CITRUS FRUIT PESTS AND MANAGEMENT PRACTICES IN TAPLI RURAL MUNICIPALITY, UDAYAPUR DISTRICT, NEPAL

Submitted by

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Submitted to

Central Department of Zoology

Institute of Science and Technology

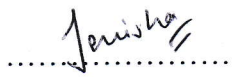
Tribhuvan University

Kirtipur, Kathmandu, Nepal

May, 2023

DECLARATION

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



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RECOMMENDATIONS

This is to recommend that the thesis entitled "**CITRUS FRUIT PESTS AND MANAGEMENT PRACTICES IN TAPLI RURAL MUNICIPALITY, UDAYAPUR DISTRICT, NEPAL**" has been carried out by Ms. Jenisha Thakuri for the partial fulfilment of the master's degree in science in Zoology with special paper Entomology. This is her original work, which has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree at any other institutions.

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms. Jenisha Thakuri entitled "**CITRUS FRUIT PESTS AND MANAGEMENT PRACTICES IN TAPLI RURAL MUNICIPALITY, UDAYAPUR DISTRICT, NEPAL**" has been accepted as a partial fulfillment for the requirements of Master's Degree of Science in Zoology with special paper Entomology.

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LIST OF ABBREVIATIONS

CDZ	:	Central Department of Zoology
CDZMTU	:	Central Department Zoology Museum of Tribhuvan University
TU	:	Tribhuvan University
Masl	:	meter above sea level
mt/ha	:	metric ton per hectar
IPM	:	Integrated Pest Management
ACP	:	Asian Citrus Psyllid
MoALD	:	Ministry of Agriculture and Livestock Development
NCRP	:	Nepal Citrus Research Programme
UNCTAD	:	United Nations Conference on Trade and Development
AWCR	:	Area-Wide Control Program
NPPO	:	Nepal Plant Protection Organization
CTV	:	Citrus Tristeza Virus

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ABSTRACT

The study was conducted in Tapli Rural Municipality, Udayapur, Nepal from 31st August to 31st October, 2022. Altogether 21 mandarin and 10 lime orchards were selected for the field data collection of citrus pests. The orchards belonged to 24 farmers. Direct observation, hand picking, sweeping, knockdown method, suction trap and commercial pheromone trap (Pheromate F) were used to collect insect pests. Questionnaire interview and focal group discussion was done to obtain details on insect pests damage and their management practices. Altogether 13 insect pest species belonging to 3 orders and 8 families were reported from the study sites. The pests include *Bactrocera dorsalis, B. sculetaris, B. correcta, Toxoptera citricidus, T. aurantii, Pseudococcus longispinus, Coccus viridus, Ceroplastes* sp., *Diaphoria citri, Halyomorpha halys, Rhynchocoris poseidon, Phyllocnistis citrella* and *Papilio demoleus.* Hemiptera (62%) was found to be the most abundant followed by Diptera (23%) and Lepidoptera (15%). The diversity of citrus insect pests of mandarin and lime orchard was 2.125 and 1.897 respectively. *Bactrocera dorsalis* (21.55%) was most abundant in mandarin orchard while *Toxoptera citricidus* (27.7%) was most abundant in lime orchard. Ten of the 13 species were categorized into major pests which were *Bactrocera dorsalis, B. sculetaris, B. correcta Toxoptera citricidus, T. aurantii, Halyomorpha halys, Rhynchocoris poseidon, Diaphoria citri, Phyllocnistis citrella* and *Papilio demoleus.* Insect pests mainly targeted fruits, foliages, leaves and shoot. Chemical pesticides used by farmers include ATSO mineral oil/Servo Agrospray mineral oil, Monocil (Monocrotophus), Rogar/ Thiodin and pheromone traps. Cultural methods included ploughing, racking, hoeing, pruning and blocking the holes in stems created by borers with mud. Mechanical methods include hand picking and pit digging.

INTRODUCTION

1.1 Background

The genus *Citrus* are flowering trees belonging to the Rutaceae family that originated from Southeast Asia including South China, North-Eastern India and Burma (Pandey et al. 2017). It includes a number of fruits such as mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis),* lemon (*Citrus limon),* grapefruits (*Citrus paradasi*), pomelos (*Citrus maxima* or *Citrus grandis*) and lime (*Citrus aurantifolia*). The plants grow well in the temperature range of 15-30 ^{0}C with an annual rainfall of 1250-1850 mm (Department of Agriculture 2013). The citrus orchard favors the most well-drained loams and sandy loam soil having the p^H 6.0 – 6.5 (Department of Agriculture 2013).

Citrus fruits rank first in terms of world fruit production and international trade value (Norberg 2008; UNCTAD 2008). Brazil, China, the United States, and Mexico are the world's highest citrus-producing countries (World Atlas 2019). They are important part of the human diet as they are very rich sources of Vitamin C, folate, and potassium, and in their fresh form, are good sources of dietary fiber. Orange juice is the largest fruit juice product consumed all over the world (Spreen 2010).

1.1.1 Citrus Production in Nepal

Mandarin is considered an indigenous crop of Nepal as a Chinese traveler had mentioned Nepal as "the country of golden fruits" about 2000 years ago upon seeing the yellow color of mandarin upon ripening (Lohar & Lama 1997). Shrestha and Verma (1998) reported that farmers of the Darchula and Sankhuwasabha districts claimed that their forefathers had collected mandarin trees in wild form.

Nepal is in greater advantage in citrus fruit production compared to neighboring countries because of very optimum temperature, sunlight, adequate rainfall, and very fertile soil. In addition, produced fruits are of very high quality (Acharya 2016; Nepal Horticulture Promotion Centre 2017). They are grown in sub-tropical climates of mid-hill districts ranging from 800-1,400 masl altitude. Systematic research and development of citrus was started only from 2013 BS with periodical developmental plans till date (Kumar et al. 2016) and is grown commercially in 48 hill and 16 Tarai districts of Nepal (NCRP 2019).

Fruits contribute to about 7% of total Agriculture GDP of Nepal (MoALD 2017). Similarly, citrus crops cover about 30% of the total area under fruit cultivation in Nepal where Mandarin orange covers 61% area of the total citrus cultivated area followed by lime (20%) sweet orange (14%), lemon (2%) and followed by others (3%) (NCRP 2019) and has ranked 43rd position in global citrus production (source: www.fao.org).

1.1.2 Insect pests of citrus fruit trees

Along with factors such as the remoteness of the production area, traditional method of crop production, biotic and abiotic stress, small scale production, lack of access of transportation, unmanaged storage facilities, etc., insect pests play a crucial role in determining the quality of citrus crops in the orchards.

Along with the flourishing of the citrus fruit industry, many different types of pests and diseases have also been introduced. Two hundred and fifty species in India and 800 species in China have been recorded as pest species of citrus fruits (Santosh Kumar et al. 2013; Urbaneja et al. 2020).

Citrus pests of Asia are categorized into key pests, occasional pests and secondary pests based on economic damage level namely *Diaphorina citri, Phyllocnistis citrella, Toxoptera citricidus, T. aurantii, Aphis gossypii, Papilio xuthus, P. polytes, Bactrocera dorsalis* are considered as key pests while *Cacopsylla citrisuga, Dialeurodes citri, Aleurocanthus spiniferus, Parlatoria pergandii, Aonidiella aurantii, Unaspis yanonensis, Icerya purchase, Planococcus citri, Eutetranychus orientalis, Aleurocanthus woglumi, Bactrocera minax, Buzura suppressaria, Anomala cupripes, Rhynchocoris humeralis* are occasional pests. The secondary pests include *Lepidosaphes beckii, Nipaecoccus vastator, Bactrocera tsuneonis, Bactrocera zonata, Papilio demoleus* (Urbaneja et al. 2020).

Major citrus pests differ from one country to the other.

Blue beetles, aphids, red mites, lemon butterflies, stem borers, caterpillars, green stink bugs, fruit flies, citrus psylla, leaf miners, white flies, scale insects, etc. are some of the common insect pest species of citrus crops recorded via various articles of Nepal.

1.1.3 Management Practices of citrus pests

Various pest management models have been introduced all over the world such as cultural control, mechanical methods, biological and chemical (Urbaneja et al. 2020).

The biological control was considered as the earliest method of pest control later use of synthetic pesticides which often hampered the nearby flora and fauna, ecology. It made people more conscious about the pesticide resistance in pests, public health and negative impacts occurred in the environment. It led to the introduction of third stage of pest management model. It introduced integration centered on biological control.

Cultural methods include field sanitation, crop rotation, mixed cropping, inter-cropping, ploughing, fertilizers, irrigation, pruning, etc. while mechanical methods comprise the direct action of killing the pests. It includes practices actions such as hand picking, pit digging, light traps, pheromones trap, etc.

The excess use of chemical methods may create negative impacts on the environment. They have adverse effects on their natural enemies, parasitoids and predators. Various plant and animal based products can be used to control pests such as neem leaves, titepati leaves, cattle urine, ash and so on.

Various systematic and contact chemical insecticides are used to kill the insect pests in citrus farming some of which includes Malathion, Dichlorovos, Immiachloropid, Chloropyrifos (Chhetri et al. 2021).

1.2 Objectives of the study

The general objective of this research is to find the diversity and abundance of different types of pests found in citrus fruits.

The specific objectives of this research work are to

1. To find the pests diversity and abundance in citrus fruit orchard.
2. To explore major citrus fruit pests and their damage pattern.
3. To document the control practices of pests problems.

1.3 Significance of the study

FAO (2015) had reported that citrus fruits were affected by different pests and had caused significant loss of quality and quantity of fruits due to various pests. Udayapur is one of the pocket area for citrus production. A report submitted by Nepal Horticulture Promotion Center (2017) stated that Udayapur district along with other 10 districts has been enlisted as prioritized districts for citrus fruits production in Eastern Region of Nepal and has been included in medium term (2014/15-2026/27) and long term

(2014/15-2036/37) citrus fruit project. However much researches involving pest identification, their diversity and abundance, soil tests, etc. has not been conducted.

The research maybe helpful to recognize the pest species occurring within the study area and understand the patterns of the damages they have caused within the research area. This understanding may be useful to provide a baseline data for developing future strategies to control different pests in different phases of citrus production. It may be helpful to enhance the quality and quantity of the citrus production.

1.4 Research questions asked to the citrus growing farmers (See Appendix III)

i. What are the insect pests of citrus crops found in Tapli Rural Municipality, Udayapur?
ii. What are the damage patterns of different pests present within the study area?
iii. What are the management practices applied by farmers to overcome the damages caused by the pests?

2. LITERATURE REVIEW

Citrus is one of the most economically important crops and is grown commercially in 48 hill and 16 Tarai districts of Nepal (NCRP 2019). Going through 16 years of record of citrus production in Nepal during fiscal year 2003/04 to 2018/19, it was found that the highest crop yield was recorded to be 11.37 Mt/ha in fiscal year 2007/08, and the lowest crop yield recorded to be 8.96 Mt/ha on the year 2016/2017 (NCRP 2019). Despite the efforts of the government and local farmers, the crop yield has increased to only 9.57 in the fiscal year 2018/19 (Statistical Information on Nepalese Agriculture 2018/19). The area and production is increasing every year however the productivity is not increasing as anticipated. The underlying reasons may constitute of various factors however insect pests is one of them. Various management practices maybe applied to control the insect pests and keep their populations below the economic injury level (EIL). The control measures include chemicals, botanical, biological and cultural methods.

Tennant (2009) reported larvae of coleopterons (*Exophthalmus* and *Pachnaeus* spp.), psyllids and lepidopterons (*Papilio demoleus*) were the major pests of citrus fruits in Andhra Pradesh, India. Blue beetles, aphids, red mites, lemon butterflies, stem borers, caterpillars, green stink bugs, fruit flies, citrus psylla, leaf miners, white flies, scale insects, etc. are some of the common insect pest species of Nepal (Shrestha 2011). Acharya et al. (2011) had enlisted Scales, Psylla, Lemon butterfly, green stink bug and borer as destructive insect pests of citrus fruits of Dailekh. According to a study on the management of mandarin orchards in the Mid Hills in the province of Gandaki, fruit flies were the most common pest, followed by leaf miners, stem borer, aphids, and lemon butterflies (Belbase et al. 2020).

Shrestha (2006) studied on fruit flies of Nepal and reported that six species of fruit flies were major pests of citrus fruits. Chinese fruit fly (*Bactrocera minax*) is a very serious insect pest causing sweet orange losses as high as 97% by the end of harvesting season in the eastern middle mountainous region of Nepal (NCRP 2012) and is moving towards the central parts of the country (Adhikari et al. 2018).

Kumar et al. (2011) reported that Tephritid fruit flies could cause as much as 90-100% yield loss and are considered one of the world's most destructive horticultural pests with more than 500 species enlisted as important pests. A survey conducted by NCDP (1978)

in Sidheswor, Gupteswor, Tima, Chhinamakhu, Annapurna and Khawa VDCs of Bhojpur district reported that 75-90% of the citrus fruits had been damaged by the fruitflies.

Adhikari et al. (2020) conducted the pest surveillance activities in two districts namely Sindhuli and Syangja using fruit fly traps where pheromone lure (methyl eugenol and cue lure) and protein hydrolyses. Six species of fruit fly of *Bactrocera* genus and one species of *Dacus* genus were reported in the sweet orange orchards of Sindhuli district which were *B. dorsalis, B. zonata, B. cucurbitae, B. tau, B. scutellaris, B.minax* and *Dacus longicornis*.

During the surveillance of fruit flies done in Dhankuta and Sindhuli. Five species of fruit flies that were trapped in hydrolyzed protein which were *B. scutellaris, B. tau, B. zonata,B. dorsalis* and *B. cucurbitae. Bactrocera minax* in addition to those fruitflies were reported in Sindhuli only (Acharya 2019).

A survey conducted by Adhikari et al. (2020) stated that the Chinese citrus fly was one of the major emerging pests causing heavy fruit loss in sweet oranges' orchards. Similar is the case in China, Bhutan and Northwest India {Formatting Citation}. However, the contrasting result showing *Bactrocera minax* as a dominant fly species was found in study done in sweet orange orchard of Sindhuli (Adhikari et al, 2018). The subsequent fruit fly species that were observed were *B. dorsalis, B. zonata, B. tau, B. scutellaris, B. cucurbitae* and *Dacus longicornis.* NPPO-Nepal is very much aware about impact of fruitflies in fruit crops of Nepal and is making update on their status through regular surveillance (Sharma et al. 2015).

Regmi (1982) and Regmi et al. (1996) had reported more than 50% of the citrus greening infested trees in Pokhara valley and upto 100% in Horticulture Research station, Pokhara. On further investigation, Asian citrus psyllid (*diaphorina citri*) had been confirmed to be a major cause of citrus decline in Kaski, Lamjung, Gorkha, Syangja and Tanahun in their research work (Regmi et al. 2010). Bove (2006) and Roistacher (1996) had confirmed that citrus greening disease as the major cause of citrus decline in Nepal.

A study done by Pandey and Rana (1992) in Tanahun district showed that about 50% of the pre-matured fruit drops was caused due to Green stink bug (*Rhynchocoris*

humeralis) during the month of August and September. Mandarin fruits were more susceptible to damage in their early growth stage.

The mealybugs and scale insects suck the plant sap and highly infested plants become weak, shoots become dry and thus indirectly affect the plants yield, The mealy bugs secrete honey dew which are deposited on leaves and twigs. It as a highly polygamous species. In Pakistan and India, Rahman and Latif (1944); Lakra et al. (1980) and Sandhu et al. 1981 had studies the effectiveness of various types of bands put around the tree trunks for checking he climbing of bug nymphs on trees.

Deka et al. (2016) had conducted a survey and surveillance of insect pests of citrus and their natural enemies in Assam. Altogether 12 species of insect and mite pests were recorded and of which natural predators included different species of predators, coccinellids, non-stinging wasps, mantids and chrysopids. Similarly, Aubert (1987) reported that the natural enemies of Asian Citrus Psyllid (nymph) were ladybeetles, Syrphid beetles, lacewings and spiders. Hall et al. (2013) stated that *Tamarixia radiate* and *Diaphorencyrtus aligarhensis* are native parasitoids of Asia that were found to attack and control citrus psyllid.

Alam (1969) reported parasitoids as *Pteromalu* spp., *Pteromalus bengalensis* and *Bugnetia musca* as parasitoids of larval stage of butterfly from Pakistan while predatory pentatomids, reduviid bugs, birds, spiders, sphecid wasps and chameleons have been reported to be biological pests of lemon butterfly which had been reported from Thailand (Clausen 1978)

Sticky traps are cheaper alternative tool for monitoring small insects especially aphids (Sarwar 2014). Yellow sticky trap, insecticides such as imidacloprid, fenpropathrin, chlorpyrifos and dimethoate can be useful to control citrus psyllids {Formatting Citation}. Saljoqi and Emden (2003) reported a drastic reduction in aphid species population by using yellow sticky trap in Peshawar, Pakistan.

Pawar et al. (1991) reported that Cue-lures traps along with field sanitation and bagging of fruits have been reported to be effective against Melon fruit flies in bitter gourd. Fang (1989a, 1989b) reported bagging of fruits of bitter gourd in Taiwan at the stage of 3-4 cm fruit lengths with 2 layers of paper bags every 2-3 days greatly enhanced fruit quality and yields and hence income increased by 45-58%. Nasiruddin and Karim

(1992) reported that hand picking is quite less effective but a necessary step to control insect pests.

It was found the average loss of sweet orange in Sindhuli district was in increasing trend since 2014 to 2018. The loss was 17% at 2014 which increased to 35% by the end of 2018. Then AWCR (Area-Wide Control Program) was applied using protein hydrolysate lethal lure bait which lowered the loss trend to 15% by 2019 (Adhikari et al. 2020).

A research work done by Baral et al. (2008) reported that majority of citrus trees at high altitude of Gorkha, Lamjung and Tanahu had deficiency of Zn, Ca, Mg and Mn; mid altitude lacked Zn, B and Mg citrus trees at low altitude showed deficiency of N and Zn.

NCRP (2013) had recommended the use of mineral oil (Servo Agro-Spray or ATSO) at 20 ml + 2 ml Rogor/l of water during the month of Falgun and Asar to control scale insects and spraying of insecticide mixture Rogor at 1 ml + Doom 1 ml/l of water at the nymph stage for the control of green stink bug. Similarly, NCDP (1978) recommended regular spray of Metacid, Folithion and Metasystocks to control black scales and use of Metasystock at 0.05% active ingredients followed by Rogor E 25 at 0.05% active ingredient to control population of leaf miners.

3. MATERIALS AND METHODS

3.1 Study area

Udayapur is one of the 14 districts of Province No. 1, located in Eastern Nepal. The elevation ranges from 360 m – 2,310 m having the co-ordinates of 26^0 54' 99.99" N and 86^0 39' 59.99" E. Citrus fruit cultivation is one of the popular income sources of the people along with agriculture. Various citrus fruits are cultivated for commercial purposes such as mandarin, sweet orange, lime, lemon, etc. Nepal Horticulture Promotion Center (2017) states Udayapur district is one of the prioritized districts for citrus fruits production in Eastern Region of Nepal. Tapli Rural Municipality is one of the important locality of Udayapur, covering an area of 106.8 km^2 and a population of 14,562. It comprises 5 wards. Altogether 24 famers were found to be engaged in commercial citrus farm in the study area. The study area comprised of 21 mandarin orchards and 10 lime orchards.

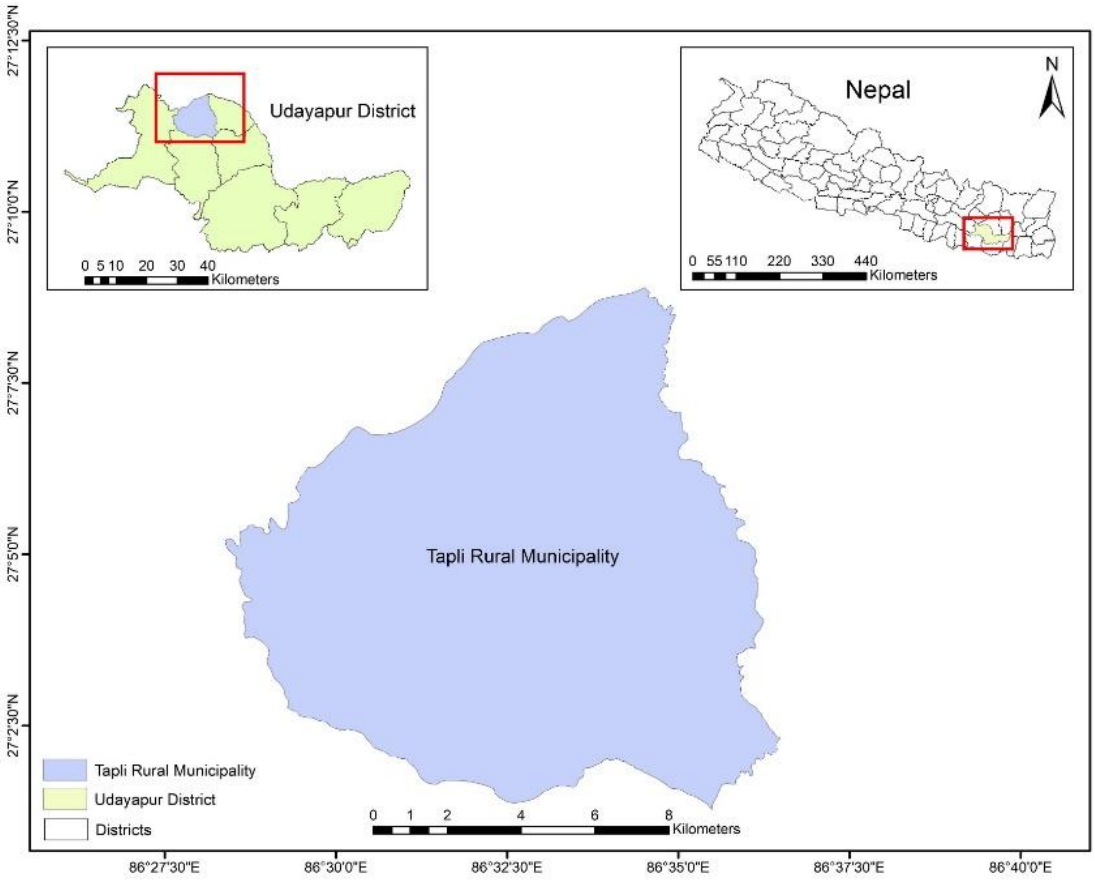

Figure 1. Map of Udayapur district showing the Tapli Rural Municipality.

3.2 Materials

The list of chemicals and materials required for the survey is given in the Appendix I.

3.3 Methods

3.3.1 Sampling methods

The study was conducted on Tapli Rural Municipality from 31st August to 31st October, 2022. Altogether 21 mandarin orchards and 10 lime orchards were taken as site of study. These orchards belonged to 24 farmers. All the orchards were observed visually as well as samples were collected via hand picking, sweeping, suction trap and knockdown methods. Trapped pests were collected by using camel hair (10A) brush. First tree was selected on random basis. Consequent trees were taken on 10th position. Altogether 5 trees were observed from each orchard. Each trees were observed for 30 minutes.

Pheromate F was a commercial pheromone trap applicable for trapping fruitflies. A trap was set in each orchard of mandarin and lime. Number of traps required were 5 sets/acre. The traps were hung 2m above the ground. The trapped samples were collected on a weekly basis.

The samples apart from pheromone traps were collected during orchard visitation. For listing out major and minor pests of citrus, insects that could cause damage between 5-10% were considered as minor and that caused damage above 10% were considered as major pests (Paul 2007). The samples were stored in vials. All the information such as date, location, and trap set number were labeled exteriorly. The preservation methods included both dry preservation and wet preservation as per the requirements of the samples. This information was recorded in the field data sheet. In liquid preservation, samples were stored in 90% alcohol while dry preservation included pinning of the sample. All collected species were brought to the laboratory of the Central Department of Zoology for identification and further confirmation up to the species level.

3.3.2 Questionnaire interview

Altogether 24 farmers were engaged in commercial citrus production as per key informants and records from Tapli Rural Municipality, Office of the Village Executive, Rupatar, Udayapur. They were interviewed using semi-structured questionnaire. Visitation was done in their own residence and their orchards were inspected visually

roaming all around the area. Focal group discussion was aided whenever possible to find more out about the insect pests and their management practices.

3.3.3 Specimen identification

The family level identification of collected samples was done by using Triplehorn et al. (2005). Further examination was done by studying their morphological characteristics under the microscope (Bestscope BS-3020T) in laboratory of Central Department of Zoology. The confirmation of the pest identification were done by comparing the characteristics of the samples with the original descriptions (Palma-Jiménez, Blanco-Meneses & Guillén-Sánchez 2018; Distant 1902; Distant 1910; Telnov 2010; Adhikari et al 2019).

3.3.4 Data Analysis

The primary data obtained were entered in MS Excel (2013) which was later transferred to other statistic software for further analysis.

Shanon-Weiner Index (1948), Pielou's evenness index (1966) and Dominance were analyzed by using the software PAST v 4.03. It showed the comparative index value of diversity, evenness and dominance of insect pests for both the mandarin and lime orchards.

Similarly, relative abundance was calculated to obtain to calculate the total percentile composition of an organism in relation to total number of organisms in the study area. It was calculated by using the formula,

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

Where,

n= Number of each individuals

N=Total number of individuals

4. RESULTS

During the research, a total of 1913 individuals were collected from the field from both the mandarin and lime orchards. Altogether 23 species of pests and non-pest insects were identified. Among them, 13 species were confirmed as citrus pests (Figure 2, Table1) from 1824 individuals. The highest number of pests individuals (N=1146) were collected from mandarin orchard (N=21) and 682 individuals were from lime orchard (N=10).

4.1 Diversity and abundance of insect pests of citrus fruits

The overall citrus pests primarily composed of three major orders: Diptera comprising 3 species, Hemiptera comprising 8 species and Lepidoptera consisting of 2 species. Hemiptera (62%) was the most abundant order followed by Diptera (23%) and Lepidoptera (15%) (Figure 2).

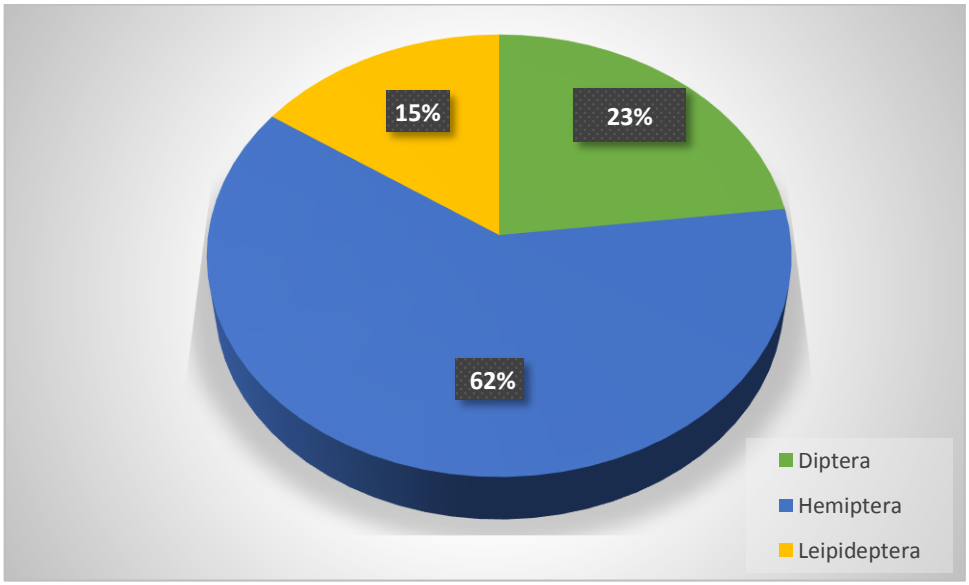

Figure 2. Order-wise composition of citrus pests in the study area

The 13 confirmed pest species belonged to 8 families of 3 orders. The family Tephritidae of Diptera had the highest number of species (three species) followed by the Hemipteran families Aphididae, Coccidae and Pentatomidae each having 2 species. Similarly, only one species was identified from each family Hemipteran family Pseudococcidae and Lividae, as well as lepidopteran family Gracillaridae and Papilionidae (Figure 3).

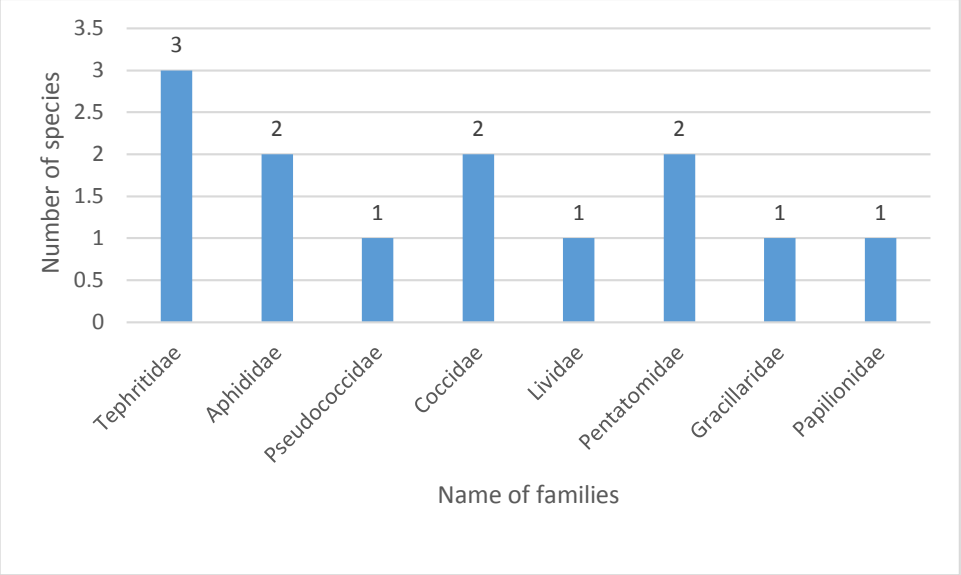

Figure 3. Family-wise composition of citrus pests of the study area

The following figure illustrates the pictures of insect pests of citrus plants found in Tapli Rural Municipality, Udayapur district, Nepal (Figure 4).

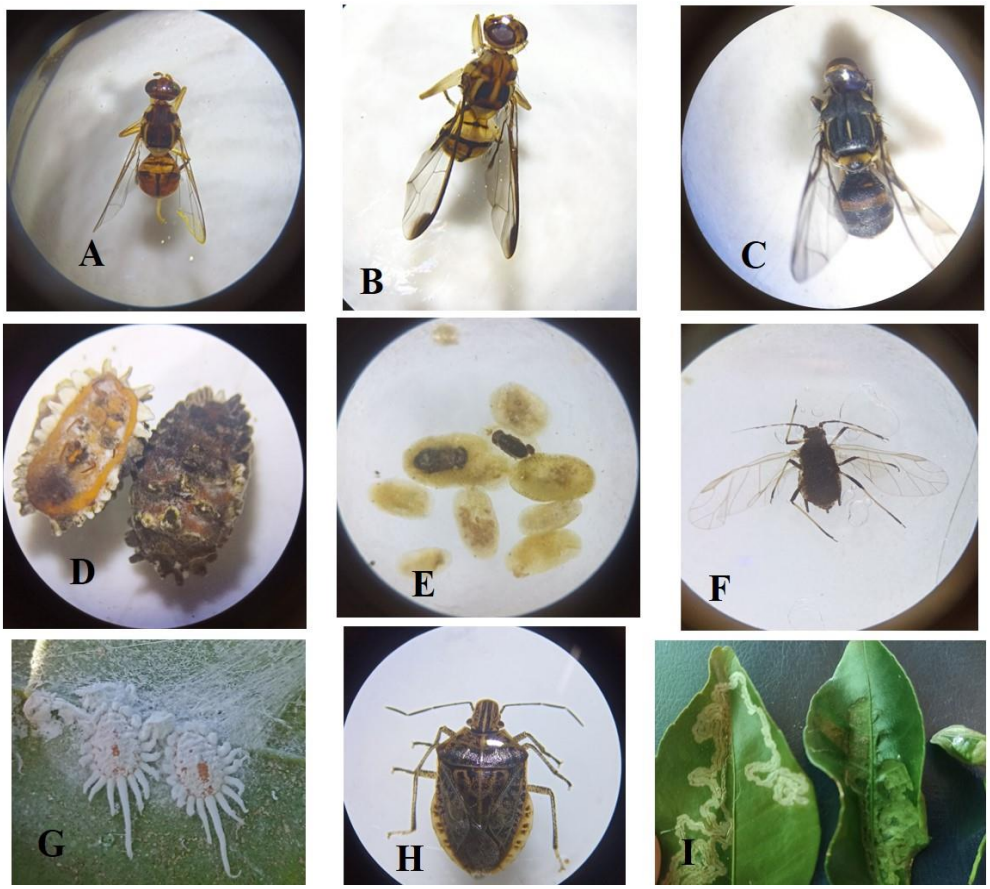

Figure 4. Some insect pests of citrus fruits (A) *Bactrocera dorsalis* (B) *Bactrocera correcta* (C) *Bactrocera scutellaris* (D) *Ceroplastes sp.* (E) *Coccus viridus* (F)

Toxoptera citricidus (G) *Pseudococcus longispinus* (H) *Rhynchocoris Poseidon* (I) *Phyllocnistis citrella*

Shanon-Weiner index (H) of insect pests of the Mandarin orchard was calculated to be 2.125. It suggests that population has moderate level of diversity and evenness of insect pests. The value of index for lime orchard was 1.897 which means that the population has moderate to low level of diversity and evenness (Figure 5).

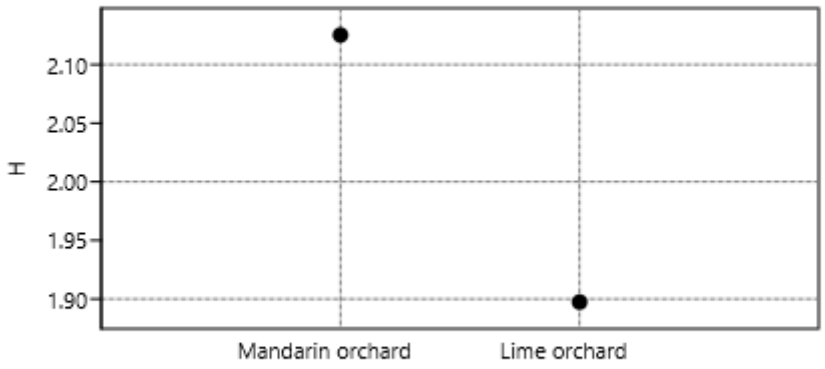

Figure 5. Plot showing the diversity of insect pest diversity in mandarin and lime orchards.

The study showed that *Bactrocera dorsalis* as the most abundant and *Ceroplastes* sp. was the least abundantly found insect pest in mandarin orchard. Similarly, *Toxoptera citricidus* was the most abundant and *Diaphoria citri* was the least abundant insect pest found in lime orchards of Tapli Rural Municipality (Table 1).

Table 1. Abundance and relative abundance of insect pests of mandarin and lime orchards.

Name of Species	(Mandarin orchard) Abundance	Relative abundance (%)	(Lime orchard) Abundance	Relative abundance (%)
Bactrocera dorsalis	247	21.55	147	21.55

Bactrocera sculetaris	102	8.9	54	7.9
Bactrocera correcta	70	6.1	43	6.3
Toxoptera citricidus	120	10.47	189	27.7
Toxoptera aurantii	160	13.96	45	6.5
Pseudococcus longispinus	27	2.35	0	0
Coccus viridus	76	6.63	8	1.1
Ceroplastes sp.	2	0.1	0	0
Diaphoria citri	7	0.61	4	0.5
Halyomorpha halys	107	9.3	98	14.36
Rhynchocoris poseidon	217	18.93	91	13.34
Phyllocnistis citrella	3	0.26	2	0.29
Papilio demoleus	8	0.69	1	0.14

4.2 Status of insect pests of citrus fruits, their damage patterns

The parts of the citrus trees damaged by the insect pest include fruits, foliage, shoots and leaves of plants. They caused damages via fruit droppings, fruit decay, sap-sucking, creating blemishes on fruits, leaf mining and defoliation. Among the 13 species of pests identified, ten (76.9%) were confirmed to be major pests and four (31%) of them were minor pests. The major pests included *Bactrocera dorsalis, B. sculetaris, B. correcta, Toxoptera citricidus, T. aurantii, Halyomorpha halys, Rhynchocoris poseidon, Phyllocnistis citrella, Papilio demoleus* and *Diaphoria citri* (Table 2).

Table 2. Status of insect pests of citrus fruits, their damaging parts and damaging patterns

Name of species	Damaging parts	Damage patterns	Pest status
Bactrocera dorsalis	Fruits	Fruits dropping and fruits decay	Major
Bactrocera sculetaris			Major
Bactrocera correcta			Major
Toxoptera citricidus	Foliage and shoots	Sap sucking, vector of Citrus Tristeza virus.	Major
Toxoptera aurantii			Major
Halyomorpha halys	Fruits	Blemishes on fruits	Major
Rhynchocoris poseidon	Fruits	Blemishes on fruits	Major
Phyllocnistis citrella	Leaves	Leaves mining	Major
Papilio demoleus	Leaves, foliage	Leaves defoliation	Major
Diaphoria citri	Foliage	Sap sucking, vector of citrus greening disease	Major
Pseudococcus longispinus	Foliage	Sap sucking	Minor
Coccus viridus	Foliage	Sap sucking	Minor
Ceroplastes sp.	Foliage	Sap sucking	Minor

4.3 Pest Management Practices

For the management of insect pests on citrus fruits in the study area, farmers tend to follow chemical, cultural, mechanical and bio-pesticide methods. They were eager to

use one or more methods at a time to mitigate the pest populations according to the needs, time of the year and the pests emerged in the orchards.

The farmers practiced the following methods to control pests in Tapli Rural Municipality, Udayapur, Nepal.

4.3.1 Control practices and the targeted pests

Table 3. Control practices and the targeted pests

Cultural methods	
Methods	Targeted pests
Ploughing	Fruit flies, larvae of butterflies
Racking and hoeing	Fruit flies
Pruning	Scales, mealy bugs and aphids
Blocking holes with wet muds	Trunk and stem borers
Mechanical methods	
Hand picking	Bugs
Pit digging	Fruit flies
Bio-pesticides	
Neem oil	Aphids, caterpillar, citrus leaf miner
Banmara leaves	Aphids and mealybugs
Titepati leaves	Caterpillars, aphids, scale insects
Animal urine	Green stink bugs, aphids
Ash	Beetles, aphids

4.3.2 Chemical pesticides used for the control of pests

Chemical pesticides most widely used by farmers of Tapli Rural municipality included ATSO mineral oil/Servo Agrospray mineral oil, Monocil and Rogar/Thiodin. They

were used used to kill scale insects, bugs and leafminers/larvae of butterflies respectively. The survey showed that that 12 (50%) farmers used ATSO mineral oil, 15 (62.5%) of them used Monocils, 5 (20.08%) used pheromone traps and all of the farmers use Rogar/Thiodin (Table 4, Figure 6).

Table 4. Chemical pesticides used by the farmers to control pests

Trade name	Physical state	Targeted pests	Using method
ATSO mineral oil/ Servo Agrospray mineral oil	Liquid	Scale insects	Should be mixed with water and sprayed over the tree making it completely wet.
Monocil (Monocrotophus)	Liquid	Bugs	Should be sprayed e2 times with a difference of 15 days after the appearance of bugs.
Rogor/ Thiodin	Liquid	Leaf miners and larvae of butterflies	Should be sprayed so that the whole plant is wet.
Pheromone trap	Solid	Fruitflies	Hung over the tree branch 2m above the ground.

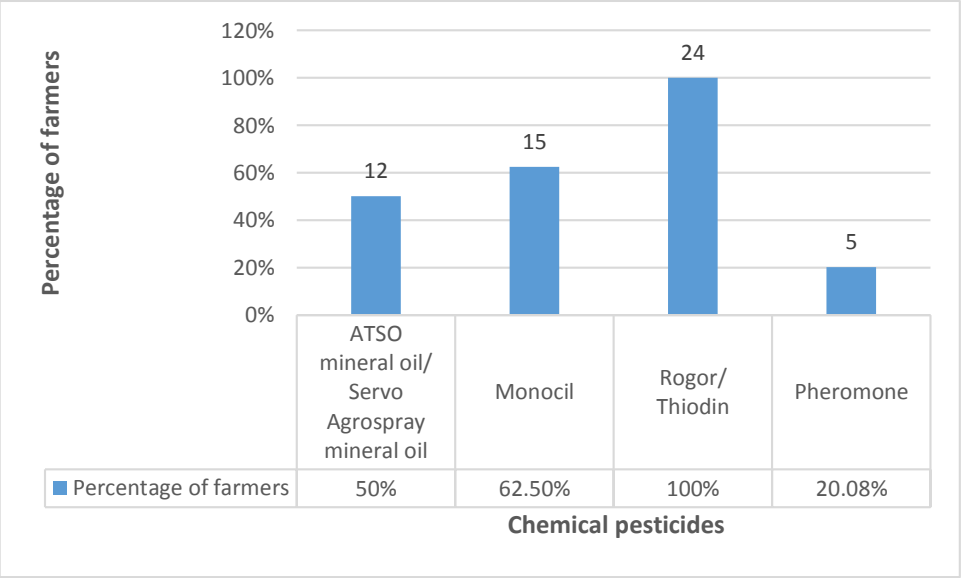

Figure 6. Use of chemical pesticides by farmers

4.3.3 Cultural methods used to control pests

Cultural methods are the oldest and the most practical method of pest control used by the farmers. The study showed that all of the farmers used irrigation, ploughing and pruning methods. However, only 8 of them applied racking and hoeing and only 2 of them blocked holes in tree branches and stems with muds to kill stem borers (Figure 7).

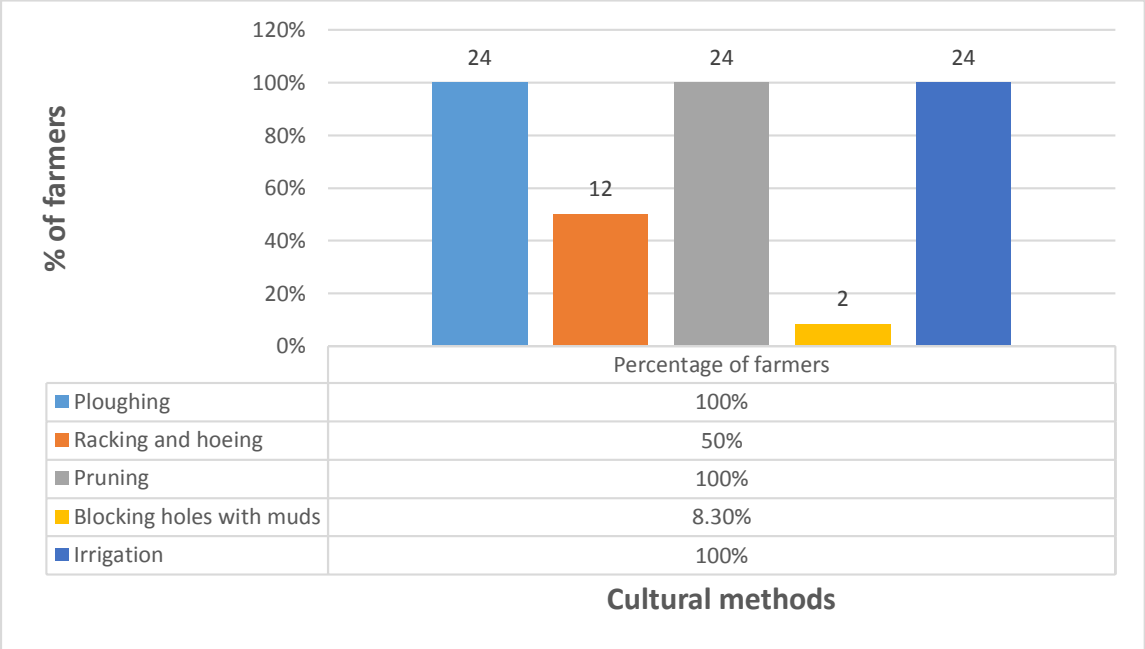

Figure 7. Cultural methods applied by farmers

4.3.4 Mechanical methods

Hand-picking, and pit digging were the mechanical methods used for the control of insect pests. Pheromone traps and pit digging were mostly used to control fruit flies and hand picking is favorably used to control bugs. It was found that 5 (20.08%) of them used pit digging while 22 (91.67%) of them used hand picking method (Figure 8).

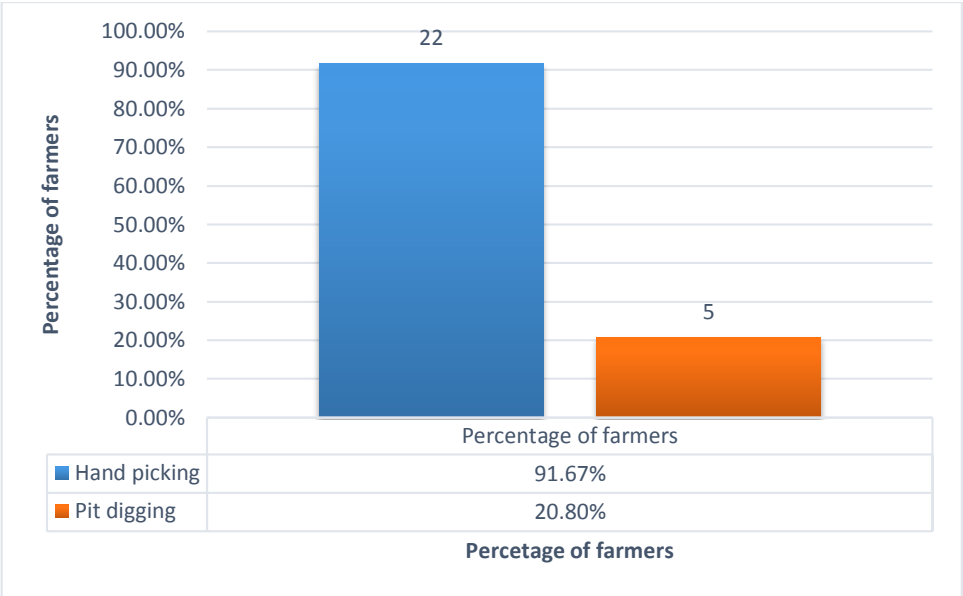

Figure 8. Mechanical methods applied by farmers

4.3.4 Use of Bio-pesticides

Neem oil, banmara leaves, titepati leaves, animal urine and ash are the bio-pesticides used by the farmers. 10 (41.67%) of them used neem oil, 7 (29.17%) of them used banmara leaves, 15 (62.50%) of them used titepati leaves, 22 (91.67%) of them used animal urine and 5 (20.83%) of them used firewood ash to deter insect pests (Figure 9).

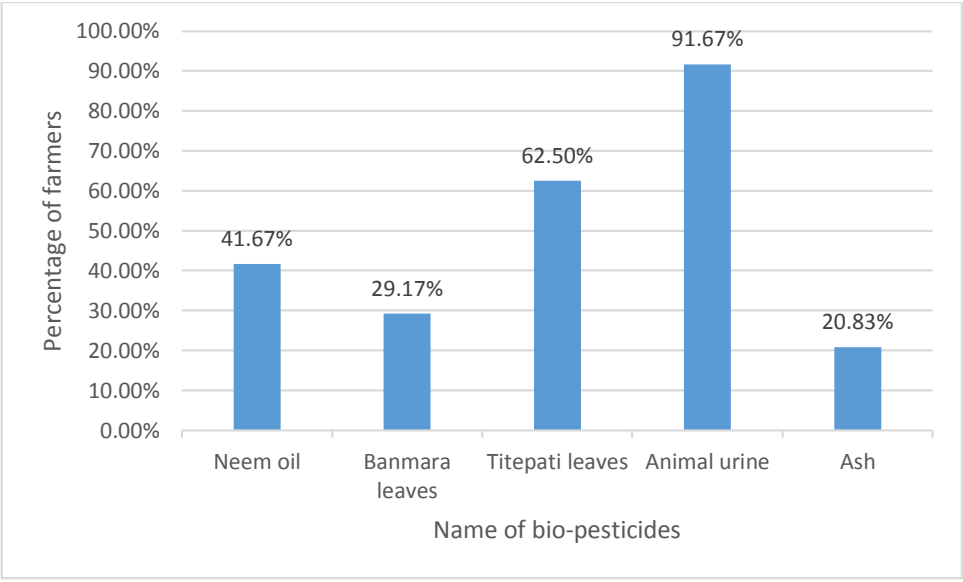

Figure 9. Bio-pesticides used by farmers

5. DISCUSSION

The orchards were found to be inhabited by various insect pests such as fruit flies, bugs, psyllids, aphids, etc. The present study found 13 citrus pest species belonging to eight families of three insect orders Diptera:Tephritidae, Hemiptera: Aphididae, Pseudococcidae, Coccidae, Lividae, Pentatomidae, Lepidoptera: Gracillaridae and Papilionidae.

The order Hemiptera was the most abundant followed by Diptera and Lepidoptera. The result coincided with the study done by Bhat and Ahangar (2018) who reported family Aphididae (order: Hemiptera) as the most abundant insect pest family during the research conducted in Kashmir valley, India.

Mandarin orchard had definitely higher abundance of insect pests in comparison to the lime orchard. *Bactrocrera dorsalis* and *Toxoptera citricidus* were the most abundant insect pests in mandarin and lime orchard respectively. The field observation noted that the fruit dropping in mandarin is higher than the lime. It explains the reason for higher rate of fruit dropping and fruit decay in the mandarin orchards in comparison to that of lime orchards. Kumar et al (2011) stated fruit drops and fruit decay are caused due to fruitflies.

Toxoptera citricidus and *T. aurantii* are vector of Tristeza viral disease. Their high presence may indicate the presence of virus in the area which is still a path to explore in Tapli Rural Municipality, Udayapur. Regmi et al. (1999) reported that CTV had spread throughout the country in which mandarins are non-symptomatic and are not damaged whereas limes are symptomatic and severely damaged by CTV. The virus and its vectors were reported from Dailekh (Regmi & Adhikari 2000), Pokhara and Bhaktapur (Regmi & Lama 1992) and Horticulture Center of Kirtipur (Roistacher 1996). In the same way, *Toxoptera* spp. were reported to be responsible for transmission of CTV in horticulture farms of Lamjung leading to huge economic loss (Ghimire 2000).

The leaf mining by *Phyllocnistis citrella* was found in almost every trees of both the mandarin and lime orchards. Study done in Florida showed 16%-23% leaf area loss caused significant yield loss of 15 years old Tahiti lime trees (Pena et al. 1994).

Symptoms of citrus greening disease was observed within the orchards. However, the vector i.e. *Diaphorina citri* was not found as abundant. It maybe because they remain active during morning and evenings and the time of field work was during the daytime. The pest and disease was also reported from Dailekh (Regmi et al. 2001). Similarly, Regmi et al. (2010) had confirmed Huanglongbing (citrus greening disease) was the primary reason for citrus decline in Kaski, Lamjung, Gorkha, Syangja and Tanahun. Similar result was affirmed by Bove (2006) and Roistacher (1996).

Green stink bugs is one of the major pest of Tapli Rural Municipality. Similar reports were provided by Shrestha (2011) stating three species of stink bugs were major cause of huge economic loss in citrus production in Kailali and reported it to be major pest in mid and far western development region of Nepal and all over Nepal (FAO 2015).

Insect pests are responsible for moderate to severe level of damages in plants. This study focuses on insect pests that were responsible for damage done to plants throughout their feeding seasons. Browning (1999) reported that citrus tree productivity and longevity were significantly impacted by insect species from diverse orders that were connected to the bloom, shoot, and root of the tree.

Pest status was determined on the basis of destruction they caused in the orchard through direct observations, interview with the farmers. Ten of the 13 pests were confirmed to be major pests. It includes tephritid fruit flies, *Toxoptera* sp., *Halyomorpha halys, Rhynchocoris poseidon, Phyllocnistis citrella* and *Papilio demoleus.* Similar report was deduced by Paneru and Giri (2011) and they stated citrus aphid, fruit fly, green stink bug, bark borer and lemon butterfly as key pests. Yosef et al. (2014) reported red scales, leaf miner, Mediterranean fruit fly, thrips and aphids as major pests of Ethiopia. Similarly, report provided by Kumar et al. (2011) stated tephritid fruitflies species *B. dorsalis, B. sculetaris* and *B. correcta* as major pests having host range as much as 123 host plants belonging to 41 plant families. Similar report was submitted by Sharma (2015) and stated that fruit flies are major pests of citrus fruits of Nepal.

For the management of insect pests on citrus fruits in the study area, farmers tend to follow chemical, cultural, mechanical and bio-pesticide methods. They were eager to use one or more methods at a time to mitigate the pest populations according to the needs, time of the year and the pests emerged in the orchards. All of the farmers

followed cultural method, mechanical methods, chemical methods and biological methods for pest control.

Four types of pesticides were used by the farmers to control pests. They were ATSO mineral oil/Agrospray mineral oil, Monocil and Rogar and pheromone traps. They were used to control scale insects, bugs and leaf miners. Similar recommendation was given by NCRP (2013). These chemicals were all in liquid state. Farmers were trained to use spray tank whilst spraying the pesticides in the orchards. Each farmers were using one or more types of pesticides throughout the year. Similar reports were given by Ouyang et al. (2010) in which mineral oils were used to control ACP, citrus leaf miner and oriental fruit fly. Rijal et al. (2018) reported high dependence on chemical pesticides in fruits and vegetables. Use of highly hazardous chemical pesticide Dichlovorous (WHO class: IB) had been reported from citrus growing area of Tanahun, Kavre, Dhading and Gorkha of Nepal (Koirala et al. 2010).

NCRP (2014) recommended 300-500 g of N, 200-250g of phosphorus and 250-350g of potassium to be applied in the ring around the tree canopy for a bearing mandarin tree to obtain a healthy yield. The farmers followed the instructions however the amount of fertilizers (Urea, DAP and Potash) used by the farmers of the study area had no actual measurements.

Ploughing, racking, hoeing, pruning of leaves and blocking holes on stem of plants with muds are some of the cultural practices of the farmers. 92% of the farmers used organic fertilizers including Urea, DAP and Potash along with compost manure. Pang and Dong (2012) reported that the use of organic fertilizers reduced the population of insect pests such as mites, scales, aphids and whiteflies.

Intercropping is found to be common method applied by farmers to increase yields. The inter-cropped plants included mostly soyabean, cauliflower, cabbage, maize and lettuce. They are considered to be good combinations for better yields. However, (Acharya et al. 2011) reported the intercropped crops including rice or maize, and wheat in citrus orchard of Dailekh district were not the best combinations for the healthy yield of citrus crops As they are heavy nutrient feeders and require adequate supply of water. Similarly, irrigations was not provided on time as they lacked sources. Poor management practices embraced by farmers such as poor irrigation, mulching, pruning, and incorrect inter-cropping, etc. has led to citrus production decline Dailekh (Subedi

& Acharya 2008). In contrast to that, irrigation in Tapli Rural Municipality was done 2-3 times depending on the rainfall. FCB (2008) states the preference of farmers towards intercropping as they believe that it provides aeration to root zones.

Pheromone traps and pit digging were most commonly practiced to mitigate the impacts of fruitflies. Use of traps is still not very popular amongst the farmers mostly because of very little knowledge about such traps and the agrovet is far away. However farmers are very proud of hand picking and destroying the notorious bugs. They do this every time they visit the orchards.

Citrus crop insect pest 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).

Neem oil, banmara leaves, titepati leaves, cattle urine and ash are some of the bio-pesticides used by the farmers. All of the bio-pesticides had been prepared by farmers using the local resources. Each family had a herd of cattle to provide them with compost manure for better yield and urine to ward off insect pests. Predatory insects can be studied for the natural control of pest species within the study area. For instance, *Amblyseius* (Phytoswiidae) can be used to control citrus red mite (Ding and Huang 1989).

6. CONCLUSIONS

The study confirmed 13 species of insect pests belonging to 8 families of 3 orders. Hemiptera (62%) was the most abundant followed by Diptera (23%) and finally Lepidoptera (15%).

It was found that species populations in the mandarin orchard had a moderate level of diversity and evenness (H=2.125) with *Bactrocera dorsalis* (21.55%) found to be the most abundant. The lime orchard had a moderate to low level of population diversity and evenness (H=1.897) of pest species with *Toxoptera citricidus* (27.7%) as the most abundant.

Insect pests mainly targeted fruits, foliages, leaves and shoot. Ten of the 13 species were categorized into major pests. Farmers use bio-pesticides, chemical, cultural and mechanical methods to control pests. Pesticides include ATSO mineral oil/Servo Agrospray mineral oil, Monocil (Monocrotophus), Rogar/ Thiodin and pheromone traps. Cultural methods include ploughing, racking, hoeing, pruning and blocking the holes in stems created by borers with mud. Mechanical methods include hand picking and pit digging.

7. RECOMMENDATION

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

- Detailed study of biology and ecology of each insect pests of citrus cultivated area is needed to control the pests.
- Seasonal study of the insect pests should be carried out.

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APPENDICES

APPENDIX I: Materials required

- Commercial pheromones traps
- Killing jars and vials of different sizes
- Alcohol, ethyl acetate, cotton, gloves, forceps
- Strings and water-proof labeling cards
- Measuring tape
- Stationary (Notebook, pen, pencil, sticky notes)

APPENDIX II: Diversity indices of insect pests of mandarin and lime orchards

	Mandarin orchard	Lime orchard
Taxa_S	13	11
Individuals	1146	682
Dominance_D	0.1382	0.1765
Simpson_1-D	0.8618	0.8235
Shannon_H	2.125	1.897
Evenness_e^H/S	0.6442	0.6062

APPENDIX III: Questionnaire

QUESTIONNAIRE SURVEY ON CITRUS FRUIT PESTS AND MANAGEMENT PRACTICES IN TAPLI RURAL MUNICIPALITY, UDAYAPUR DISTRICT, NEPAL

1. Respondent's information

Name: Age: Gender:

Education: HH:

2. Citrus problems

- How long have you been involved in commercial citrus production? ……. Years
- Which citrus fruits do you produce?

- What are the main problems you face in your farming production?

- What are the major pests that destroy your crops?

Citrus fruit	Name of insect pets	1st emergence of insects	Most damaging period	damaging pattern (Defoliation, sap-sucking, leaf mining, leaf rolling, bud eating, fruit-eating, fruit decay)

3. Citrus pest control practices

- Which chemical fertilizers do you use?

Citrus plants	Name of fertilizers	Purposes/ Months

- Who recommends you to use these insecticides/pesticides?

Self	Friend	JT/JTA	Gov. official	Training	I/NGO

- What are the local level practices you use in your orchards?

Citrus fruits pests	Management practices

Photo plates

Photograph 1. Interaction with local farmers during questionnaire interview

Photograph 2. Pesticides and fertilizers used by farmer

Photograph 3. Leaf mining and symptoms of citrus greening on citrus leaves.