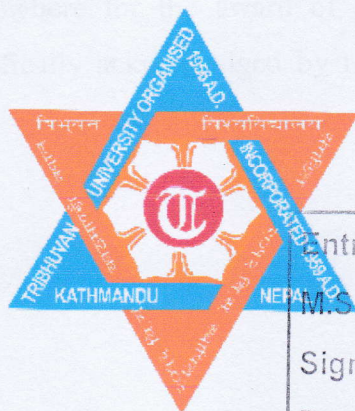


**INSECT SPECIES ASSOCIATED WITH MANDARIN (*CITRUS
RETICULATE*) AND PEST MANAGEMENT PRACTICES IN
SIGANA, BAGLUNG, NEPAL**



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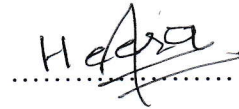
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DECLARATION

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).



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This is to recommend that the thesis entitled “**INSECT SPECIES ASSOCIATED WITH MANDARIN (*CITRUS RETICULATE*) AND PEST MANAGEMENT PRACTICES IN SIGANA, BAGLUNG, NEPAL**” has been carried out by Ms. Heera K.C. for the partial fulfillment of Master’s Degree of Science in Zoology with special paper Entomology. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institutions.

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LIST OF ABBREVIATIONS

Abbreviated form	Details of Abbreviations
Asl	Above sea level
CDZ	Central Department of Zoology
CDZMTU	Central Department of Zoology Museum of Tribhuvan University
FAO	Food and agriculture organization
MoAC	Ministry of agriculture and co-operatives
MT	Million ton
TCP	Translation complex profile sequencing
TU	Tribhuvan University

ABSTRACT

The study was conducted in Mandarin orchard at Sigana, Baglung district from 2 September to 23 November 2022. Insects were collected by hand-picking, beating, sweeping method and pheromone trap. Farmers were interviewed by using questionnaire to know the pest management practices. Altogether nine predator species and 13 pest species were recorded. Among predators Coleoptera (88.77%) and Dermaptera (11.21%) and among pest species belong to four orders, Hemiptera (94.12%), Diptera (5.45%), Coleoptera (0.38%) and Lepidoptera (0.02) were recorded. The Shannon-Winner diversity index and evenness for non-pest was 1.549 with Pielou's species evenness as 0.5231 and for insect pests species was 1.186 and 0.2517 respectively. Majority of the farmers (50%) used chemical plus cultural method, 25% adopted chemical plus bio-pesticides and remaining 25% adopted IPM method.

1. INTRODUCTION

1.1 Background

The genus *Citrus* belongs to the subfamily Aurantioideae of the family Rutaceae. It is native to subtropical and tropical regions of Asia. It grows in well drained and sandy soils having pH range from 6.0-6.5 (DAF 2013) and temperature of 15-30° with annual rainfall of 1250 to 1850mm (FAO & MoAC 2011).

Barrett and Rhodes (1976) claimed that the three citrus species, namely pummelos, mandarins, and citrons, were the predecessors of all other citrus species. They argued that these ancestral varieties had interbred to produce hybrids, that made up the rest of the citrus species. Nicolosi et al. (2000) have proven the hypothesis suggested by them using molecular marker evidence. However, there might be other species that could also be considered as ancestors.

Citrus fruits have become more popular in many countries and continents in recent years, with a significant increase in their production and consumption (FAO 2017). Citrus fruits comprising mandarin, sweet orange, lemon, lime and grapefruits are the most commonly growing citrus for commercial purpose in the world. About 143755.6 thousand tons of citrus fruits were produced worldwide in 2019. Oranges are the most widely produced citrus fruit in the world, with a production volume of 76292.6 thousand tones, followed by mandarins with a volume of 37429.3 thousand tones. Lemon and limes have a production volume of 20529.6 thousand tones, and grapefruits have a volume of 9504.1 thousand tones. (Smilanick et al. 2019). The advancements in farming techniques, transportation, and packaging technology has resulted in better quality citrus fruits and processed products and also made them more affordable during the last decade (FAO 2003).

Citrus fruits are popular and highly demanded as they are an essential part of our diet. Citrus fruits are well-known for their unique flavor and contain healthy compounds like carotenoids and flavonoids that act as antioxidants and contain provitamin A. They are also an excellent source of carbohydrates, dietary fiber, B vitamins, and minerals. The consumption of citrus fruits is crucial for maintaining good health due

to their nutrient richness, low-fat, low-sodium and have been linked to reducing the risk of chronic diseases (Liu et al. 2012).

1.1.1. Citrus cultivation and production in Nepal

Citrus fruits are being cultivated in about 60 districts of Nepal (Acharya 2016). Out of the 46,412 hectares of citrus cultivation, only 28,406 hectares are productive, producing 271,908 metric tons of citrus and yielding 9.57 metric tons per hectare. Out of total fruit production, citrus contributes about 22.7% in Nepal (MoALD 2018).

The cultivation of citrus fruits, particularly that of Suntala (Mandarin) and Junar (Sweet orange), has long been an important aspect of agriculture in Nepal. This sector is essential to local communities, particularly in the mid-hill region and terai plains. The country is renowned hub of citrus diversity (Adhikari et al. 2012).

The government established the National Citrus Development Program (NCDP) in order to focus into the potential advantages of commercializing citrus farming in Nepal in 1972. The government also launched the Commercial Agriculture Development Program in 1994/95 to encourage the commercialization of citrus cultivation in mid-hill region of Nepal. The commercialization of citrus farming in the country has been encouraged by government efforts such as the National Agriculture Policy 2004 and the Agri-Business Promotion Policy 2007 (FAO & MoAC 2011). The Fruit Area Expansion Program was launched during the 2015-2016 fiscal year to promote the commercialization of citrus farming. The program aims to increase citrus production from 39,035 hectares (in FY 2014/15) to 94,554 hectares by the end of FY 2036/37. It also aims to increase production from 2,22,894 metric tons to 5,93,877 metric tons and productivity from 8.82 metric tons per hectare (in FY 2015/16) to 10.22 metric tons per hectare (Nepal Horticulture Promotion Centre 2017).

Among the citrus fruits, Mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis*) and acid lime (*Citrus aurantifolia*) are the three most important citrus species in Nepal in which Mandarin takes 1st position, then after sweet orange and acid lime in term of cultivation and production. The top producer of Mandarin is Gandaki province (52,478Mt) with 7,602 Ha area of cultivation followed by Province 1 (44,540 Mt), Bagmati (28,588 Mt), Province 5 (24,139 Mt), Karnali (19,063 Mt) and Sudurpaschim with 8,573 Mt (MoALD 2018).

Mandarin fruit production in Nepal has increased by more than two times in the last decade, but productivity has only slightly improved. Nepal's mandarin productivity rate of 10.8 metric tons per hectare is lower than other countries that produce mandarins, whose rates range from 20 to 50 metric tons per hectare (NARC 2009). The increase in mandarin production in Nepal is mainly due to expanding the cultivated land rather than improving productivity (NCRP 2010).

1.1.2 Problems of Citrus Cultivation and production

Poor management practices, including the use of low-quality planting materials, insufficient soil maintenance, and climatic variability, have led to decreased orchard productivity by causing diseases and pest outbreaks (FAO 2011). The western region of Nepal experienced a severe citrus decline, which has also affected other parts of the country (NARDF 2015). Diseases including root rot, Huanglongbing (HLB), canker, gummosis and pink disease have impacted citrus groves in Nepal, leading to a decline in productivity. Citrus greening disease is the main cause of this decline and is more severe in the lower belts (upto 900 meters above sea level) (Roistacher 1996). Similarly, insects like citrus psylla, fruit fly, scale bug, stem borer, and leaf miner seriously threaten citrus cultivars, contributing to their decline (Budathoki & Pradhanang 1992). The Chinese fruit fly (*Bactrocera minax*), severely damages plants and is considered the most destructive pest (Sharma et al. 2015). Similarly, *Citrus psylla*, vector of citrus greening disease is now widespread in Nepal (Regmi & Yadav 2007).

Citrus trees in numerous fruit-growing regions in Ethiopia are susceptible to various pests and diseases. Pests like Leafminer, Orange dog, Red scale, Woolly whitefly, false codling moth, thrips, aphids and bud mites are commonly found in these areas (Yosef et al. 2014). Woolly whiteflies have invaded citrus orchards in different parts of Ethiopia, causing leaf wilting and shedding by feeding on phloem sap. Furthermore, they provide favourable environment for the growth of sooty mold (Getu 2007). Similarly, the citrus green stink bug (*Rhynchoris humeralis*) is the main insect pest causing premature dropping of citrus fruits (Pandey & Rana 1993).

1.1.3 Citrus pest management practices

Farmers used different methods, such as using pesticides and integrated pest management to protect citrus crops from pests. Biological methods, like introducing natural enemies, such as spiders, ants, and lacewings, were also used to control pests. Systemic pesticides were used to control the population of leaf miners. Some predators like *Ageniaspis citricola*, *Closterocerus cinctipennis*, *Horismenus fraternus*, and *Pnigalio minio*, were successfully parasitized, which helped in controlling the pests (Michaud 2002). A range of various strategies such as use of pheromone traps, chemical pesticides and proper management of attacked fruits from the orchards were employed for fruit fly management (Jaisawal et al. 1997). Nepal has been using biological methods to control citrus stink bugs by parasitizing them with wasp species, including *Anastatus* sp, *Trissolcus letisculus*, and *Ooencyrtus utitheisee*. The most effective method to control the Citrus Green Stink Bug is to release more wasps and disperse them near parasitized eggs (Pandey & Rana 1993).

The top 10 common pesticides used by farmers in Nepal were Dichlorovous, Alphametrin, Carbendazin, Cypermetrin, Chloropyrifos, Mancozeb, Imidacloprid, Dimethoate, Malathion, Emamectin benzoate (Aryal et al. 2016). Chemical pesticides can be highly effective at controlling pests but it also pose a risk to helpful invertebrates (Tahir et al. 2010). The use of chemically synthesized pesticides can harm both on environment and human health (Bukhari et al. 2012). The overuse of pesticides has led to pests becoming resistant to them (Rogers & Dewdney 2012). The efforts are being made to use methods that do not harm natural predators, such as organic farming, mulching, and intercropping. These methods help to conserve the natural predator ecosystem (Sunderland & Samu 2000). The preservation of overwintering sites was done to boost the diversity and population of natural predators (Landis et al. 2000).

Integrated pest management strategy utilizes biological controls, such as natural predators, to control pest populations, and is a crucial component of pest management (Amalin et al. 2001). Natural predators such as Ladybeetles, lacewings *Chrysoperlacarnea*, and spiders are effective for controlling different pests (Michaud et al. 2002, Sunderland and Samu 2000, Tahir & Butt 2009).

1.2 Objectives

The general objective of this study was to explore insect species of Mandarin in Sigana, Baglung.

The specific Objectives were:

1. To find pests and associated insect species diversity and their abundance in Mandarin orchard of Sigana, Baglung district
2. To explore damage patterns of mandarin by insect pests in the study area.
3. To document the existing local knowledge and control measures of insect pests in the study area.

1.3 Significance of the study

Citrus is one of the most important and popular fruits of Nepal. Gandaki province is known commercially for growing citrus species mandarin with the highest production of 52,478 Mt in which Baglung contributes 2, 550 Mt with 10.41 Mt/ha yield. In 2021, citrus growing farmers of Sigana, Municipality 8 of Baglung district that has become known as the village of oranges earned Rs 20 million by selling oranges (<https://english.dcnepal.com>). Citrus fruits are affected by different pests and cause significant loss of quantity and quality of citrus growing area of Nepal (FAO 2015). Despite the immense potential for citrus production in the mid-hills of the country and the government's ongoing efforts, citrus farmers are confronted with various production challenges, resulting in unsatisfactory yields. The use of traditional methods, insufficient technical knowledge, and inadequate orchard management practices are primarily responsible for these challenges (TCP 2011). Additionally, pest infestations, diseases, a shortage of healthy seedlings, limited access to market information, and unpredictable pricing are all significant obstacles to citrus production (Aryal et al. 2021).

There is virtually no information available in this field in Sigana. Therefore this study aims to identify pest species of Mandarin and associated insect species in this area. It will be the first hand information, regarding to the insect pest in this area. This information might be useful to the farmers and policy makers for scientific management and reducing pests in my study area.

2. LITERATURE REVIEW

2.1 Origin of Citrus

According to the recent research, the cultivation of lemon originated in India, while sweet oranges and mandarins from China, Australia, New Caledonia and New Guinea are believed to be the actual native place of citrus fruits, despite the fact that some commercial species such as oranges, mandarins, and lemons were first grown in Southeast Asia (Anitei 2007).

There is a debate about the origins of citrus fruits. Some experts believed that citrus is native to subtropical and tropical regions of Asia, from the certain areas of Southeast Asia like India, China and the Malay Archipelago, others support this claim (Scora 2010). As per old manuscripts found among ancient Chinese documents, citrus fruits, particularly mandarins and pummelo, were considered precious tributes during the reign of Ta Yu (around 2205 to 2197 BC) (Webber 1967).

2.2 Citrus production in the world

The global production and consumption of citrus fruits such as oranges, tangerines, lemons, limes, grapefruit, and various hybrids within the Citrus genus of Rutaceae family, has increased in recent years in different countries and continents (FAO 2017).

The worldwide production of Citrus fruits reached approximately 124.2 million tons, highlighting their significant economic worth in 2016. Brazil is the top producer and exporter of oranges and orange juice worldwide with 14.350 million tons of production in 2016. Meanwhile, countries including China, Mexico, India and United States become the most significant producers of tangerines, limes, lemons and grapefruits. The global citrus production trend shows that oranges make up about 60% of the total output, with mandarins, clementines and tangerines in second followed by lemons and limes and grapefruit and pomelo (FAO 2017). Advancements in cultivation techniques, transportation infrastructure, and packaging technology have contributed significantly to the growth of processed Citrus goods throughout the last decade and also resulting in increased quality and reduced costs of both Citrus fruits and their derived products (FAO 2003).

2.3 Citrus Cultivation and Production in Nepal

Nepal has a long-standing tradition of growing citrus fruits, particularly Suntala (Mandarin) and Junar (Sweet Orange) in mid-hill region. The country is known as one of the hub of citrus diversity with multiple varieties (Adhikari & Rayamajhi 2012). Commercial citrus farming is now expanding even to the Terai region of Nepal and farming taking place in approximately 60 districts throughout the country currently (Acharya 2016).

The area of citrus cultivation has been increasing as well as there is gradual increase in the citrus production (MoALD 2020). However the productivity data has been fluctuating from 2008 to 2018 (Table 1).

Table 1: Citrus Species Production, potential area and productivity in Nepal over last ten years

Year	Total area (h)	Production (mt)	Productivity (mt/ha)
2008/09	32,322	253,766	11.3
2009/10	33,898	259,191	11.3
2010/11	35,576	263,710	11.2
2011/12	37,565	240,793	10.0
2012/13	36,975	216,188	9.1
2013/14	38,988	224,357	8.8
2014/15	39,035	222,789	8.8
2015/16	40,554	218,447	8.8
2016/17	46,328	239,773	9.0
2017/18	44,424	245,176	9.4
2018/19	46,412	271,908	9.57

Source: Ministry of Agriculture and Livestock Development, 2020.

2.4 Diversity and abundance of citrus insect pests

Fadamiro et al. (2008) carried out a sampling in 6 Mandarin orchards in which 4 were conventionally sprayed and two were unsprayed during 2005-2006 in order to determine the population dynamics of Arthropod pests and their natural enemies. During the research, 28 arthropod pest species were encountered. Among them, major pests such as citrus whitefly, *Dialeurodes citri*, purple scale, *Lepidosaphes beckii*, Glover scale, *Lepidosaphes gloveri* and citrus red mite, *Panonychus citri*. The major differences were recorded in the relative abundance of different arthropod pest species in the orchards. Citrus whitefly, purple scale and Glover scale were found predominantly in the unsprayed orchards whereas the infestation of citrus red mites was more severe in the sprayed orchards. The most important natural enemies of citrus whitefly were found to be *Encarsia lahorensis* that causes parasitism and *Aschersonia aleyrodis* Webber, a pathogenic fungus that causes infection. The natural enemies of citrus red mite were the predatory mites belonging to several families of which *Typhlodromalus peregrinus* was the predominant species.

Deka et al. (2016) conducted a survey and surveillance of insect pests of citrus and their natural enemies in Assam during 2011-2014. A total of 12 species of insect and mites and many species of natural enemies were found in the orchard. In most of the orchards, the insect pests such as: trunk borer, *Anoplophora versteegi* (4.40-48.65%), bark eating caterpillar, *Inderbela quadrinotata* (10.80-43.76%), citrus leafminer, *Phyllocnistis citrella* (4.00-49.27%) and citrus butterfly, *Papilio* spp (3.32-27.89%) were found to have severe incidence. Among the natural enemies, different species of spiders, coccinellids, non-stinging wasps, mantids and chrysopids were found to be the main predators observed in the fields.

Uddin and Ahmed (2016) carried out a study on status and spatial distribution of major insect and mite pests attacking citrus at Sylhet region in Bangladesh during May to October 2014. In this study, 12 insect and 1 mite species were found to attack Mandarin (*Citrus reticulata*), sweet orange (*Citrus sinensis*), jara lemon (*Citrus pennivesiculata*) plants. There were 4 major insect pest i.e, lemon butterfly, citrus leafminer, Asian citrus psyllid, spined citrus bug and one mite species, citrus red mite. Citrus leafminer was found as the most devastating pest followed by lemon butterfly and spined citrus bug.

During the period between August 2018 and February 2019, a study was carried out to study the seasonal incidence of insect pests on Khasi Mandarin in Mawryngkneng village of East Khasi Hills districts of Meghalaya (Kumar et al. 2021). The study revealed about 7 insect species were the predominant out of 32 insect species encountered. Among them, citrus leaf miner (*Phyllocnistis citrella*) and Hemipterans pests found frequently while lemon butterfly (*Papilio demoleus*) and citrus trunk borer (*Anoplophora versteegi*) were least common.

Singh et al. (2021) carried out a case study on the insect pests responsible for the decline of citrus production in Manipur and their control measures. It was found that trunk borer had the highest incidence while citrus psylla, black aphids and black fly had medium incidence. The incidence of red scale, leafminer, mealy bugs, lemon butterfly, fruit-sucking moth, and citrus looper was found low in the orchard. In order to control the incidence of whitefly, blackfly, and leaf miner, yellow sticky traps were used while sticky bands were applied in the trunk section to prevent the climbing of mealy bugs crawling.

Gurung et al. (2022) reviewed on the problems and future prospects of Mandarin in Darjeeling and Sikkim Hills. Many severe pest and diseases, lack of quality planting materials and less technical knowledge in cultivation aspects caused the reduction in productivity during those years. The major pests like trunk borer, fruitfly and citrus psylla were the predominant. Direct damage was caused by the insect pests that act as vectors of some deadly diseases like Citrus Tristeza Virus, Psylla with greening and leafminer with canker.

Lad et al. (2022) carried out an investigation on infestation of major insect pests and diseases on sweet orange at Aurangabad and Jalna districts of Marathwada region in Maharashtra during 2021-2022. Investigation showed that black fly, citrus psylla, fruit sucking moth, leaf miner, mite infesting fruits, mite infesting leaves, Phytophthora gummosis, Thrips, whitefly and bark eating caterpillar were the major insect pests and diseases on sweet orange on both districts. All these pests and diseases infestations were found in both districts throughout the years.

Budathoki and Pradhanang (1992) carried out a research on production constraints of mandarin in western hills of Nepal. They concluded that diseases like greening disease, root rot, pink disease, fruit drop and other management factors were

responsible for decline in mandarin. In addition insect pests such as psylla, citrus leaf miner, blackfly, lemon butterfly, bark eating caterpillar, aphids, thrips, fruit sucking moth and citrus mites were found attacking mandarin trees. Among them, green stink bug (*Rhynchocoris humeralis*) was found to be very common and serious pest of Tanahun, Gorkha and Lamjung districts.

Adhikari et al. (2012) during field visits found the insect pests such as Citrus green bug, scale insect, borer, leaf miner, fruit fly, lemon butterfly, aphids and mites as important insects of Junar.

Mainali et al. (2012) reviewed on entomological research works on major fruit crops of Nepal. Under entomological research on citrus, it is said that mandarin orange was more susceptible to citrus green stink bug damage in earlier growth stage of the crop. The extent of the fruit drop was about 21 percent (Pandey & Rana 1992).

Sharma et al. (2016) conducted a research on fruit fly surveillance in Nepal in order to access the population density, yield loss and management measures to prevent yield loss by fruit fly. Farmers were found practicing the use of pheromone traps, field sanitation and application of chemical measures for management. The preliminary surveillance of fruit flies reported *Bactrocera cucurbitae*, *B. dorsalis*, *B. zonata*, *B. tau* and *B. scutellaris*.

Adhikari et al. (2022) carried out a study during the period of 2018 and 2019 on farmer's perception on pestilence and management of Chinese citrus fly, *Bactrocera minax* in the citrus orchards of Nepal. The study found that lemon was found to be extremely vulnerable to Chinese citrus fly infestation. It was revealed that Chinese fruit fly was found to regularly invade the orchards of lemon, sweet orange and Mandarin of 20 citrus dominated districts in Nepal.

Dhakal et al. (2022) carried out a survey by Plant Quarantine and Pesticide Management Centre, Lalitpur, in coordination with Prime Minister Agricultural Modernization Project, Project Implementation Unit, and Sindhuli during the second week of April 2021. The survey was carried out on 6 major citrus growing pockets in Sindhuli district. The result revealed the presence of *Diaphorina citri* in the orchard of Golanjor rural municipality ward no. 3. Also it was found that 2.96% and 20% of the surveyed orchards Sindhuli and Golanjor-3 were infected by *D. citri*, respectively.

2.5 Management practices

Das and Roy (2010) carried out a study on diversity of arthropod natural enemies in the tea pests of North Bengal. The study reported the presence of 94 species of predators and 33 of parasitoids. On the basis of observation in field and rearing on laboratory, new records on tea-natural enemy associations were made. During the survey period, spider and lady bird among the predators, and Braconidae and Ichneumonidae among the parasitoid groups were dominant.

A review was carried out by Stathas and Skouras (2013) on biological control on insect pests in citrus orchards in Greece. This paper mentioned that between 1910-1913, *Rodolia cardinalis* was introduced for controlling the scale, *Icerya purchase*. Then, between 1962-1972, five hymenopteran parasitoid species were introduced to control the red- scale, *Aonidiella aurantii*. Again, to control the scale insect such as *Saissetia oleae* and *Coccus pseudomagnoliarum*, predator *Rhyzobius forestieri* was reared and released during 1983-1992. Predators, *Cryptolaemus montrouzieri* (in 1970 and 1991-92), *Nephus reunion* (in 1970), *N. anomus* and *N. quadrimaculatus* (in 1991-92) and were reared and used against the mealy bug, *Planococcus citri*. Against the armored scale (*Lepidosaphes gloverii*), the predators (*Rhyzobius lophanthae* and *Chilocorus bipustulatus*) were reared during 2001-2003. For the control of white flies, *Dialeurodes citri* and *Aleurothrix floccosus* predators, *Encarsia lahorensis* and *Cales noacki* were introduced respectively. *Harmonia axyridis*, the predator of aphid pests was introduced from France.

Mahmood et al. (2014) reviewed on the prospects of biological control of citrus insect pests in Pakistan. The review showed that citrus was attacked by number of insect pests in Pakistan. Such as: Citrus psylla (*Diaphorina citri*), Leaf miner (*Phyllocnistis citrella*), White flies (*Aleurocanthus woglumi*, *A. husaini*), *Aleurotuberculatus citrifolli*, *A. jasmine*, *Amurrayae*, *Aleurolobus niloticus*, *Aleurotrachelus* sp, *Dialeurodes citri* and *D. elongate*, Scale insects (*Aonidiella aurantii*, *A. citrina* and *A. orientalis*), mealy bugs (*Nipaecoccus vastator*, *virgala*, *Planococcus citri*, *Pseudococcus filamenetosus*, *Spilococcus* sp and *Rastrococcus spinosus*, coccids *coccus hesperidum* and *Pulvinaria psidii*, margarodids *Drosicha stebbingi* and *Iceryia egyptiaca*, fruit flies (*Bactrocera zonata*, *B. dorsalis*) and butterfly (*Papiliode moleus*). Farmers rely on pesticide sprayings in orchards to control pests and diseases.

Deka et al. (2018) conducted a research in order to evaluate three modules i.e Bio-intensive IPM module (BIPM), IPM module and Farmers Practice (FP) for insect pest management of khasi Mandarin under climatic conditions of north-eastern India. IPM includes common cultural practices, installation of light traps, yellow sticky trap and pheromone trap, smearing tree trunk by the mix of 50ml Dimethoate 30 EC+2kg lime in 10 liters of water, spraying of NSKE 4% application of *Paecilomyces lilacinus* fungal which was found to be the effective measures followed by BIPM (Ploughing and application of *Beauveria bassiana*, *Metarhizium anisopliae*, application of *Verticillium lecanii* for aphids, black flies, leafminer, scales and psylla, application of *Paecilomyces lilacinus* and application of Bordeaux paste, insert petrol/kerosene soaked cotton into the holes followed by closing the exit hole with mud for the managements of trunk borer and bark eating caterpillar.

Fitiwy et al. (2019) carried out a research in order to evaluate some botanical extracts against major insect pests (Leafminer, Armored scale and Woolly Whitefly) of citrus plants in Central Zone of Tigray, North Ethiopia. An experiment was carried out in the established citrus orange farm in Kolla Temben at two farmers' fields, Adiha and Agibe during the off-season of 2018 under irrigation growing condition in a randomized complete block design with six treatments and replicated thrice. The findings in both sites showed that the Neem seed extract had a significantly ($p=0.001$) lower leafminer infestation levels compared to the untreated control. On other hand, in both areas, whitefly mortality of more than 81% on average was recorded from Neem seed extract followed by tree tobacco (70%), ($p=0.001$). For scale insects, in both experimental sites, the highest mean percent mortality was recorded from the insecticide Dimethoate 40% EC (86.9%, 87.2 and 86.0% on average) followed by Neem seed and tree tobacco extracts, 70.1 and 65.4% respectively. The study found the Neem seed extracts followed by tree tobacco were as effective as the chemical insecticide, Dimethoate 40% EC, even works better in some cases in management of target pests.

Pathania et al. (2021) worked on incidence and severity of insect pests and diseases of Kinnow mandarin in south-western Punjab. Along with the 18 species of insects and mites and 7 diseases he also reported the presence of 6 species of natural enemies i.e, *Coccinella septempunctata*, *Coccinella transversalis*, *Brumus suturalis*, *Scymnus* sp,

Chrysoperia carnea, *Syrphid* sp and others different species of spiders in the Kinnow agroecosystem.

Singh et al. (2021) conducted a survey during 2017 and 2018 on natural occurrence of Entomopathogenic Fungus (EPF), *Aschersonia aleyrodis* on citrus whitefly in Punjab, India. During Oct-Dec, EPF was found to infect nymphs and pupae of citrus whitefly, *Dialeurodes citri* on the lower surface of Mandarin from the orchards of Hoshiarpur, Ludhiana, Mansa and Fazilka districts.

Maharjan and Thapa (2018) conducted an experiment in laboratory of Entomology Division, Nepal Agricultural Research Council (NARC), Khumaltar and concluded that *Coccinella septempunctata* is an effective predator to control different aphid species.

Adhikari et al. (2020) undertaken a research on fruit fly management in Nepal from September 2013 to July 2016 in Nepal. The study reported after the aphids, fruit fly was found to be a major insect problem. The most affected groups of horticultural crops affected by fruit flies were cucurbitaceous vegetables by 79% followed by fruits by 14% (guava, sweet orange, mandarin, mango, peach and pomegranate) and Solanaceae vegetables by 6%. Use of para-pheromone lure/ traps, sanitation and cultural measures were mostly recommended for the fruit fly management.

Acharya et al. (2022) carried out a study on Chinese citrus fly management in Mid-hills of Nepal in which two sets of fruit fly management were conducted at NCRP, Dhankuta and Junar super zone, Sindhuli in the year 2018. Protein hydrolysed product, Protein 17 with spinosad, Great fruitfly bait (GFF), Ceranock bait, locally made bear wast-hydrolysed protein with spinosad, Dimethoate spray and no spray treatments were replicated 4-5 times with single tree as a replication in both locations. At 15 days interval, the treatments were repeatedly sprayed on same fruiting sweet orange trees and GFF bait was used in weekly basis. The result showed that there was complete fruit loss from other treatments to less than 7% loss from the trees sprayed with GFF bait. At Tinkanya area, the result showed the reduced infestation with more fruit yield by the area wide management strategies with GFF bait in Sindhuli.

Acharya and Adhikari (2022) reviewed on strategies for managing citrus decline in Nepal. This paper reviewed that due to many biotic and abiotic factors, commercial cultivation had not been picked up. Among the various problems Citrus Greening

disease was the major one. Citrus greening disease was reported from every citrus cultivating district. For the management of this disease, as there was no single method, IPM technology was found to be effective worldwide. Thus, this paper mentioned the use of healthy sapling, vector control and removal of infected trees, quarantine system while transporting saplings within district, province and country should be strictly followed.

3. MATERIALS AND METHODS

3.1 Study Area

The study area was Sigana ward no. 8, Baglung Municipality in Baglung District. The study area lies at the altitude of 1416 m asl. The coordinates of the study area is 28°N and 83.56°E. Sigana, Baglung is one of the important mandarin growing areas developing as a mandarin pocket zone of Nepal.

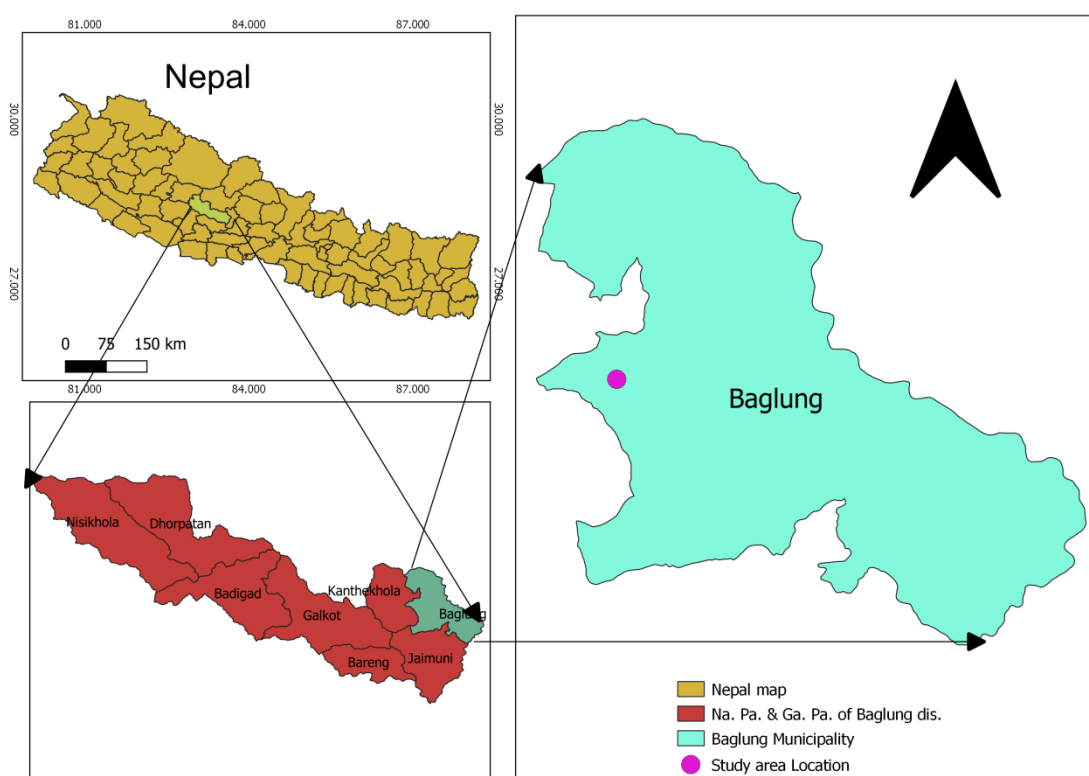


Figure 1: Map of study area, Sigana, Baglung

3.2. Sampling Methods

3.2.1. Collection of pests

Insect pest species were collected once a week for three months from September 2 to November 23 of 2022. For collection of pests, single orchard of 5 Ropani was selected and divided into three blocks. Each block comprising 100 trees and sampled alternate trees of block once a week for insects collection. Hand picking method, sweeping method and pheromone F trap were adopted including beating method for collection of insects.

Trapped pests were collected by camel brush and preserved in 70% alcohol. Handpicking method was applied using feather weight forceps.

3.3.2. Questionnaire Survey

For the assessment of pest management, questionnaire survey and informal discussion with farmers was made and the pest management status was recorded. The people's perception about the pest management practices and health hazard were documented.

3.3.3 Identification of specimens

The collected insect pests were identified by using standard keys (Borror and De Long, 1964; Richards and Davies, 1977; Sharma et al. 2015). Further specimen were identified by using the book "Fauna of British India" (Distant 1918) for the identification of *Atkinsoniella opponens*, (Distant 1902) for the identification of *Rhynchocoris* and other published articles and original descriptions. The collected specimens were deposited at the Museum of Central Department of Zoology Museum of Tribhuvan University (CDZMTU) Kirtipur, Kathmandu, Nepal. Identified species and their short description are given in Appendix III and IV.

3.3.4 Data Analysis

The primary data were managed in excel software and later transformed to statistics software (Past 4.07b) for further analysis.

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.

$$\text{Relative abundance (\%)} = (n/N) * 100$$

Where, n = Number of each individual

N = Total number of individual

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

$$H = \sum (p_i) * (\ln p_i) \dots \dots \dots (\text{Shannon Wiener, 1949})$$

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.

4. RESULTS

4.1 Diversity of insect species associated with Mandarin

A total of 3018 individuals of insects both pests and non pests were collected belonging to five orders (Hemiptera, Diptera, Coleoptera, Dermaptera and Lepidoptera) from the Mandarin orchard in Sigana, Baglung district. The order Hemiptera (90.8%), was the most abundant order followed by Diptera (5.3%), Coleoptera (3.4%), Dermaptera (0.4%) and Lepidoptera (0.02%) (Figure 2).

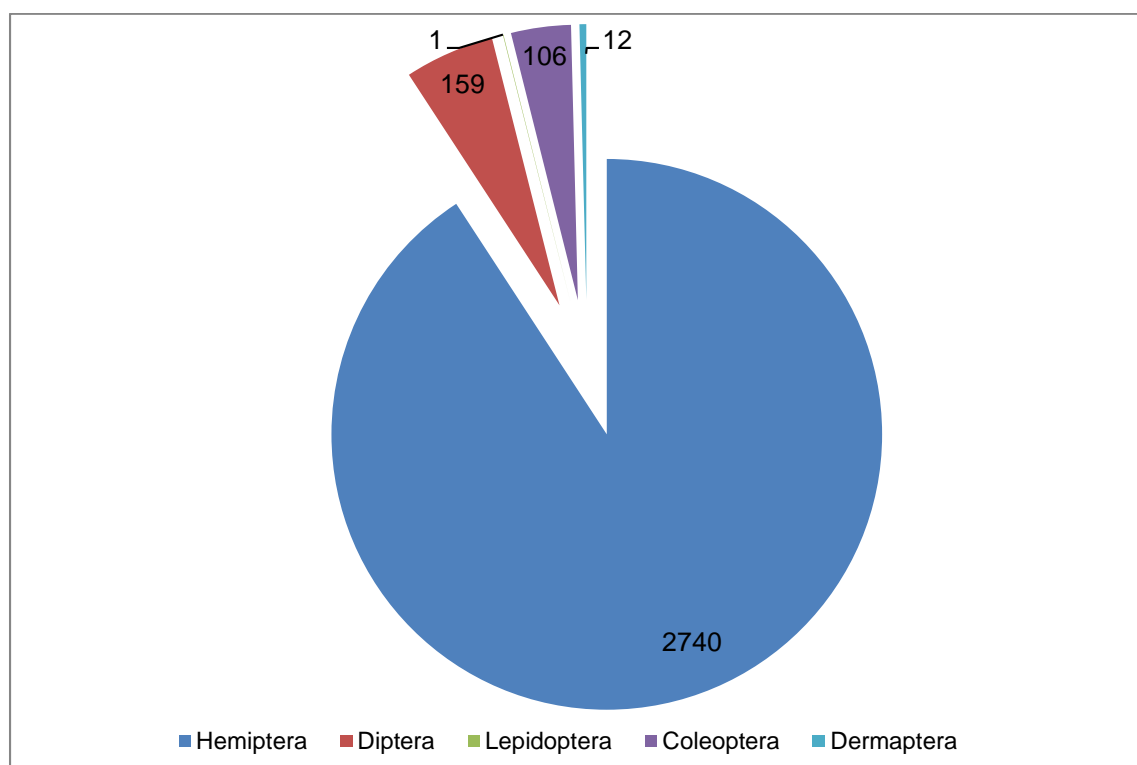


Figure 2: Order wise composition of insect associated with Mandarin in study area

Among the collected samples, insect species were identified that included 22 genera and 12 families belonging to all above five orders. The highest number of pest families were reported within the order Hemiptera comprising six families. -From high to low abundance of these families were Aphididae (82.84%), Pseudococcidae (5.6%), Diaspididae (1.05), Pentatomidae (0.95%), Coreidae (0.12%), and Cicadellidae (0.07%). Other insect pest families were Tephritidae (5.3%) of Order Diptera, Chrysomelidae (0.35%) of Coleoptera and Papilionidae (0.02%) of Lepidoptera. Non-pest families but predators were Coccinellidae (3.15%) of

Coleoptera, and Forficulidae (0.3%), and Labiduridae (0.1%) of Dermaptera (Figure 3).

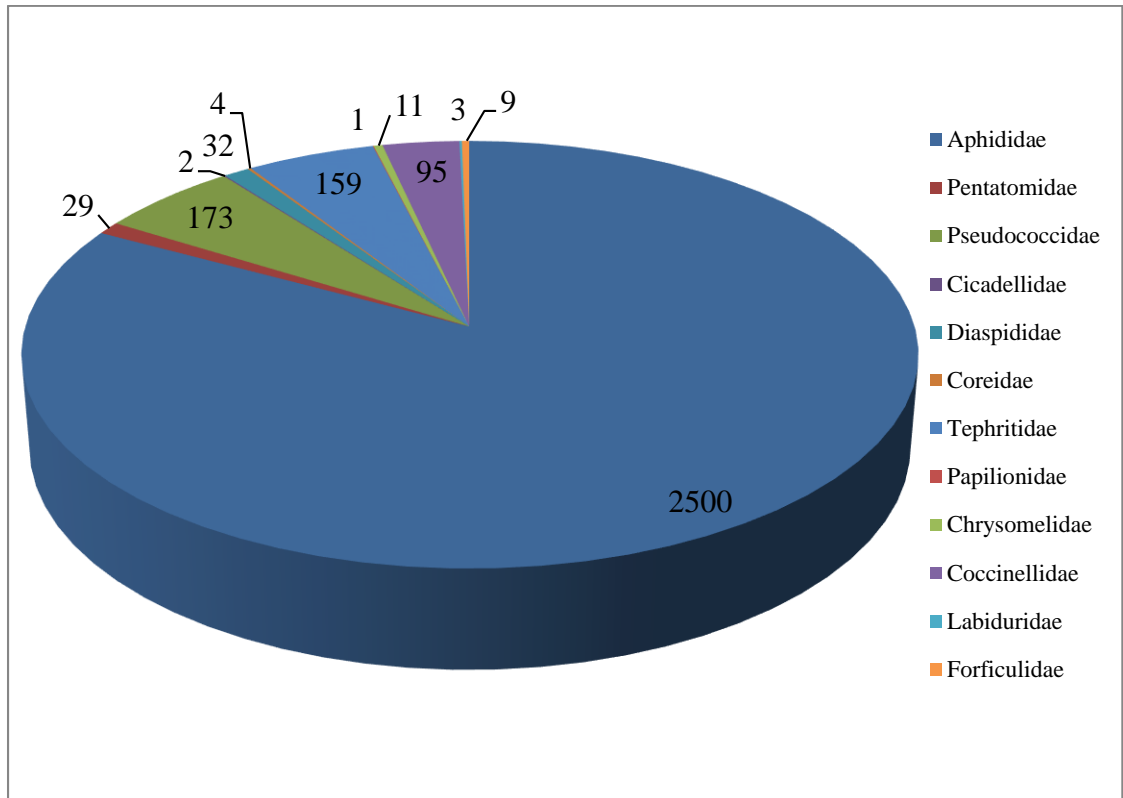


Figure 3: Family wise composition of insect associated with Mandarin in study area

4.1.1 Non-pest insect species

Within the non-pest species order Coleoptera (88.77%) was dominant followed by the order Dermaptera (11.21%). There were 6 species of ladybird beetles *Jauravia quadrinotata*, *Chilocorus melas*, *Oenopia quadripunctata*, *Oenopia kirbyi*, *Megalocaria dilatata* and *Coccinella septempunctata* and 3 species of earwigs, *Labidura nepalensis*, *Elaunon bipartitus* and *Pterygida bosei* were identified (Table 2).

Table 2: Diversity and relative abundance of non-pest insects of Mandarin

Common Name	Scientific Name	Order	Family	Abundance	Relative abundance (%)
	Coleoptera: Coccinellidae				
Ladybird beetle	<i>Jauravia quadrinotata</i>	Coleoptera	Coccinellidae	49	45.78%
Ladybird beetle	<i>Chilocorus melas</i>	Coleoptera	Coccinellidae	27	25.22%
Ladybird beetle	<i>Oenopia quadripunctata</i>	Coleoptera	Coccinellidae	1	0.92%
Ladybird beetle	<i>Oenopia kirbyi</i>	Coleoptera	Coccinellidae	1	0.92%
Ladybird beetle	<i>Megalocaria dilatata</i>	Coleoptera	Coccinellidae	3	2.7%
Ladybird beetle	<i>Coccinella septempunctata</i>	Coleoptera	Coccinellidae	14	13.07%
	Dermaptera: Labiduridae				
Earwig	<i>Labidura nepalensis</i>	Dermaptera	Labiduridae	3	2.7%
	Forficulidae				
Earwig	<i>Elaunon bipartitus</i>	Dermaptera	Forficulidae	2	1.87%
Earwig	<i>Pterygida bosei</i>	Dermaptera	Forficulidae	7	6.53%

4.1.2 Pest identification of Mandarin tree

Insect pests of Mandarin were collected and identified. Among insect species, altogether 2911 pest species were collected comprising 2740 individuals of Hemiptera comprising six families. From high to low abundance of these families were Aphididae (82.84%), Pseudococcidae (5.6%), Diaspididae (1.05), Pentatomidae (0.95%), Coreidae (0.12%), and Cicadellidae (0.07%). Other 159 insect pests of family Tephritidae (5.3%) of Order Diptera, 11 insect pests of family Chrysomelidae

(0.35%) of Coleoptera and single species of family Papilionidae (0.02%) of Lepidoptera (Figure 4).

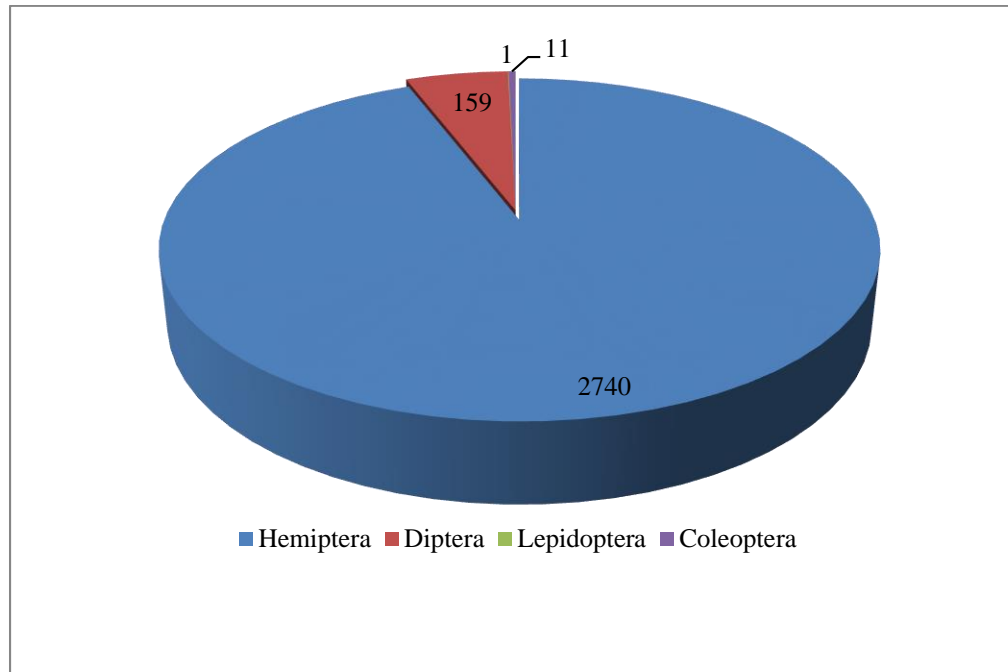


Figure 4: Order wise composition of insect pests of Mandarin in study area

4.1.3 Relative abundance of Mandarin pest species

Toxoptera aurantii, *Toxoptera citricidus*, *Rhynchocoris* sp, *Cappae* cf. *taprobanensis*, *Planococcus citri*, *Atkinsoniella opponens*, *Aonidiella aurantii*, *Cletus rubidiventris* belonging to order Hemiptera; *Bactrocera dorsalis*, *Bactrocera correcta* belonging to Diptera; *Papilio demoleus* belonging to Lepidoptera and *Cassida varians* and *Cassida* sp belonging to Coleoptera (Table 3) (Figure 5).

Table 3: Diversity and relative abundance of Mandarin pest species

Common Name	Scientific Name	Abundance	Relative abundance (%)
Hemiptera: Family Aphididae			
1. Black Citrus Aphid	<i>Toxoptera aurantii</i>	916	31.47%
2. Citrus Aphid	<i>Toxoptera citricidus</i>	1584	54.40%
Family: Pentatomidae			
Citrus Green Stink Bug	<i>Rhynchocoris</i> sp	17	0.57%
Stink bug	<i>Cappae</i> cf. <i>taprobanensis</i>	12	0.40%
Family: Pseudococcidae			
Mealy Bug	<i>Planococcus citri</i>	173	5.93%
Family: Cicadellidae			
Leafhopper	<i>Atkinsoniella opponens</i>	2	0.07%
Family: Diaspididae			
Red Scale	<i>Aonidiella aurantii</i>	32	1.1%
Family: Coreidae			
Red-bellied clerid	<i>Cletus rubidiventris</i>	4	0.14%
Diptera: Family Tephritidae			
Fruit Fly	<i>Bactrocera dorsalis</i>	139	4.77%
Fruit Fly	<i>Bactrocera correcta</i>	20	0.69%
Lepidoptera: Family Papilionidae			
Citrus Lemon Butterfly	<i>Papilio demoleus</i>	1	0.02%
Coleoptera: Family Chrysomelidae			
Tortoise beetle	<i>Cassida varians</i>	10	0.33%
Tortoise beetle	<i>Cassida</i> sp	1	0.02%

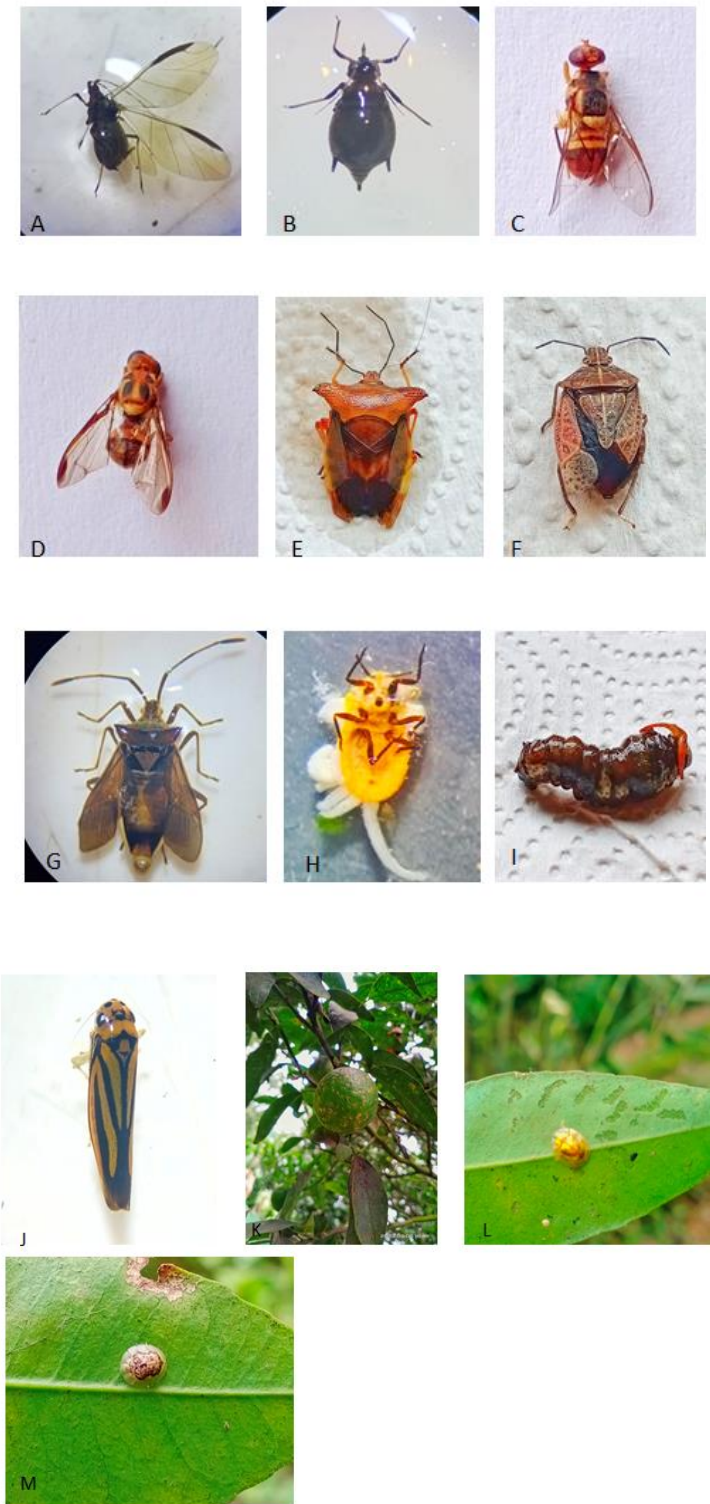


Figure 5: Mandarin pest species. A. *Toxoptera citricidus*, B. *Toxoptera aurantii*, C. *Bactrocera dorsalis*, D. *Bactrocera correcta*, E. *Rhynchocoris* sp, F. *Cappae* cf. *taprobanensis*, G. *Cletus rubidiventris*, H. *Planococcus citri*, I. *Papilio demoleus*, J. *Atkinsoniella opponens*, K. *Aonidiella aurantii*, L. *Cassida varians*, M. *Cassida* sp.

4.2 Insect pests damage pattern observed in Mandarin

Damages done by various insect pests were noted in the field. Various insect pests damaged the mandarin in different parts of the plant such as buds, leaves, fruits, stem and twigs. Insect pests cause various damages to the mandarin trees. Species specific damage patterns of insect pests are listed in the following table (Table 4) (Figure 6).

Table 4: Damage patterns of insect pests on Mandarin

Insect pest species	Damaged part	Symptoms of damage
Hemiptera		
<i>Toxoptera aurantii</i>	Leaves and Buds	Leaf curling, yellowing, stunted growth
<i>Toxoptera citricidus</i>	Flowers and Foliage	Leaf curling, yellowing, stunted growth
<i>Cappae cf. taprobanensis</i>	Leaves, Fruits	Leaves feeding, fruit sucking
<i>Atkinsoniella opponens</i>	Leaves	Leaves feeding
<i>Rhynchoris sp</i>	Twigs and Fruits	Feed on the surface of fruits, puncture the fruit, discoloration
<i>Planococcus citri</i>	Fruits and Foliage	Wilting of leaves, discoloration
<i>Aonidiella aurantii</i>	Stem, Fruits and Leaves	Discoloration, deformation, dropping of premature leaves
<i>Cletus rubidiventris</i>	Twigs, fruits	Feeding on twigs, scarring and deformation of the fruits
Lepidoptera		
<i>Papilio demoleus</i>	Tender leaves	Feed on tender leaves
Diptera		
<i>Bactrocera dorsalis</i>	Fruits	Fruit becomes soft, discolored, rotting
<i>Bactrocera correcta</i>	Fruits	Fruit becomes soft, discolored, rotting
Coleoptera		
<i>Cassida varians</i>	Leaves	Leaves feeding
<i>Cassida sp</i>	Leaves	Leaves feeding



Figure 6: Damage pattern of pest species observed in field. A. Aphid infection on Mandarin buds, B. Nymphal stage of *Cappae* cf. *taprobanensis* aggregating on leaf, C. Mealy bug *Planoccus citri* on leaf, D. Red scale *Aonidiella aurantii* infection on mandarin fruit, E: Tortoise beetle *Cassida varians*, F. Tortoise beetle *Cassida* sp. feeding ventral part of the leaf

4.3 Pest Management Practices

All 20 farmers were interviewed who grow Mandarin commercially. Among them 60% were male and 40% were female respondents. Out of total respondents, 15% were illiterate while 85% were literate respondents. Farmers use various techniques for pest control, such as chemical and biological, cultural, and integrated pest management (IPM). The majority of farmers used the chemical and cultural method for the pest control while some used IPM and chemical and bio-pesticides.

The study revealed that farmers in the research area do not rely solely on cultural methods for pest control but rather employ a range of pest control strategies that integrate cultural and scientific practices. Among the cultural practices, they employed pruning, raking, hoeing and removing or burying weeds. They practiced pruning to control aphids and mealy bugs, burying for fruit flies, destruction of weed hosts for moth, Ploughing for caterpillar and fruit flies while racking and hoeing as a management strategies for fruit flies.

The study showed that 50% of farmers used chemical and cultural methods, 25% use IPM, and 25% use chemical and biological pesticides (Figure 7).

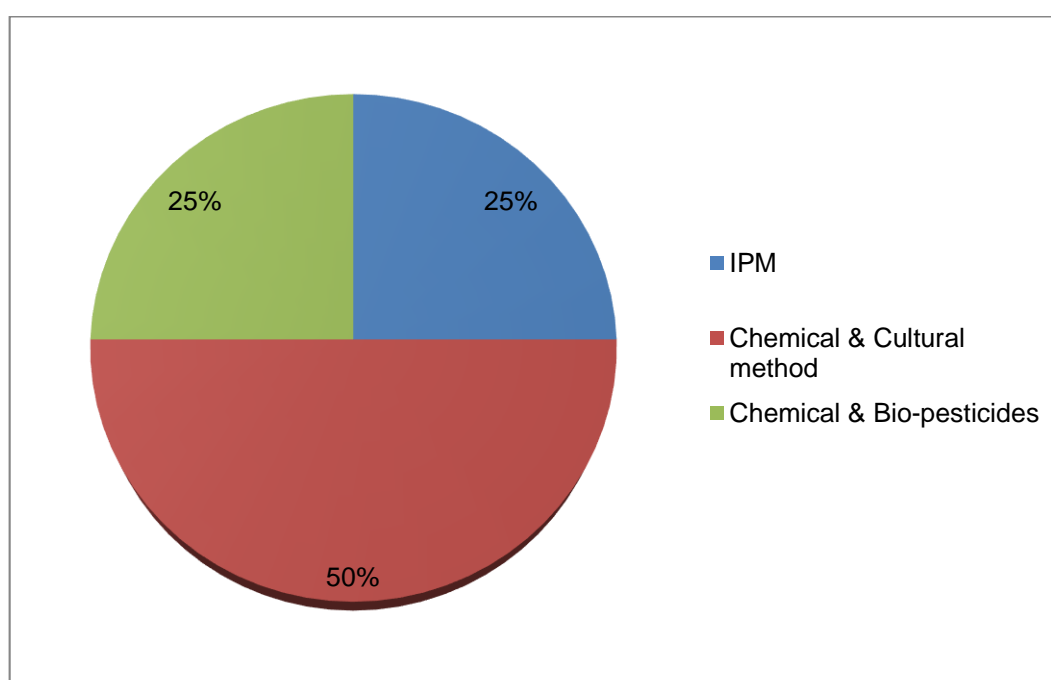


Figure 7: Methods of pest management

4.3.1 Use of Chemical pesticides to control insect pests

The study showed that half of the farmers combine chemical pesticides with cultural practices for pest management. They consider using only cultural methods to be inadequate, hence the use of chemical and cultural methods together. Imidacloprid, Dimethoate, Malathion, Monophin, and Dichlorovous are the top five chemical pesticides used by farmers in the study area for pest control. Bordeaux mixture is the most commonly used pesticide for controlling insect pests (Table 5).

Table 5: Chemical pesticides used to control insect pests in study area

Trade Name	Common Name	Pesticide Group	WHO class	Physical State
Rogerplus	Dimethoate	Organophosphate	IB	Liquid
Malathion 50% EC	Malathion	Organophosphate	IB	Liquid
Monocrotophos 36% SL	Monophin	Organophosphate	V	Liquid
Nuvan	Dichlorovous	Organophosphate	IB	Liquid
Marathon	Imidacloprid	Nicotinoid	II	Solid/Liquid

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

4.3.2 Use of bio-pesticides and traditional ways for the control of pests

Farmers in the study area use both chemical and biological pesticides to control insect pests in their orchards, with a quarter of them opting for the combination of the two. The majority of farmers make their own bio-pesticides, while only a few purchase products like Neem oil from the market. A combination of titepaati leaves (*Artemisia vulgaris*), banmara (*Eupatorium* spp), animal urine and bakaino (*Melia azadarach*) is the most commonly used bio-pesticide mixture. Banmara is the most widely used pesticide for pest management among farmers, followed by ash and animal urine (Table 6).

Table 6: Bio-pesticides used by farmers

Botanical Pesticides	Target Pest
<i>Azadirachta indica</i> (Neem oil)	Aphids, Caterpillar, leaf miner
<i>Melia azadarach</i> (Bakaino)	Scale insects, whiteflies, mealy bugs, aphids
<i>Artemisia vulgaris</i> (Titepaati leaves)	Aphids, fruit sucking pests
<i>Eupatorium</i> spp (Banmara leaves)	Aphids & Mealy bugs
Animal urine	Aphids, bugs
Ash	Aphids, beetles

4.3.3 Farmer's perception on pesticides

According to the study, the largest proportion of farmers (35%) rely on pesticides to manage insect pests, while quarter of them use them to control diseases, and an equal proportion employs them for both pests and diseases. Pesticides are used by only 15% of farmers to boost productivity. Although some respondents believed that chemical pesticides did not contribute to increased productivity in mandarin orchards, most of them agreed that these chemicals helped reduce insect pests (Figure 8).

Table 7: Reason of using pesticide by farmers

Reasons	No. of Respondents
Control Pest	7
Control Disease	5
Control pest & disease	5
Increase Production	3
Total	20

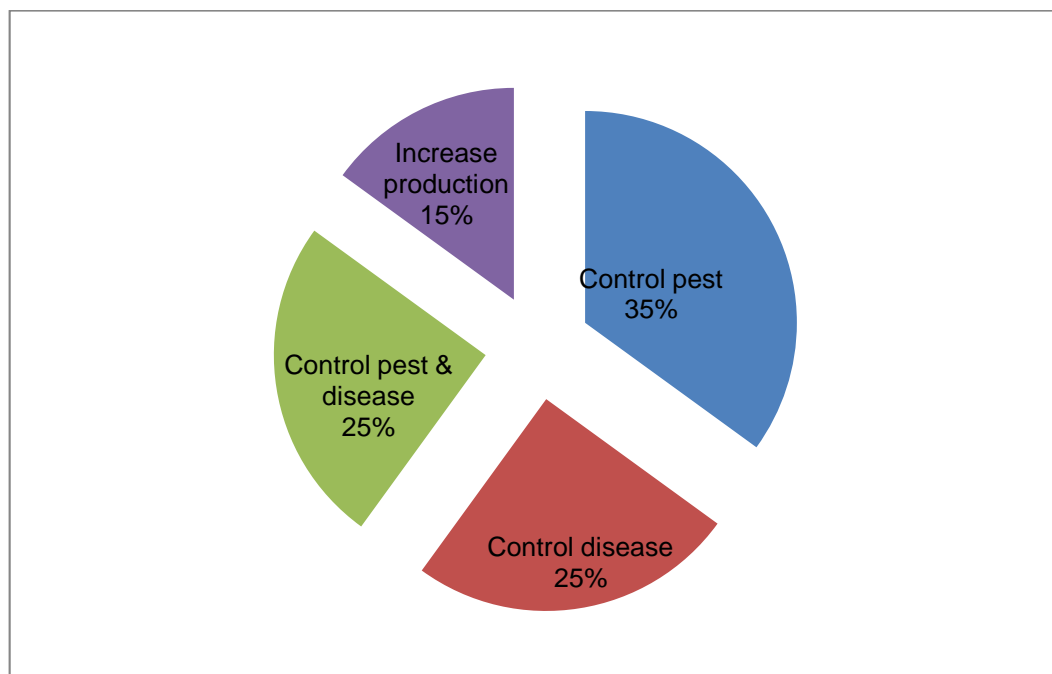


Figure 8: Farmers perception on pesticides

4.3.4 Protective measures adopted during use of pesticides

The study showed that, nearly all farmers took safety precautions while handling insecticides. About half of the respondents used a complete set of protective gear, which included masks, gloves, long-sleeved clothing, and shoes. About 10% of farmers only used gloves, while 40% used both gloves and masks. Even though most farmers were aware of the health risks associated with pesticide exposure, some failed to use the recommended protective gear due to their lack of knowledge and habitual tendencies (Figure 9).

Use of personal protective equipment

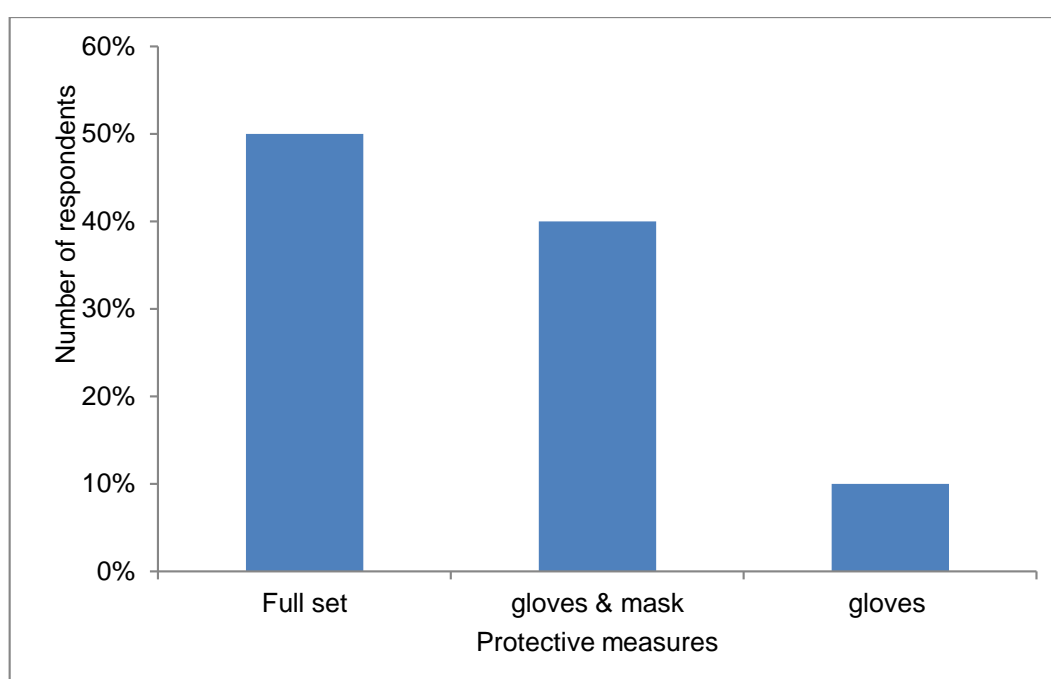


Figure 9: Protective measures adopted by farmers

4.3.5 Disposal techniques

Most of the farmers (45%) dispose pesticides container and 30% of them burned while 25% of them throw the pesticide containers randomly anywhere they like (Figure 10).

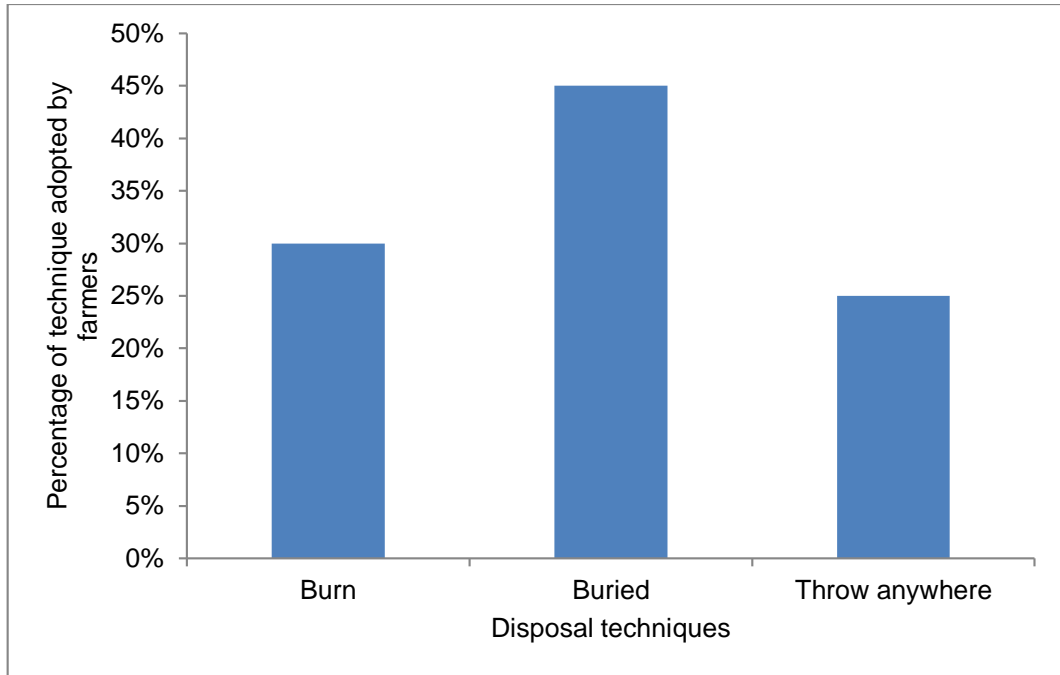


Figure 10: Disposal techniques adopted by farmers

4.3.6 Pesticide Health hazards experienced by the farmers while applying pesticides

The survey showed that 75% of the respondents experienced headache and nausea while 25% replied that they did not experience any health effect (Figure 11).

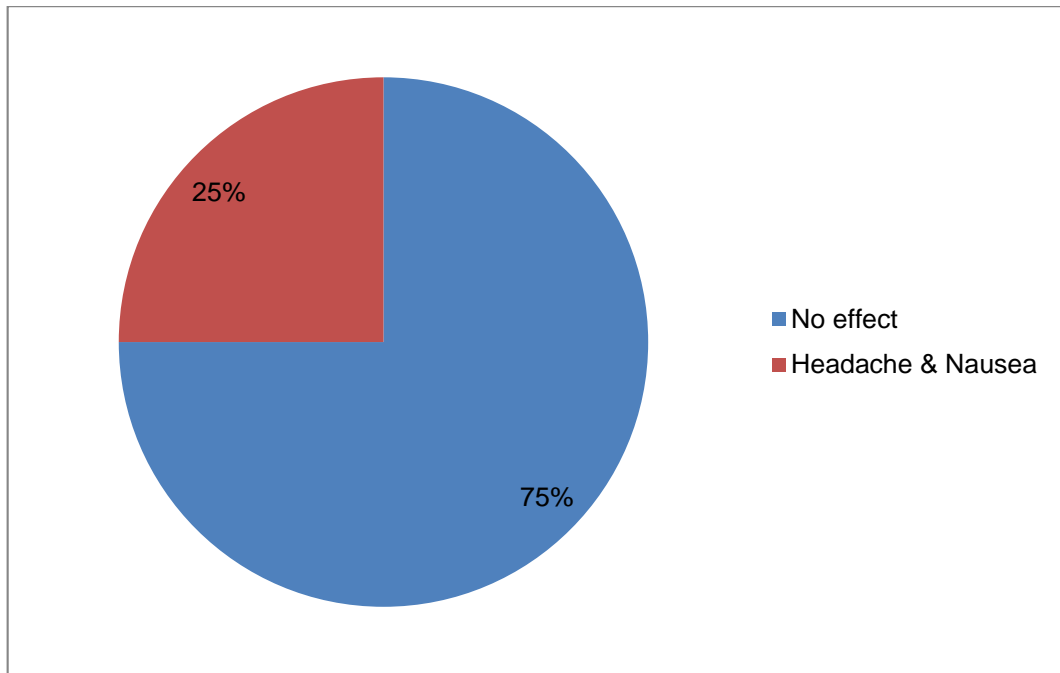


Figure 11: Health hazards experienced by farmers

5. DISCUSSION

5.1 Abundance and diversity of insect pests

The present study found 22 insect species associated with citrus tree belonging to 12 families under 5 orders. Six species were non-pest belonging to order Coleoptera (88.77%) and Dermaptera (11.21%). They were *Jauravia quadrinotata*, *Megalocaria dilatata*, *Coccinella septempunctata*, *Chilocorus melas*, *Oenopia kirby* and *Oenopia quadripunctata* belonging to single family Coccinellidae of Coleoptera while *Labidura nepalensis* of Labiduridae family, *Elaunon bipartitus* and *Pterygida bosei* of Forficulidae family of Dermaptera. Similarly, *Toxoptera citricidus*, *T. aurantii*, *Rhychocoris* sp, *Bactrocera dorsalis*, *Bactrocera correcta*, *Planoccus citri*, *Papilio demoleus*, *Aonidiella aurantii*, *Cappaea* cf. *taprobanensis*, *Atkinsoniella opponens*, *Cletus rubidiventris*, *Cassida varians* and *Cassida* sp of pests were recorded.

Family Aphididae of the order Hemiptera was most abundant. The study result shows resemblance with the study of Bhat and Ahangar (2018) who had reported family Aphididae as the most abundant insect pest family representing 12 species (*Acyrtosiphon pisum*, *Aphis craccivora*, *Aphis fabae*, *Aphis gossypii*, *Dysaphis rumecicola*, *Liphaphis erysimi*, *Liphaphis pseudobrassicae*, *Macrosiphum euphorbiae*, *Myzus persicae*, *Semiaphis heraclei*) in the research conducted on vegetables crops and fruit in Kashmir valley, India. In the study two species of aphids namely *T. aurantii* and *T. citricida* were found from mandarin orchard of Sigana, Baglung. 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 found abundant and considered as a major vector for the transmission of the Citrus Tristeza Virus.

Fruit flies (*B. dorsalis*, *B. correcta*) were collected from the field in which *B. dorsalis* was dominant. Similarly, Adhikari et al. (2018) conducted a fruit fly surveillance in Sindhuli and identified several fruit fly species, including *B. dorsalis*, *B. tau*, *B. scutellaris*, *B. cucurbitae*, *B. zonata* and *Dacus longicornis*. The study reported that *B. dorsalis* was the predominant species in sweet orange orchards in the area. Among the

pests documented in the present study, some have been reported in some literature as a major pests, in terms of causing damage to the citrus plants. These included, *B. dorsalis*, *P. demoleus*, *T. citricida* was reported as the major pests problematic to mandarin in North Eastern Hill regions of Darjeeling and Sikkim (Gurung et al. 2022). Similarly, *P. citri* and *A. aurantii* was reported as the major citrus pests in different countries of Mediterranean basin (Tena & Garcia-Mari 2011). Similarly, *Rhychocoris humeralis* was identified as one of the major causes of premature fruit drop in mandarin and appeared to be responsible for 50% of loss (Pandey & Rana 1993).

Leafhopper (*Atkinsoniella opponens*), bug pests (*Cletus rubidiventris*), tortoise beetles (*Cassida varians* and *Cassida* sp) were also found in the study area. But they weren't reported as citrus insect pests before. *C. rubidiventris* was known pest of Cashew apple and cereals and recorded as a new minor pest in cashew, sucking the sap from immature Cashew apple from Goa in 1984 (Sundararaju 1984). *Cassida* usually feed on both dorsal and ventral side of leaves (Swietojanska & Borowiec 2007). Leafhoppers injure plants either directly through feeding or indirectly through transmission of plant pathogen such as phytoplasmas and viruses, (Rayeni et al. 2016). *Cappae taprobanensis* is well known pest of China, India, Srilanka, Bangladesh, Myanmar and Indonesia and was recorded on Ceylon to attack the young shoots of citrus but not reported in Nepal (Das et al. 2010). This species was reported from Nepal first time however the taxonomic confirmation of the identification of this species is still to be done.

The species diversity index of pest species was 1.186, which indicates relatively high diversity of citrus insect pests and species evenness was calculated to be 0.2517.

Non-pest insects are considered as predator and reported from the different countries in various crops and fruits as a natural enemies of various insect pests. Many coccinellids are predators and major biological control agents of hemipteran pests such as aphids, mealy bugs and scale insects as well as thrips and mites (Majerus 1994). *Megalocaria dilatata*, *Chilocorus melas*, *Coccinella septempunctata* along 13 species belonging to family Coccinellidae were reported as predaceous coccinellids in mango-ecosystem of Jharkhand, (Das & Kumar 2014). Similarly, *Coccinella septempunctata* was reported as the important insect predators of India that feed on

wheat aphids, mustard aphid and cotton aphid as well as on the nymphs of the mango-hoppers. Other ladybird beetles *Jauravia quadrinotata*, *Oenopia kirby* and *Oenopia quadripunctata* were also found in the study area. They were known as predators of tea pests in North Bengal (Das et al. 2010). According to EI-Hussieni (1969), earwigs are considered important predators of various life stages of eggs, larvae and pupae of moths and beetles.

The species diversity index of non-pest species was 1.549, which indicates a moderate level of diversity and species evenness was calculated to be 0.5231.

5.2 Damage patterns of insect pests

Various insect pests damaged the mandarin in different parts of the plant such as buds, leaves, fruits, stem and twigs. Insect pests cause various damages to the mandarin trees. During the field observation, they were collected from different parts of mandarin tree.

Aphids (*T. citricidus* and *T. aurantii*) found to cause leaf curling, yellowing and stunted growth in the field. The presence of high aphid population leads to the reduction in vigor of the host plant and causes great damage both directly and indirectly by leaf deformation, malformation of flowers, underdeveloped shoots, damage on fruits (Labdaoui et al. 2015). Similarly, mealy bug (*P. citri*) was found to cause discoloration and wilting of leaves. Mealy bugs are serious pests of agriculture and ornamental gardens, reducing the vigor of perennial crops by removing plant sap, secreting toxic enzymes (Khoo 1974) and sheltered on their feeding locations i.e under leaves, at plant nodes, or on roots within the soil (Donahue et al. 1998). Similarly, *P. citri* damages plants by feeding on roots, bark, foliage and fruit. During feeding *P. citri* injects toxic saliva into plants and extracts phloem sap and induces symptoms including defoliation, fruit discoloration and fruit drop (Fayyaz-ur-Rehman et al. 2009). Larvae of Lemon butterfly (*Papilio demoleus*) are found on tender leaves and feed on them. Narayanamma et al. (2001) mentioned that *P. demoleus* caused 83% defoliation in sweet oranges grown in the Southern Zone of Andhra Pradesh. *P. demoleus* feeds on the foliage of citrus trees and is regarded as a major citrus pest especially in nurseries the larval forms cause serious damage to citrus family by devouring large quantity of foliage during the later stages of their development, particularly in Southern and Southeast Asia. Severe infestation results in defoliation

of the tree and leads to retarding of plant growth and decreases fruit yield (Jahnavi et al. 2018). Fruit flies (*B. dorsalis* and *B. correcta*) found on fruits causing fruit soft, discoloration and rotting. Similarly, the Chinese fruit fly and the green stink bug were mentioned as the major causes of fruit drop that causes a significant yield loss in 97% of the orchards by (Tshetrim & Chhetri 2014). *Rhynchocoris* sp was encountered in orchard to cause discoloration and feed on the surface of fruits and puncture the fruit. Manandhar et al. (2004) identified *R. humeralis* as one of the major causes of premature fruit drop in mandarin, especially in the lower hills. Both adults and nymphs fed upon developing fruits. Fruit fly infestation causes direct loss on citrus which causes fruit drop and render the fruit inedible because of fungal infection (Ekesi et al. 2006). Red scale (*Aonidiella aurantii*) found on stem. Fruits and leaves causing discoloration, deformation and dropping of premature leaves. Urbaneja et al. (2020) found red *A. aurantii* in California and Texas, causing significant damage to all aerial parts of the tree and causing the fruit to be culled if infested with more than 10 scales.

5.3 Pest management practices

For the pest management practices questionnaire survey included control practices of insect pests, farmer's knowledge on insects and health concern. Farmers use multiple method of pest control including, chemical, cultural, biological, as well as IPM. The study found that 50% farmers used chemical plus cultural method, 25% of farmers adopted chemical plus bio-pesticides and remaining 25% of farmers used IPM for control of insect pests in their field.

Different types of chemical pesticides used in the study area were Dichlorovous, Dimethoate, Malathion, Monophin, Imidacloprid and Bordeaux mixture. 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 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 Gorkha of Nepal.

Among 25% of farmers who used biopesticides to control insect pests. They prepare biopesticides by using locally available Titepati, Bakaino, Banmara, animal urine and ash. It may be due to the easy availability and simple method of use. However,

commercial Neem oil was purchased. Similarly, (Naharki and Jaishi 2020) documented the use of locally available plants (Neem, Bojho, Marigold, Titepati) , dusting of ash and spray of cow urine in western mid-hill of Nepal.

Adoption of safety precaution during and after pesticide application is very important to prevent harmful impact of pesticides. The various safety measures like mask, gloves, use of long sleeved clothes, glass, shoes, hat, etc were found to be used. During this study it was found that half of the respondent used protective equipment. They are almost known about the health hazards caused by pesticides. Thus, half of the respondent applied their knowledge practically in the field and use almost all available protective equipment while half of the respondent don't use full set but 40% of them used gloves and mask and 10% of them used gloves only. The reason for not using full set were not having easy access of safety measures equipments 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). Common health problems experienced by the farmers in the study area were headache and nausea. Despite, being well known about the negative health impacts, 75% of them experienced headache and nausea. It may be due to the improper use of safety measures.

IPM is eco-friendly and long term pest control measures. During this study, 25% of the respondents are familiar with this methods and they are practicing. Also they have received training programs of IPM.

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

A total of 22 insect species associated with citrus plant belonging to 12 families under 5 orders: Hemiptera was the most abundant followed by Diptera, Coleoptera, Dermaptera and Lepidoptera. Among them, 13 insect species were reported as pest species belonging to 9 families under 4 order. Hemiptera comprised the most abundant pests that include *Toxoptera citricidus*, *T. aurantii*, *Planococcus citri*, *Aonidiella aurantii* and *Rhynchoris* sp. Thereafter, Dipteran pests include *Bactrocera dorsalis*, and *B. correcta*. Similarly Coleopteran pests (*Cassida varians* and *Cassida* sp) and Lepidopteron (*Papilio demoleus*) were the important pest species found in the mandarin orchard. While, 9 insects were found as non-pest species but they are known as natural enemies of other insects. They belong to 3 families under two order i.e. Coleoptera including *Jauravia quadrinotata*, *Chilocorus melas*, *Oenopia quadripunctata*, *O. kirbyi*, *Megalocaria dilatata* and *Coccinella septempunctata* and Dermaptera including *Labidura nepalensis*, *Elaunon bipartitus* and *Pterygida bosei*. Majority of the farmers (50%) use chemical plus cultural methods, 25% adopted chemical plus bio-pesticides while remaining 25% used IPM methods for the control of insect pests. Chemical pesticides used in the study area were Dimethoate, Malathion, Monophin, Dichlorovous and Imidacloroprid.

6.2 Recommendation

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

- Pest biology (life cycle) studies to develop control measures strategy.
- Loss assessment by insect pests is highly recommended.
- It is recommended to know the status of natural enemies occurred in Mandarin orchard.

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APPENDICES



APPENDIX I. Shannon- Weiner diversity index (H) and evenness index (J) of insect pests of Mandarin

Scientific Name	Ni	Pi	LnPi	PI*LnPi
<i>Toxoptera aurantii</i>	916	0.315	-1.16	-0.364
<i>Toxoptera citricidus</i>	1584	0.543	-0.60	-0.326
<i>Rhynchoscoris</i> sp	17	0.006	-5.12	-0.031
<i>Cappae cf taprobanensis</i>	12	0.003	-5.81	-0.016
<i>Planococcus citri</i>	173	0.058	-2.85	-0.164
<i>Atkinsoniella opponens</i>	2	0.0007	-7.25	-0.004
<i>Aonidiella aurantii</i>	32	0.0110	-4.61	-0.051
<i>Cletus rubidiventris</i>	4	0.0014	-6.56	-0.008
<i>Bactrocera dorsalis</i>	139	0.048	-3.04	-0.146
<i>Bactrocera correcta</i>	20	0.007	-4.95	-0.035
<i>Papilio demoleus</i>	1	0.0003	-8.10	-0.001
<i>Cassida varians</i>	10	0.002	-6.20	-0.011
<i>Cassida</i> sp	1	0.0003	-8.10	-0.001
Shannon Weiner Diversity Index (H)				1.186
Evenness Index(J)				0.2517

APPENDIX II. Shannon- Weiner diversity index (H) and evenness index (J) of non-pest insect species

Scientific Name	Ni	Pi	LnPi	PI*LnPi
<i>Jauravia quadrinotata</i>	49	0.458	-0.77	-0.353
<i>Chilocorus melas</i>	27	0.251	-1.37	-0.344
<i>Oenopia quadripunctata</i>	1	0.008	-4.81	-0.038
<i>Oenopia kirbyi</i>	1	0.008	-4.81	-0.038
<i>Megalocaria dilatata</i>	3	0.027	-3.60	-0.096
<i>Coccinella septempunctata</i>	14	0.131	-2.02	-0.265
<i>Labidura nepalensis</i>	3	0.027	-3.60	-0.096
<i>Elaunon bipartitus</i>	2	0.019	-3.95	-0.074
<i>Pterygida bosei</i>	7	0.064	-2.75	-0.175
Shannon Weiner Diversity Index (H)				1.549
Evenness Index(J)				0.5231

APPENDIX III. Identified insect pest species associated with Mandarin

<p>1. <i>Toxoptera citricidus</i> (Kirkaldy, 1907)</p> <p>Common name: Brown citrus aphid</p> <p>Order: Hemiptera</p> <p>Family: Aphididae</p> <p>Diagnostic characters: For both alate and apterygote aphids <i>T. citricida</i> approximately 12% larger. On the alate forms only the third antennal segments for <i>T. citricida</i> are distinctly and entirely black. The pterostigma sector of the fore wings of <i>T. citricida</i> is light transparent brown. Median vein is always branched twice.</p>	
<p>2. <i>Toxoptera aurantii</i> (Fonscolombe, 1841)</p> <p>Common name: Black citrus aphid</p> <p>Order: Hemiptera</p> <p>Family: Aphididae</p> <p>Diagnostic characters: On the alate form only the third segments of <i>T. aurantii</i> are transparent or light colored. The pterostigma sector of the fore wings is distinctly dark to black colour in <i>T. aurantii</i>. Median vein is always once branched in <i>T. aurantii</i>.</p>	

3. *Bactrocera dorsalis* (Hendel, 1912)

Common name: Oriental fruit fly

Order: Diptera

Family: Tephritidae

Diagnostic characters: Body length 8mm, the wing is 7.3mm in length and is mostly hyaline. Colour is prominent yellow and dark brown marking on the thorax. The abdomen has two horizontal black stripes. The ovipositor is very slender and sharply pointed.



4. *Bactrocera correcta* (Bezzi, 1916)

Common name: Guava fruit fly

Order: Diptera

Family: Tephritidae

Diagnostic characters: *B. correcta* is distinguished by the colour of the thorax and the facial spots being united and form a black transverse band. The whitish cross band on the second abdominal segment is less developed.



5. *Rhychocoris* sp.

Common name: Citrus stink bug
(Citrus shield bug)

Order: Hemiptera

Family: Pentatomidae

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. Larvae are mainly green with black markings.



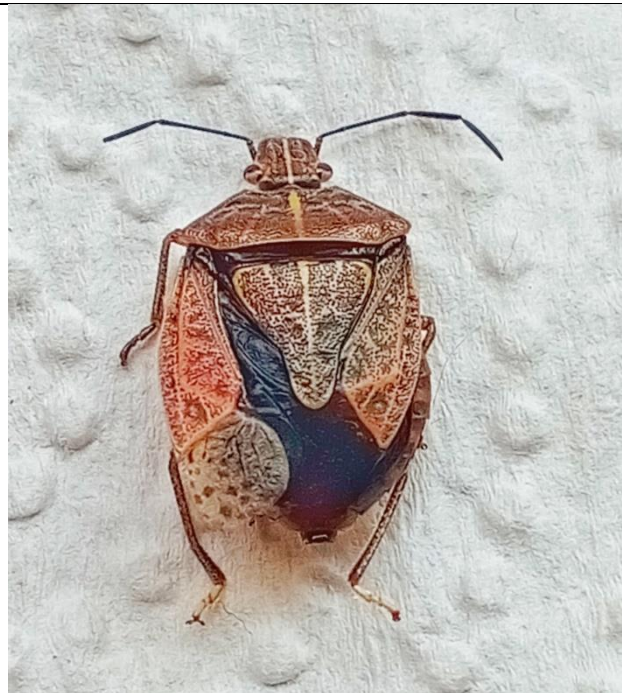
6. *Cappaea* cf. *taprobanensis*
(Dallas, 1851)

Common name: Bug

Order: Hemiptera

Family: Pentatomidae

Diagnostic characters: Body above black except lateral margins and three longitudinal lines to head are brownish-yellow. Margins, a central fascia and lineate reticulations on lateral areas of pronotum; a central fasciate line and two united more or less curved lines on basal area of scutellum; margins, a submarginal line and other irregular markings.



7. *Planococcus citri* Risso, 1813

Common name: Citrus mealy bug

Order: Hemiptera

Family: Pseudococcidae

Diagnostic characters: Adult size 4.5 mm. White to light brown in colour. Brown legs. 8 segmented antennae. Oval body with slightly longer pair of filaments present at the rear end of their body.



8. *Papilio demoleus* Linnaeus, 1758

Common name: Lemon butterfly

Order: Lepidoptera

Family: Papilionidae

Diagnostic characters: 2nd instar larvae, have a dark brown, glossy head with short hairs. The anterior, middle, and posterior parts have broad transverse off-white bands,



9. *Aonidiella aurantii* Maskell

Common name: Citrus red scale

Order: Hemiptera

Family: Diaspididae

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.



10. *Atkinsoniella opponens* (Walker, 1851)

Common name: Leafhopper

Order: Hemiptera

Family: Cicadellidae

Diagnostic characters: This species can be distinguished by the crown with extensive markings and aedeagal shaft narrowed antepically and broader apex laterally.



11. *Cassida varians* Herbst, 1799

Common name: Tortoise beetles

Order: Coleoptera

Family: Chrysomelidae

Diagnostic characters: Exuvia and faeces create thick triangular structure, 6 long, thin setae reaching slightly behind anterior margin of labrum, on each side ventrally 3 setae. 6 dentate, scoli as long as body width or slightly longer.



12. *Cassida* sp.

Common name: Tortoise beetles

Order: Coleoptera

Family: Chrysomelidae

Diagnostic characters: In dorsal view, head not visible, concealed under explanate margin of Pronotum. Tarsal claws lacking a comb-like structure at the base. Second joint of antenna shorter than third, live beetles never covered with a white coating.



13. *Cletus rubidiventris*
(Westwood, 1842)

Common name: Bug

Order: Hemiptera

Family: Coreidae

Diagnostic characters: It is easily recognized by its elongated body. Head subquadrate, declivent, wider than long, clypeus longer than paraclypei, clypeus and paraclypei fused, a longitudinal slit on middle of head, length of anteocular region less than remainder of head; antenniferous tubercle widely separated antennal segment I stout, II and III slender, cylindrical, segment IV clavate; buccula long, extending beyond antenniferous tubercles, Pronotum gradually declivent, length distinctly shorter than width.



APPENDIX IV. Identified non-pest insect species associated with Mandarin

<p>1. <i>Coccinella septempunctata</i> (Linnaeus, 1758)</p> <p>Common name: Seven-spot lady bird</p> <p>Order: Coleoptera</p> <p>Family: Coccinellidae</p> <p>Diagnostic characters: Adult round and red. Pronotum is black with large white spots on each side. There are seven black spots total, three on each wing cover and one central spot at the base of the Pronotum.</p>	
<p>2. <i>Megalocaria dilatata</i> (Fabricius, 1775)</p> <p>Common name: Lady beetle</p> <p>Order: Coleoptera</p> <p>Family: Coccinellidae</p> <p>Diagnostic characters: Body is large sized with circular outline, bright orange to yellowish colored and hemispherical strongly convex dorsum with ten black spots on elytra. The roughly rounded elytral spots are</p>	

arranged in 1-2-2 pattern as-
1 pair of black spots- one on lateral margin, one on basal margin, one on either side of scutellum, two pairs are just before the middle and one near the sutural line and 2 pairs are located just after the middle of elytra, one on lateral side very close to middle and one near the sutural line. Pronotum lateral margin and elytral anterolateral margins black colored..

3. *Oenopia quadripunctata*
Kapur, 1963

Common name: Lady beetle

Order: Coleoptera

Family: Coccinellidae

Diagnostic characters:
Elytral pattern black and yellow, with four yellow spots. Pronotum black except for a pale yellow area on either side extending from anterior margin to almost the base.



4. *Oenopia kirbyi* Mulsant,
1850

Common name: Lady beetle

Order: Coleoptera

Family: Coccinellidae

Diagnostic characters: Elytra lemon yellow and black, with four black spots and borders black. Pronotum with a median, basal hat-shaped black, marking with only anterolateral corners yellow.



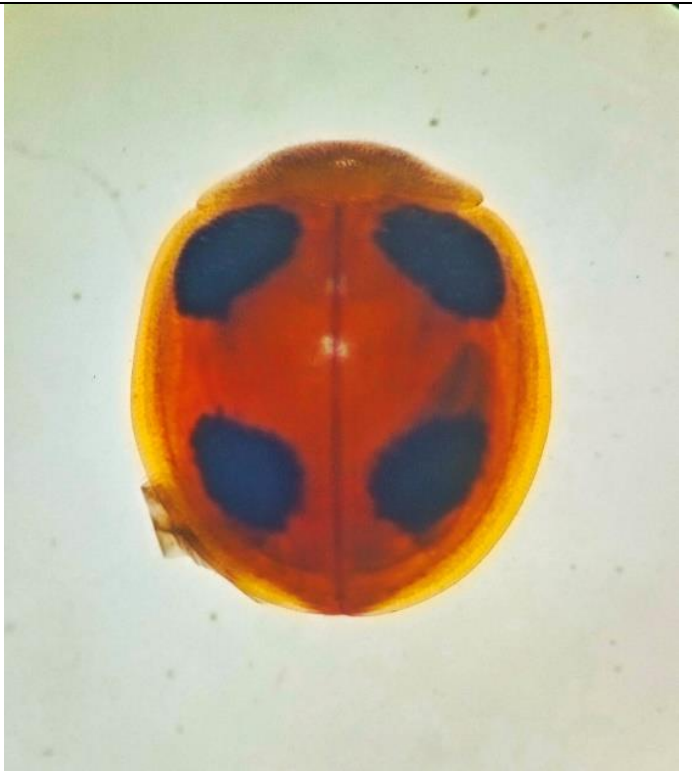
5. *Jauravia quadrinotata*
Kapur, 1946

Common name: Lady beetle

Order: Coleoptera

Family: Coccinellidae

Diagnostic characters: Size about 2.4 mm in length and 1.9mm in breadth. Small circular convex pubescent brownish body. Elytron has 2 large subrounded black spots, 1 on base and 1 on sub apical part. Eyes black. Metasternum and first abdominal sternite rather fuscous.



6. *Chilocorus melas* Weise, 1898

Common name: Ladybird beetle

Order: Coleoptera

Family: Coccinellidae

Diagnostic characters: Elytra without spots. Elytral entirely black. Body round. Dorsum without metallic lustre. Pronotum black except anterior angles yellow.



7. *Elaunon bipartitus* (Kirby, 1891)

Common name: Earwig

Order: Dermaptera

Family: Forficulidae

Diagnostic characters: Male: Abdomen almost parallel sided. Forceps macrolabic not dilated near base. Mesotarsus lobately expanded. Genital lobe single with a basal vesiculum and long virga.



8. *Labidura nepalensis* (Burr, 1907)

Common name: Earwig

Order: Dermaptera

Family: Labiduridae

Diagnostic characters: Head smooth and convex, sutures obsolete. Pronotum somewhat longer than broad. Elytra long, truncate, granulate, carina sharp and well defined and dull black. Abdomen dull chocolate- black, with a pale sparse pubescence.



9. *Pterygida bosei* (Bharadwaj & Kapoor, 1967)

Common name: Earwig

Order: Dermaptera

Family: Forficulidae

Diagnostic characters: Branches of male forceps normally developed, very long. Inner margins ornamented with a smaller but prominent tooth, which is in median position.



APPENDIX: IV Questionnaire

Central Department of Zoology

Kirtipur, Kathmandu

**INSECT SPECIES ASSOCIATED WITH MANDARIN (*CITRUS
RETICULATE*) AND PEST MANAGEMENT PRACTICES IN
SIGANA, BAGLUNG, NEPAL**

Date of interview:

Survey ID number:

Name of the respondent:

Gender:

Age:

Education:

1. How much area of cultivated land you have?
2. Do you adopt any type of land preparation before farming?
 - a. Applying manure
 - b. Chemical fertilizers
3. Do you have pest problems in your field?
4. 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

5. What are the major insects that are harmful to the mandarin plant?
6. Do you use any pesticides on your mandarin orchard?
 - a. Yes
 - b. No

7. If yes, what types of pesticides you use?

- a. Chemical pesticides
- b. Bio-pesticides

8. Why do you use it?

- a. To control the pest
- b. To improve productivity
- c. To control diseases

9. 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

10. What are the different types of pesticides you use in your fields?

S.N.	Name of the pest	Pesticides used

11. From where do you purchase pesticides?

- a. From local shop
- b. From authorized shop/retailers
- c. Other places

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

- a. Information as per on label
- b. According to retailer
- c. According to neighbor

13. Do you wear mask while spraying pesticides?

- a. Yes
- b. No

14. Protective gears used during application.

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

15. Do you change clothes after application of pesticides?

- a. Yes
- b. No

16. If yes, what do you do?

- a. Take a bath
- b. Clean hands and feet

17. How do you dispose pesticides usually?

- a. Burn
- b. Burry in field
- c. Throwing in dumping sites

18. Do you have knowledge about health hazards of pesticides?

- a. Yes
- b. No

19. What kind of negative impacts do you have after handling pesticides?
- a. No effect
 - b. Headache and nausea
 - c. Skin problems
20. Do you have any knowledge about integrated pest management?
- a. Yes
 - b. No
21. If yes, do you currently use any IPM practice method?
- a. Yes
 - b. No
22. Which method do you use?
- a. Smoke
 - b. Rotation of crop
 - c. Light trap
 - d. Pheromone trap
 - e. Biological control
23. If not, why don't you practice IPM?
- a. Pesticides are cheaper
 - b. IPM requires lot of labor
 - c. Lack of knowledge about IPM