	  Adult and colony of *Toxoptera citricidus*

5. *Rhychocoris humeralis*, Thunberg Common name: Citrus green stink bug (Citrus shield bug) Order: Hemiptera Family: Pentatomidae Collected host plant: mandarin, lime Diagnostic characters: The citrus stink bug is 17 mm long with prominent spine on each shoulder of the thorax. Abdomen carries laterally six pairs of short spines. There are five nymphal stages. Larvae are mainly green with black markings.	  Nymph and adult (*Rhychocoris humeralis*)
6. *Aonidiella aurantii*, Maskell Common name: Citrus red scale Order: Hemiptera Family: Diaspididae Collected host plant: mandarin, lime Diagnostic characters: The dorsal macroducts are one-barred, slender, 5-6 on each side of the pygidium, none on the pre-pygidial segments. The entire body adheres to the shield and cannot be separated. The pygidium bears three large lobes, all externally notched, the fourth lobe appearing as a mere point. Four club-like processes (paraphyses) arise from the lobes on either side of the pygidium, and the anus is located halfway between the median lobes and the vagina. There are	  *Aonidiella aurantii* on fruit

no perivulvar pores. The shield is thin, almost transparent, brownish, round and slightly convex, the darker juvenile exuviae at center. The ventral exuvium ("velum") is retained as a thin membrane.	
7. *Phyllocnistis citrella,* Stainton Common name: Citrus leaf miner (CLM) Order: Lepidoptera Family: Grillariidae Collected host plant: mandarin, lime Diagnostic characters: Adults of the CLM are minute moths with a 4 mm wingspread. They have white and silvery iridescent scales on the forewings. The hind wings and body are white, with long fringe scales extending from the hind wing margins. The antenna ciliate and brown with silvery and short scale. The head is very smooth-scaled and white, and the haustellum has no basal scales.	 Adult (*Phyllocnistis citrella*)
8. *Papilio demoleus* Linnaeus Common name: Lemon butterfly Order: Lepidoptera Family: Papilionidae Collected host plant: mandarin, lime Diagnostic characters: The adult wingspan 87 mm. The hind wing has no tail. The upper portion of the forewing is largely black and the outer wing margin has a	

series of irregular yellow spots. Two yellow spots are present at the upper end of the discal cell with several scattered yellow spots in the apical region.	 Larva and adult (*Papilio demoleus*)
9. *Eudocima* sp. Common name: Fruit sucking moth Order: Lepidoptera Family: Diaspididae Collected host plant: mandarin, lime Diagnostic characters: The adult moths are large and stout-bodied, with a wingspan of 100 mm and body 50mm long. The forewings are brown hind wings are yellow orange, with black patches and spots.	 (Adult) *Eudocima* sp.
10. *Bactrocera dorsalis*, Hendel Common name: Oriental fruit fly Order: Diptera Family: Tephiritidae Collected host plant: mandarin Diagnostic characters: Body length is 8 mm, the wing is 7.3 mm in length and is mostly hyaline. The colour is prominent yellow and dark brown marking on the	 Adult (*Bactrocera dorsalis*)

thorax. The abdomen has two horizontal black stripes. The ovipositor is very slender and sharply pointed.	

APPENDIX: III

Questionnaire

Central Department of Zoology

Kirtipur, Kathmandu

INSECT PESTS OF CITRUS FRUITS AND THEIR MANAGEMENT PRACTICES IN SAHAJPUR, KAILALI, NEPAL

Date of interview: Survey ID number:

Name of the respondent: Gender:

Age: Education:

Village: District:

1. How much area of cultivated land you have? ……..
2. What types of Citrus plant you cultivate?
3. Do you adopt any type of land preparation before farming?
    a) Applying manure
    b) Chemical fertilizers
4. Do you have pest problems in your filed?
5. What type of problems you are facing by pests in the field?

S.N.	Name of pest	Problem caused by pest	Infected part	Infected time

6. What are the major insects that are harmful to the citrus plant?
7. Do you use any pesticides on your citrus fields?
    a. Yes
    b. No
8. If yes, what types of pesticides you use?
    a. Chemical pesticides
    b. Bio-pesticides
9. Why do you use it?
    a. To control the pest
    b. To improve productivity
    c. To control diseases
10. What do you think about the use of pesticides?
    a. Should be increased
    b. Should be decreased
    c. Should be used to certain extend
    d. Shouldn't be use at all
11. What are the different types of pesticides you use in your citrus fields?

S.N.	Name of the pest	Pesticides used

12. Where do you get pesticides from?
    a. From local shop
    b. From authorized shop/ retailers
    c. Other places

13. How do you determine the amount of pesticides you use?

    a. Information as per on label

    b. According to retailer

    c. According to neighbor

14. How do you mix the pesticides?

    a. With bare hand

    b. With stick but bare hand

    c. With hands wearing gloves

    d. With stick and wearing gloves

15. Do you wear mask while spraying pesticides?

    a. Yes

    b. No

16. Are you grown Citrus crop for commercial or non-commercial purpose?

    a. Commercial

    b. Non-commercial

17. Do you wear glass/ eye shield while spraying pesticides?

    a. Yes

    b. No

18. Protective gears used during application.

S.N.	ITEMS	YES	NO
1.	Hats/ head covers		
2.	Shoes		
3.	Glasses		
4.	Full sleeves/ shirt/ trousers		
5.	Gloves		
6.	Mask		

19. Do you change clothes after application of pesticides?
    a. Yes
    b. No
20. If yes, what do you do?
    a. Take a bath
    b. Clean hands and feet only
    c. Yes
    d. No
21. How do you dispose pesticides usually?
    a. Burn
    b. Burry in field
    c. Throwing in dumping sites
    d. Used for household purpose
22. Do you have knowledge about health hazards of pesticides?
    a. Yes
    b. No
23. What health hazards have you experienced after handling pesticides?
    a. No effect
    b. Headache and nausea
    c. Do you have any knowledge about integrated pest management?
    d. Skin problems
24. Do you have any knowledge about integrated pest management?
    a. Yes
    b. No
25. If yes, do you currently use any IPM practice method?
    a. Yes

b. No

26. Which method do you use?

a. Smoke

b. Rotation of crop

c. Light trap

d. Pheromone trap

e. Biological control

27. If not, why don't you practice IPM?

a. Pesticides are cheaper

b. IPM requires lot of labor

c. Lack of knowledge about IPM