INSECT PESTS OF VEGETABLES AND THEIR MANAGEMENT PRACTICES IN CHITWAN ANNAPURNA LANDSCAPE (CHAL), NEPAL

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A thesis submitted in partial fulfillment of the requirements for the award of the degree of Master of Science in Zoology with special paper Entomology

Submitted to:
Central Department of Zoology
Institute of Science and Technology
Tribhuvan University
Kirtipur, Kathmandu
April, 2019

DECLARATION

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

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RECOMMENDATION

This is to recommend that the thesis entitled "**INSECT PESTS OF VEGETABLES AND THEIR MANAGEMENT PRACTICES IN CHITWAN ANNAPURNA LANDSCAPE (CHAL), NEPAL"** has been carried out by Miss. Tara Maya Gurung 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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On the recommendation of supervisor "Associate Prof. Dr. Daya Ram Bhusal" this thesis submitted by Miss. Tara Maya Gurung entitled **"INSECT PESTS OF VEGETABLES AND THEIR MANAGEMENT PRACTICES IN CHITWAN ANNAPURNA LANDSCAPE (CHAL), NEPAL"** is approved for the examination and submitted to the Tribhuvan University in partial fulfillment of the requirements for Master's Degree of Science in Zoology with special paper Entomology.

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ACKNOWLEDGEMENTS

It is great pleasure to acknowledge my deepest gratitude to my supervisor Asso. Prof. Dr. Daya Ram Bhushal for his patient guidance, enthusiastic encouragement and support from initial to final level of dissertation work. It is a great honor to work under his supervision.

I would like to thank Prof. Dr. Tej Bahadur Thapa, Head of Department of Zoology, Tribhuwan University for providing me platform to carry our this research.

I also acknowledge with a deep sense of reverence, my gratitude towards my parents who has always supported me morally as well as economically. I am very thankful to University Grand Commission (UGC) for providing me a grant to assist my thesis work economically. I would like to thank my colleagues especially Ms. Ichha Roka Magar and Ms. Sulesha Shrestha for their help during lab work.

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LIST OF ABBREVATION

Abbreviated form	Details of abbreviation
%	Percentage
Asl	Above Sea Level
ANOVA	Analysis of Variance
CHAL	Chitwan Annapurna Landscape
BLB	Black Bean
BLM	Broad Leaf Mustard
CAB	Cabbage
CAU	Cauliflower
CPB	Cowpea Bean
et al.	and others
Fig	Figure
GLM	Generalized Linear Model
GPS	Global Positioning System
GRB	Green Bean
IPM	Integrated Pest Management
LMB	Lima bean
PCA	Principal Component Analysis
POT	Potato
PUM	Pumpkin
Sp.	Species
SPG	Sponge gourd

ABSTRACT

This study was conducted along Kaligandaki and Marsyangdi river basin of Chitwan Annapurna Landscape (CHAL), Nepal to explore the insect pests of vegetables and their management practices in summer season. Accessible walking trail in different agricultural field was made to collect the insect pests. The sampling points were randomly selected focusing most important agricultural areas. In each sampling points at least 30% area was covered for searching the pests. Insect pests were collected by netting, beating and hand picking methods. The twigs, leaves, flowers and fruits of host plants were assessed to collect the pests, meanwhile the frequency of insect pests were recorded. This study found 23 insect species belonging to four insect orders, 12 insect families and 21 genera. Family Aphididae (61%) was most abundant and family Meloidae (0.35%) was least abundant. Eleven types of vegetable crops Potato, Cauliflower, Cabbage, Lima Bean, Cowpea Bean, Green Bean, Black Bean, Broad leaf mustard, Pumpkin and Sponge gourd were found as vegetables of local people. The highest abundance of insect pest was found on Cowpea Bean and the least abundance of insect pest was found on Lima Bean. The frequency of insect pest showed positive correlation with temperature and altitude and negative relation with humidity. By using questionnaire method and informal discussion with farmers the pest management status was assessed in the study area. Majority of the farmers (52%) use chemical pesticides, 27% bio pesticides and 21% used other methods for the control of insect pests. It was found that majority of farmers did not adopt safety precaution during pesticides application due to the lack of awareness and knowledge of pesticide handling. This may put them in high risk of acute and chronic health hazards. So, there is urgent need of awareness programs and training to the farmers in this area.

1. INTRODUCTION

1.1 Background

Vegetables are herbaceous plants grown for an edible part that is usually eaten as a part of meal. They contain various nutritional content such as vitamins, protein, minerals, fats and carbohydrate. Some of the vegetables such as garlic and onions have been claimed to have high medical values that help to reduce the risk of heart disease, stroke, gastrointestinal issues, high blood pressure and many more (Terry, 2011). Vegetables are also one of the major sources of cash for small to highly commercial farmers. They can be grown quickly, produce good yield and generate higher price at market as compared to cereal crops. Their production is increasing day by day and these can be grown in different seasons in different regions. China ranks first in the world with the production of 537,935,000 metric tons during 2012-13. India ranks second with a record production by 140,554,000 tons (FAO, 2013).

Among various factors insect pests are one of the most important biotic constrictions to the agricultural production. Many of them also act as the vectors for several viral diseases. Pests and disease are the major increasing problem in the agricultural product in the world. They cause reduction in the quality and quantity of yield, reduction in market yield and increase in farm cost (Thapa, 2017). Depending on the frequency of occurrence, the behavior and level of damage caused, insect pests can be classified into five categories: major pests, minor pests, occasional pests, potential pests and migrant pests (Pokhrel, 2002). The insects which cause damage between 5-10% are called minor pests and those that cause damage above 10% are considered as major pests (Paul, 2007). About 35% of crops are damaged only by insect pests in Nepal (Palikhe, 2002). Insects may cause damage to the crops either in larval stage or adult stage but some insects may cause damage in both larval and adult stages. The most common insect pests that cause damage to the foliage of crops are larvae of moths and butterflies (Lepidoptera), larvae and adult of some beetles (Coleoptera) and nymph and adult of some grasshoppers (Orthoptera). Some insects that belongs to the order Hemiptera (bugs and aphids) and Thysanoptera (thrips) cause destruction to the crops by sucking plant sap from the phloem or xylem or from the general tissues of roots or fruits (Sorensen,1995). Larvae of flies (Diptera) cause damage to the root crops by feeding and burrowing into roots, bulbs and stems of plants.

1.2 Agriculture system in Nepal

Nepal is an agricultural country where almost 66% people are involved directly and indirectly in agriculture (MOAC, 2006/7). In Nepal, agriculture is the major source of food, income and employment for the majority of the population. The contribution of agriculture sector to the national GDP is 33.1% (MOAD, 2014). Nepal is rich in agro-biodiversity. Geographically, the country is divided into three regions: mountains in the north, hills in the middle, and the Terai plains in the south with high climatic variation. Terai is the grain belt of Nepal. This region extends from east to west along the southern side of the country and about 40% of its land is under cultivation. Because of the tropical and sub-tropical climate in the region, food crops, vegetables and fruits of tropical and sub-tropical nature are the main agricultural product. The hills, which occupy 42% of the total land area, are intensively terraced for agricultural purposes. This region has the largest land area of the country with about 10% being suitable for cultivation (Rajbhandari, 1999). In hills different climates are available. For e.g. at the foot of the hills the climate is sub-tropical whereas at the top of hills it is temperate. The main crops are rice, maize, and millet. The mountain region covers about 35% of the total area of the country out of which only about two percent of the land is cultivable (Sharma, 1998). Limited area for cultivation, remote and steep land, cold climate, and consequent slow plant growth rate and no easy access to roads and markets are the major constraints faced by the mountain farmers. The land is steep and less fertile than in other zones. Almost all major rivers of the country originate here (Gautam, 2002). Potatoes, buckwheat, maize and barley are grown in this area. The major crops grown in the country are rice (paddy), maize, wheat, pulses, oilseeds, potato, vegetables and fruits. Similarly, oilseeds, potato, tobacco, sugarcane, jute and cotton are the important cash crops whereas lentil, gram, pigeon pea, black-gram, and soya bean are the important pulse crops. Nepal is also famous for tea, large cardamom, turmeric and zinger too (Sharma, 1998).

1.3 Vegetable cultivation and production in Nepal

Vegetable is a very important crop grown from high hill to terai in Nepal. It plays an important role in Nepalese economy. It contributes about 9.71% to national GDP (MOAD, 2014). Nepal has rushed to the commercial production of vegetables. The most common commercial vegetables are cauliflower (339,273 metric tons), tomato (283,999 metric tons) and cabbage (269,294 metric tons). The broad leaf mustard is the most common vegetable crop in Nepal. In terms of area planted, cauliflower is number one vegetable crop. The area is 33,172 hectares and it is 14% of the total area under vegetable crops (CBS, 2010). The demand of vegetables has increased over the years and hence increased in area, production and productivity. Vegetable productions in the terai, mid-hill and high hills were recorded as being 55%, 40% and 5% respectively (MoAC, 2006/7). Production of vegetables was increased with 118043 MT per year while area was increased with 6160.8 ha per year from1991/92 to 2015/16 (Pandey *et al*., 2017). It occupies an area of 280,807 ha with the total production of 3929,034 MT and total yield is 13,992 kg/ha (MOAD, 2015).

1.4 Vegetable pests in Nepal

Some of the insects associated with vegetable crops are gradually attaining the major pest status in different regions of the country, due to the change in ecosystems and habitats. Potato tuber moth, cutworm, Green peach aphid, Epilachna beetle and Semi-looper are the major insect pests of potatoes in Nepal (Giri *et al.*, 2013). *Helicovera armigera* Hubner and whitefly are the important pest of tomato (Joshi, 1994). According to AICC, 2012, Diamondback moth, Aphids, Cabbage butterfly, Tobacco caterpillar are the major insect pests of cole- crops in Nepal. Similarly, Hairy caterpillar, Aphids and Pod borer are the major pests of legume vegetables in the country.

Pieris brassicae nepalensis Doubleday, *Spodoptera litura* (Fabricius), *Spilarctia casigneta* (Kollar), *Plutella xylostella* L., *Lipaphis erysimi* Kaltenbasch and *Brevicoryne brassicae* (L.) are the major insect pests of cruciferous vegetables (Neupane, 1999).

The use of chemical insecticides is commonly used insect pest management practice by the farmers in the country. They are using these pesticides to destroy the pests and increase crop yield. Use of pesticide is higher in commercial farming of vegetables and fruits. About 80% of imported pesticides are applied only in vegetables in Nepal (Sharma *et al*., 2015). According to PPD, 2014 the average use of pesticides in Nepal is 396gm/ha. The proper use of pesticides control pests and results increase in production while misuse of pesticides is harmful to human health and environment.

1.5 Objectives

1.5.1 General objective

To explore the different insect pests of vegetables in Chitwan Annapurna landscape (Kaligandaki and Marsyangdi river basin area).

1.5.2 Specific objectives

- To list out the insect pest species of different vegetables from study area.
- To find out the relation of insect pests with physical parameters (temperature, humidity and elevation)
- To find the abundance of insect pests in different host plant.
- To assess pest management practices from the study area.

1.6 Rationale of the study

Agriculture is the major livelihood means in Kaligandaki and Marsyangdi river basin area of Chitwan Annapurna Landscape (CHAL). This is one of the most important aspects of economic growth from this region but no studies have been done so far on the insect pests in different vegetable crops from this region. Therefore, this study report insect pest of different vegetable crops of this region and their management practices. The result obtained could be useful as a baseline for further research on control of insect pests in the affected areas, which might be of great benefit to both the farmers as well as the entire nation economically.

2. LITERATURE REVIEW

2.1 Diversity and abundance of insect pest in vegetable crops

Globally many researcher have studied the diversity and abundance of insect pests in different vegetables crops in different parts of the world. There is greater variation in insect pests abundance and diversity with local habitat and host plants. In Hindu Kush Himalayan region especially in Kashmir region, India, Bhatt and Ahangar (2018) conducted a survey on systematic checklist and species richness of insect pests associated with vegetable crops in Jammu Kashmir, India. They reported 102 insect pest species belonging to nine insect orders: Lepidoptera, Coleoptera, Hemiptera, Homoptera, Diptera, Thysanoptera, Orthoptera, Dermoptera and Hymenoptera and 35 insect families associated with 39 species of cultivated vegetable crops. The highest number of insect pest species belonged to family Aphididae (Homoptera) representing 12 species.

Similarly, Khajuria *et al*. (2014) revealed that 28 species of insect-pests were found to be associated with the solanaceous vegetable crops in Gujarat, India. Among the insect pests, the maximum number of insect species were from order Hemiptera (13) which is followed by Lepidoptera (7) Coleoptera (4), Acarina (2), Diptera (1) and Thysonoptera (1).

Similarly, Bhatt *et al*. (2011) reported more than 25 insect pest species belonging to six insect orders: Coleoptera, Diptera, Hemiptera, Homoptera, Hymenoptera and Lepidotera and 13 insect families infesting 23 host vegetable crops in Kashmir valley, India. Among the insect pests encountered during the study, four species were reported as new pests of vegetables for Kashmir region.

Paneru and Bhattarai (2011) reported major insect pests of vegetable crops in five development regions of Nepal. Cabbage butterfly, aphids, tomato fruit worm, melon fruit fly, red pumpkin beetle, spotted beetle, thrips, leaf miner, cutworms were major insect pests in Eastern Development Region of Nepal. Likewise, Green peach aphid, cabbage aphid, mustard aphid, cotton aphid, eggplant fruit and shoot borer, whitefly, tomato fruit worm, red pumpkin beetle, spotted beetles, thrips, leaf miner, cutworms, diamondback moth, flea beetle, stink bug, cabbage butterfly, leaf webber were major insect pests in the Central Development Region of Nepal. Cabbage butterfly, diamondback moth, cabbage aphid, fruit fly, red pumpkin beetle, cotton aphid, tomato fruit worm, whitefly, red ant, melon fly, tobacco caterpillar were major insect pests in the Western Development Region of Nepal. Similarly, diamondback moth, cabbage butterfly, cabbage aphid, tomato fruit worm, cutworm, potato aphid, white grub, melon fruit fly, flea beetle, red ants, 28-spotted beetle, mustard sawfly, whitefly were major insect pests in the Mid-Western Development Region of Nepal. Eggplant fruit and shoot borer, aphids, cabbage butterfly, tomato fruit worm, melon fruit fly, pumpkin beetle, spotted beetles, thrips, leaf miner were major insect pests in the Far-Western Development Region of Nepal.

2.2 Insect pests of solanaceous vegetables

The Solanaceae family of vegetables include potatoes, tomatoes, eggplant, capsicum, chillies etc. Solanaceous vegetables are attacked various insect pests.

Giri *et al*. (2013) reported that White grub (*Brahmina coriacea* Hope), Cutworm (*Agrotis* spp.), Wireworm (*Drasterius* spp.), Potato tuber moth (*Phthorimaea operculella* (Zeller) and Green Peach Aphid (*Myzus periscae* (Sulzer)) are the major insect pests of potato in India. Similarly, Giri *et al*. (2013) described Potato tuber moth (*Phthorimae opercullela*), Red ant (*Dorylis orantalis* Westwood), White grubs (*Melolantho* sp., *Anomala* sp.) , Green Peach Aphid (*Myzus periscae*), Leafminer fly (*Liriomyza huidobrensis* Blanchar), Cutworm (*Agrotis ipsilon* (Hufnage), Cotton boll worm (*Helicoverpa armigera*), Semi looper (*Thysanoplusia orichalcea* (Fabricius), Epilachna beetle (*Epilachna vigintioctopunctata*) and Black blister beetle (*Epicauta hirtipes* Waterh) as major insect pest of potato in Nepal which attack on foliage and tubers of potato plants.

Among these several insect pests of solanaceous vegetables, Green peach aphid (*Myzus persicae*) is one of the most important insect pests of solanaceous crops in the world. Heavy infestation of *M. persicae* can cause considerable damage to the potato crop by severely dwarfing and curling the leaflets (Saljoqi *et al.*,2009). It is an important vector of many viruses in potato crop. More than 150 plant viruses have been reported to be transmitted by this aphid species (Hill, 1983).

Epilachana vigintioctopunctata, also known as hadda beetle, is also one of the most destructive pests of solanaceous crops (Richards, 1983; Hashmi, 1994). It has been reported from Australia, Africa, Asia, Afghanistan, America, China, Middle East, Siberia and Sri Lanka (Jamwal *et al.,* 2013). It is highly destructive at both, adult and larval stages which feed on the epidermal tissues of leaves, flowers, and fruits by scrapping the chlorophyll content and causes a heavy yield loss (Srivastava and Butani, 1998). The damage was greater during April-October and 80% of leaves were injured (Rajagopal and Trivedi, 1989) and the high incidence of the pest has been reported during temperature range of 24-31°C and relative humidity 58-75% RH in the field (Ghosh and Senapati, 2001). In Nepal, it is a serious pest of Brinjal, Potato, Bitter gourd (Joshi, 1994). It is reported as major pest of Potato in Kathmandu valley (Joshi, 2002).

Potato tuber moth (*Phthorimaea operculella*) is the major pest of potato growing areas in Kathmandu and Rolpa (Tiwari *et al*., 2006).

2.3 Insect pests of cruciferous vegetables

Cruciferous vegetables are diverse group that includes broccoli, cauliflower, cabbage, kale, bok choy, arugula, Brussels sprouts, collards, watercress and radishes. They are infested by various inscet pests.

Bhat (2018) reported *Thysanoplusia orichalcea*, *Pieris brassicae*, *Pieris rapae*, *Plutella xylostella, Agrotis ipsilon* and *Helicoverpa armigera* were the major lepideptrous insect pests of cole crops from Srinagar, India.

Pieris brassicae is one of the most important pest of cruciferous crops and particularly cabbage and cauliflower (Kumaranag *et al*., 2014; Shahzad *et al*., 2017). It bores holes in the leaves of crops and left just veins which results in decrease rate of photosynthesis (Clementine *et al*., 2009).

The mustard aphid, *Lipaphis erysimi*, the most serious aphid pest of brassica worldwide. The damage by this insect ranges from as low as 10% to as high as 90% depending on the intensity of population development and crop growth stage (Ahuja *et al*., 2009). Sahito *et al*., (2016) reported *Lipaphis erysimi* as a serious pest of Brassica crops in Khairpur Pakistan, in Bangladesh (Rouf and Kabir, 1997) and in India (Patel *et al*., 2004). It causes severe damages to the plant by sucking plant sap from tender shoots of the plants in the beginning and later sucking the sap from tender pods. The infested plants become weak and stunted (Hasan *et al.*, 2018). It has been reported to transmit about 13 different viruses, including important viruses of the Brassicaceae, such as Beet mosaic virus, Cabbage black ring spot virus, Cauliflower mosaic virus, and Radish mosaic virus (Blackman and Eastop, 1984). Likewise, cabbage aphid, *Brevicoryne brassicae* is considered as key pest of cabbage and cauliflower in Himanchal Pradesh India (Bhalla, 1990). It has been reported that *B. brassicae* is a vector of at least 23 viral diseases within the family Brassicaceae (Hill, 1983).

In case of Nepal, *Pieris brassicae nepalensis* Doubleday, *Spodoptera litura* Fabricius, *Spilarctia casigneta* Kollar, *Plutella xylostella*, *Lipaphis erysimi* and *Brevicoryne brassicae* are the major insect pests of cruciferous vegetables (Neupane, 1999).

2.4 Insect pests of leguminous vegetables

Leguminous vegetables belong to the family Fabaceae. The most common leguminous vegetables are beans, cowpeas, green peas, chickpea, Pigeon pea, etc. These vegetable are attacked by several types of insect pests.

Legume pod borer (*Maruca vitrata*), aphids (*Aphis* spp*.),* blister beetle (*Myalbris* spp*.),* leaf hopper (*Empoasca krameri),* pod sucking bug (*Riptortus* spp*.),* green stink bug (*Nezara* spp.) are the important insect pests of leguminous vegetables (Singh, 1979; Singh, 2012; Sharma *et al*., 2012; Srinivasan, 2014). Sharma *et al*., (2012) reported *Alcidodes signatus*, Boheman is the serious pest of bean in Udhampur district India which has caused 75% of damage to the crops in the study area. Adults externally feed on the soft parts of the plant and larvae feed internally and induce gall (Abrol, 2006; Sharma, 2012). It has caused damage of 33-70% in red kidney bean in Jammu, India (Azam *et al*., 2009). Barwal (1990) has studied bean weevil, (*Alcidodes signatus*) as a pest of temperate beans in Shillong and Kullu and revealed that feeding of grub causes formation of galls.

Riptortus pedestris (Fabricius) is regarded as the major pests of soyabean in Korea and Japan when soyabean is bearing mature pods (Kim and Lim, 2010). Similarly, Riptortus *linearis* damage on soyabean in India is reported to be 30-40% (Kashyap and Adlakha, 1971).

Among the sap feeding insects the more common are aphids, especially, cowpea aphid (*Aphis craccivora* Koch) is the main aphid pest of grain legumes. It causes yield loss by directly infesting leaves, stems, fruits, roots and also cause damage indirectly by secreting honey dew which cause development of sooty mold as well as attracting ants as transporting agent of the aphids to the different host plants(Singh *et al*., 2014). It is known to be an important vector of plant viral disease, transmitting over 30 plant viruses (Wightman and Wightman, 1994) . The adults and nymphs suck the cell sap from underside of the tender leaves, growing tips, flower stalks and pods. In heavy infestation, the pods become deformed causing 20-40 % yield loss in Asia (Singh and Allen, 1980). In Nepal, it is a serious pest in Mid-hill and Terai region. The peak populations is during January to February and October to November (Tamrakar, 2000).

The chief pod borers of leguminous vegetables comprise the lepidopteran caterpillars – the spotted pod borer, *Maruca vitrata* and the spiny pod borer (*Etiella zinckenella* Tretsche) however, the blue butterflies (*Lampides boeticus* Linnaeus) and the gram caterpillar, (*Helicoverpa armig*era Hubner) have also been reported among the major pests (Swaminathan *et al.*, 2007) The blister beetles (*Mylabris* spp.) is another serious pests of leguminous vegetables. The adult beetles severely damage buds, flowers and even tender leaves by feeding either solitarily or gregariously. The damage caused to flower is so extensive that there is no pod and seed setting resulting in severe yield loss (Dhingra and Sarup , 1992) .

Cowpea aphid (*Aphis craccivora*), Broad bean aphid (*Aphis fabae*), Pea aphid (*Acyrthosiphon pisum* Harris), Black bug (*Riptortus linearis*), Green stink bug (*Nezara antennata* Scott), Bean stem weevil (*Alcidodes* sp.), Spotted pod borer (*Maruca vitr*ata) are the important insect pest of leguminous vegetables in Nepal (Joshi, 1994; Neupane, 2000).

2.5 Insect pest of cucurbit vegetables

Cucurbits are warm weather crops which are grown during spring, summer and autumn seasons. Among the vegetables, the cucurbitaceous crops form one of the largest groups with their wide adaptation from arid climates to the humid tropics. In Asia, about 23 edible major and minor cucurbits are grown and consumed (Nath and Velu, 2006).

The major insect pest of cucurbit vegetables are Fruit fly, Red pumpkin beetle, Flea beetle, Spotted beetle, Green stinky bug, Aphids, Squash bug and whitefly (Neupane, 2002). Red pumpkin beetle (*Aullcophora foveicollis*) is a very destructive pest of cucurbitaceous vegetable crops. They defoliate the cucurbit leaves and can cause severe damage in the early stage of the crop (Rahman and Prodhan, 2007). In some cases, the losses due to this pest have been reported up to 30%–100% in the field (Rashid and Khan, 2014). Mahmood *et al*., during 2005, reported the trend of red pumpkin beetle towards eight cucurbit crops i.e. cucumber, watermelon, long melon, red gourd Bottle gourd, sponge gourd, muskmelon and tinda gourd. Experiment was performed in Islamabad, Pakistan. Long muskmelon and melon was the most favorable host and no plant reached to 5 true leaves stage after germination when they receive beetle's attack.

Red pumpkin beetle (*Aulacophora foveicollis*) is a very destructive pest of cucurbitaceous vegetable crops especially pumpkin, musk melon and long melon in Nepal (Thapa and Neupane, 1992).

2.6 Pest management practices

IPM comprises combination of cultural, biological and chemical control of insect pests (Gogi *et al*., 2014). Adipala *et al*. (2000) concluded that selected combination of agronomic, chemical and cultural control measures (IPM), particularly when combined with early planting provides better control of cowpea pests like aphids in Uganda. Cultural controls are the oldest methods that have been used to manage pest populations.

Cultural practices such as crop rotation, filed sanitation, early showing, tillage and use of resistant varieties considerably contribute to the reduction of pest infestation in potatoes at Himanchal Pradesh, India (Chandla, 1985). Early sowing in the season reduce *Aphis craccivora* infestation in cowpea (Jackai and Daoust, 1985). Pheromones traps are widely used for monitoring, mass trapping and mating disruption of many insects.

Sticky traps are an alternative tool for the monitoring of the insects which are one of the cheaper and almost equal effective for small insects especially aphids (Sarwar, 2014). Yellow traps have been found very effective for trapping aphids. Saljoqi *et al*., (2009) by using a yellow sticky plastic sheet traps reported a remarkable reduction in aphid (*Myzus periscae*) population in the research conducted in Peshawar, Pakistan.

2.6.1 Application of chemical control

Vegetable producers around the world rely heavily on the use of chemical pesticides for pest control. Although pesticides do not directly contribute to agricultural yields, there is evidence to suggest that intensive use of pesticides has significantly increased agricultural production (Brethour and Weersink, 2007). Halder and Rai (2018) reported that the acetamiprid pesticide was highly effective for the control of *Myzus periscae*, *Aphis craccivora* and *Lipaphis erysimi* in Uttar Pradesh, India.

Bala *et al*. (2016) conducted experiment on the efficacy of some insecticides against Epilachna beetle (*Epilacha vigintioctopunctata*) and jassid *Amarsca biguttulla* on brinjal in West Bengal, India. The most effective treatment was cypermethrin 25 EC @ 0.4 kg a.i/ha followed by cypermethrin 25 EC @ 0.3 kg a.i/ha.

Sen *et al*. (2017) concluded that chemical pesticides imidacloprid, thiamethoxam and diafenthiuron were effective against *Lipaphis erysimi* at Nadia, West Bengal, India.

An experiment conducted by Kafle (2015) for the management of Turnip aphid (*Lipaphis erysimi*) in Lamjung, Nepal reported that Dimethoate (Rogor 30 EC) was highly effective for the control of pest. Khan *et al*. (2011) studied efficacy of imidacloprid and thiamethoxam against *M. persicae*. Both the foliar insecticides significantly reduced *M. persicae* infestation. Haider *et al*. (2007) evaluated the toxicity of various synthetic pyrethroids and organophosphorus insecticides to *M. persicae* by direct spray and leaf-dip method in the laboratory. Among the synthetic pyrethroids, alpha-cypermerthin was the most toxic insecticide and profenofos was the most toxic organophosphorus insecticide.

Chiranjeevi *et al*. (2002) evaluated imidacloprid, lambda-cyhalothrin, monocrotophos and cypermethrin against *M. persicae* and found that imidacloprid was proved to be the most effective insecticide.

2.6.2 Application of botanical control

Botanical insecticides are naturally occurring extracted or derived from plants or minerals. They are also called natural insecticides. Botanical pesticides are considered to be the best alternative to synthetic pesticides that are highly effective, target specific and reduce environmental risks. Botanical pesticide of Neem and tobacco were found effective to control aphids, thrips and whietflies in the research carried by (Kunbhar *et al*., 2018) in Tandojam, Sindh, Pakistan. Ara *et al*. (2015) carried out study to assess the larvicidal efficacies of some indigenous plant seed extracts against Epilachna beetle, *Epilachna* *vigintioctopunctata* in the laboratory of the Department of Entomology, HSTU, Dinajpur, Bangladesh. Petroleum ether and methanol solvent extracts of ata (*Annona squamosa*), neem (*Azadirachta indica*), dhutura (*Datura metel*) and castor (*Ricinus communis*) seeds were evaluated for their larvicidal properties against the larval stage of *E. vigintioctopunctata*. The result indicated that, among the extracts, ata seed extract at maximum dose (4.0 ml/l water) showed the highest efficacy with the inhibition of total eggs (74.1%), viable eggs (80.4%) and number of emergent adult progeny (87.3%). Rajagopal and Trivedi (1989) observed the repellent and anti feedant properties of Neem, mahua and groundnut cakes against *E. vigintioctopunctata* attacking potato. Garlic as intercrop with potato was found to be effective in minimizing Cutworm damage in potato crop at Shimla, India (Chandla ,1985). Neupane (1999) reported that the water extracts of green leaves of Neem, chinaberry, malabar nut and Indian privet were found effective in controlling insect pest of cruciferous vegetables in Nepal. Among botanicals, several plant products have shown promising results for their efficacy against *Myzus. persicae*.

2.6.3 Biological control:

Biological control is the use of natural enemies of insect pests to suppress target pest populations. It is an important component of integrated pest management. Natural enemies of insect pests include predators, parasitoids and pathogens. Pathogenic micro-organisms include bacteria, fungi and virus. Common predatory insects are ladybug, lacewings and praying mantids. Deka *et al.* (2017) reported that four types of entomopathogenic fungi *Metarhizium anisopliae, Nomuraea releyi, Verticillium lecanii* and *Beauveria bassiana* were effective against *Lipaphis erysimi* in Guwahati, India.

Coccinella septempunctata was effective in reducing mustard aphid *Lipaphis erysimi* population in Punjab, India (Shenmar and Brar, 1995).

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

Family Anthocoridae, an extremely important group of small predators, which are excellent natural enemies of aphids, whiteflies, young caterpillars, insect eggs and, especially, thrips. The genera *Anthocoris* and *Orius* are fundamental for the bio control of thrips species around the world. Several *Orius* species are multiplied in the laboratory and applied under diverse climate conditions, from temperate to tropical, only to regulate thrips populations, especially in protected cultivation. Braconidade and Ichneumonidae both oth are widely distributed in the tropical regions and the braconids are often used in pest biological control programs. The braconids are parasitoids of aphids, caterpillars and fly larvae. This family has been successfully used in the biological control of aphids, fruit flies and stem borers (Sampaio *et al*., 2010).

3. MATERIAL AND METHODS

3.1. Study Area

The Chitwan-Annapurna Landscape (CHAL) is located in central Nepal between 270’35” and 29.0’33” N and 820’88” and 850’80” E, covering an area of 32,057 square kilometers. Elevation ranges from approximately 200 m to 8,091 m (Mount Annapurna) above sea level. The landscape is drained by six major perennial rivers, namely, Kali Gandaki, Seti, Marsyangdi, Budhi Gandaki, Trishuli and Rapti and the tributaries of the broader Gandaki River system. This study was focused on Kaligandaki and Marsyangdi river basin of three districts Manang, Mustang and Myagdi. Kaligandaki river basin covers nearly 11,770 sq km and ranges from 188 to 8,143m above mean sea level. The basin includes 11 districts of western Nepal. It consists of 1.7 million population and most of them are dependent on agricultural based livelihood (Manandhar *et al*., 2011). Marsyangdi river basin system has a total area of 4,787 sq km. The elevation of the basin varies between 200 masl to 7800 masl. Physiographically, the basin extends from high Himalaya in the north to lesser Himalayan region in the south.

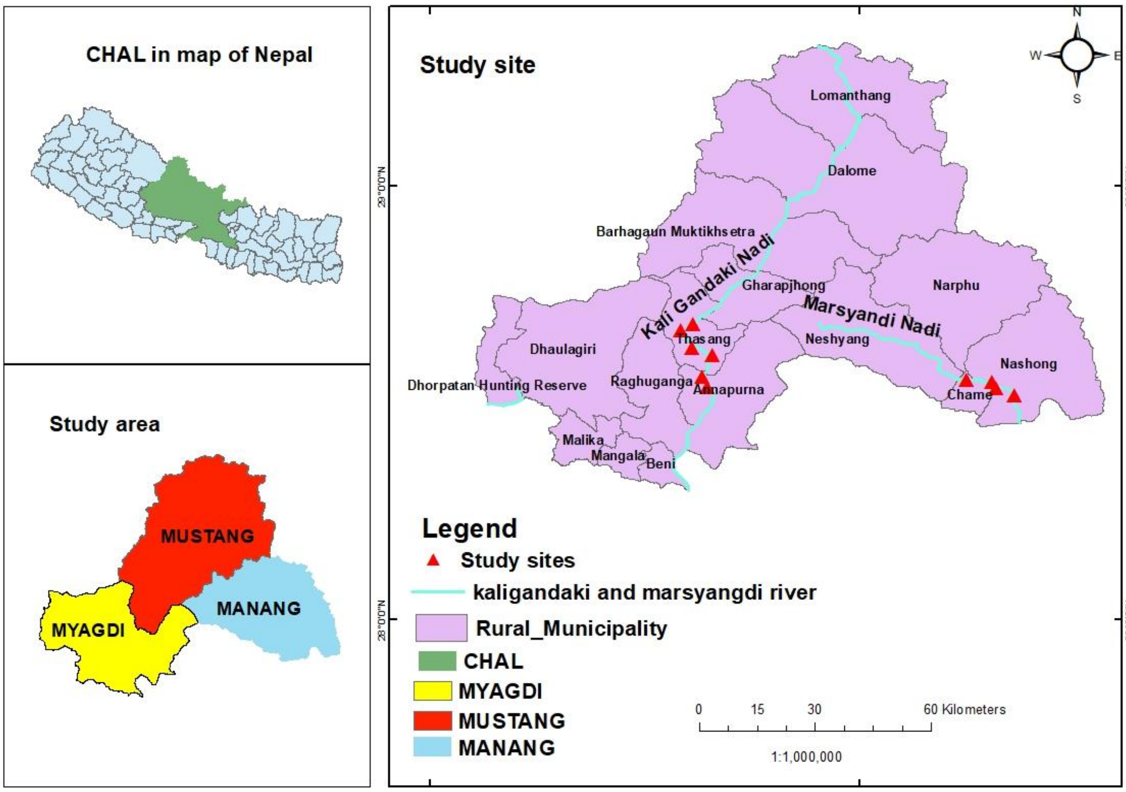

Fig 1: Map of study area

3.2. Materials

Following material were used during field work:

a. Sweeping net
b. Collecting vials
c. Transparent envelop
d. Field guide book
e. Camera
f. Forceps
g. GPS
h. Hygrometer
i. 70% alcohol

3.3 Sampling method

Kaligandaki and Marsyangdi river basin area of three districts Myagdi, Mustang and Manang were followed extensively in summer season. Accessible walking trail in different agricultural field was made to collect the insect pests. The sampling points were randomly selected focusing most important agricultural areas. In each sampling points at least 30% area was covered for searching the pests.

3.4 Insect collection

Extensive survey was done following accessible walking trials to collect the pests. Pests were collected by netting, beating and hand picking method. The twigs, leaves, flowers and fruits of host plants were assessed to collect the pest meanwhile the frequency of insect pests were recorded. Aphids were removed from the affected parts of plants with the help of soft brush and placed on a piece of white paper. The number were counted by using magnifying hand lens. Plants were randomly selected for counting and its average was calculated. Hard bodied insect pests were collected in plastic vials and soft bodied pests such as caterpillars were collected in 70% alcohol. During the pest collection the altitudes and local habitat characteristics were also collected. The collected species were brought to the laboratory for further identification.

3.5 Collection of bioclimatic parameters

For the collection of bioclimatic parameters (temperature and relative humidity) hygrometer was used and GPS was used to collect altitude and GPS coordination.

3.6 Assessment of pest management

By using questionnaire method and informal discussion with farmers and agro-vet dealers the pest management status was assessed in the study area**.** The people perception about the pest management practices and other ways of pest management were documented.

3.7 Species identification

Collected specimen were identified by using identification keys (Borrer and De Long, 1964; Richards and Davies, 1977; Hill, 1983; Blackman and Eastop, 1984; Joshi, 1994; Mohamedsaid, 1994; Neupane, 2000) and through literatures. Later the specimen were reconfirmed by comparing with voucher specimen in Nepal Agricultural Research Council (NARC).

3.8 Data processing and statistical analysis

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

A. Relative abundance (%)

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

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

Where,

n= Number of each individual

N= Total number of individual

B. Shannon-Wiener diversity index (H):

Shannon-Wiener diversity index was used to calculate the species diversity in Kaligandaki and Marsyangdi river basin area

H= Σ (pi)* (lnpi)……………….(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.

Pi= n/N= Relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individual in the community

C. ANOVA

ANOVA was used to obtain the relationship of insect pest abundance with family of pests.

D. Principal Component Analysis (PCA)

PCA was done to find out the relation of physical parameters temperature, humidity and altitude with frequency of insect pests.

E. Generalized linear model (GLM)

Generalized linear model was used to find the variation (diversity and abundance) insect pests in different host plants.

4. RESULTS

The present study found 23 insect pest species belonging to four insect orders , 12 families and 21 genera infesting 11 types of vegetable crops (Appendix i). The description of identified insect pest species are as below:

4.1 Identified insect pests

Order: Lepidoptera

1. *Maruca* sp.

Common name: Legume pod borer

Family: Crambidae

Collected host plant: Lima Bean

Diagnostic characters: Adult has forewings brown with a white oblong translucent spot. Larvae are greenish white. The head capsule is light to dark brown. It has two pairs of dark spots on the back of each segment. Mandible with two inner teeth and an outer tooth (Photo 1).

Damage pattern: Pods of bean

Locality: Tatopani (Myagdi)

Altitude: 1320 m

2. *Pieris brassicae* (L., 1758)

Common name: Cabbage white butterfly

Family: Pieridae

Collected host plant: Cabbage, cauliflower

Diagnostic characters: The wings of adult are pale white, with a black patch on the apical angle of each fore wing and a black spot on the costal margin of each hind wing. Larval body covered with short hairs, yellow in color with black spots. Head is black and shiny, five pairs of prolegs (Photo 2).

Damage part: Leaves and buds.

Locality: Dana, Kavre (Myagdi), Lete, Ghasa, Larjung (Mustang), Nesyang, Thanchok, Danadque, Dharapani (Manang)

Altitude: 1472 m - 2774 m

3. *Agrotis* sp.

Common name: Cutworm

Order: Lepidoptera

Family: Noctuidae

Collected host plant: Potato

Diagnostic characters: Larva: gray-brown to black in color. Body is covered with granules and the head possesses many dark spot. The abdominal segments are nearly equal in width, and there is an indistinct, narrow, pale, mid-dorsal stripe (Photo 3).

Damage part: Root

Locality: Ghasa (Mustang), Chame (Manang)

Altitude: 1948 m, 2724 m

4. *Thysanopulsia* sp.
Common name: Cabbage looper
Order: Lepidoptera
Family: Noctuidae
Collected host plant: Cauliflower
Diagnostic characters: Larvae are green with a thin white line on each side just above the spiracles and two other white lines on the dorsum. Setae are white, long and thick. The thoracic legs and head capsule are usually pale green (Photo 4).
Damage part: Leaves
Locality: Lete (Mustang), Timang(Manang)
Altitude: 2536 m, 2633 m

5. *Alcidodes* sp.
Bean stem weevil
Order: Coeloptera
Family: Curculionidae
Collected host plant: Green Bean
Diagnostic characters: Adult body stout, convex dorsally with longitudinal grey and black strips alternating with each other and running longitudinally throughout the length of elytra. Head small, rounded. Presence long snout bearing mouth parts. Snout bears mandibles and a pair of eyes. It has spines on the inner edge of all tibiae and on the fore-femora (Photo 5)
Damage part: Stem
Locality: Dana (Myagdi)
Altitude: 1472 m

6. *Lagria* sp.
Common name: Darkling beetle
Order: Coleoptera
Family: Tenebrionidae
Collected host plant: Green Bean
Diagnostic characters: Body elongated, tanned metallic color, elytra covered with dense light yellowish-brown hairs. Body length 15 mm. Antenna 11 segmented and moniliform (Photo 6)
Damage part: Flowers and leaves
Locality: Dana (Myagdi)
Altitude: 1472 m

7. *Aulacophora* sp.
Common name: Pumking beetle
Order: Coleoptera
Family: Chrysomelidae
Collected host plant: Pumpkin

Diagnostic characters: Body oval in shape. The head, antennae and legs yellow, thorax brownish yellow, elytra reddish orange, ventral side of the abdomen black with shining small hairs. Tarsi four segmented (Photo 23)
Damage part: Leaves
Locality: Dana (Myagdi)
Altitude: 1472 m

8. *Aplosonyx chalybaeus* (Hope, 1831)
Common name: Taro corm-borer
Order: Coeloptera
Family: Chrysomelidae
Collected host plant: Taro
Diagnostic characters: Elytra bright metallic blue, head and thorax orange in color. The ventral side is yellowish to orange in color. Fifth to eighth segment of antenna and apices of tibia and tarsi are black with a metallic sheen (Photo 8)
Damage part: Leaves
Locality: Dana (Myagdi)
Altitude: 1506 m

9. *Phylloterta* sp.
Common name: Flea beetle
Order: Coeloptera
Family: Chrysomelidae
Collected host plant: Cabbage
Diagnostic characters: Metallic blue black and oval body, two irregular yellow stripes running down the length of the elytra, enlarged hind femur, tarsi four segmented and last tarsal segment is notched (Photo 9)
Damage part: Leaves
Locality: Dharapani (Manang)
Altitude: 1904 m

10. *Mylabris* sp.
Common name: Banded blister beetle
Order: Coleoptera
Family: Meloidae
Collected host plant: Sponge-gourd
Diagnostic characters: Four orange red and black alternating bands on the elytra, Antennae moniliform and composed of 11antennomere, prothorax as wide as head (Photo 10)
Damage part: Flower
Locality: Kabre (Myagdi)
Altitude: 1690 m

11. *Epilachna vigintioctopunctata* (Fabricius, 1775)
Common name: Hadda beetle
Order: Coleoptera
Family 5: Coccinellidae
Collected host plant: Potato
Diagnostic characters: The orange and black spotted adults are 10 millimeters long. The head, prothorax and elytra covered with short fine hairs. The head is rectangular in shape, freely articulated in a deep groove on the anterior margin of the pronotum. Antennae are short, clavate and composed of 11 segments. Elytra are covered with 28 black spots. Pairs of spots by the mid line of the second and fourth transverse rows join each other (Photo 11)
Damage part: Leaves
Locality: Ghasa, Larjung (Mustang), Chame, Syarkhu, Timang, Danaque (Manang)
Altitude: 1948- 2724 m

12. *Aphis* sp.
Common name: Aphid
Order: Hemiptera
Family: Aphididae
Collected host plant: Cowpea Bean, Green Bean
Diagnostic characters: Wingless adult are dark brown with solid black shiny carapace from the metanotum to abdominal tergite 6, antenna six segmented, all stages have white and black legs, nymphs are lightly dusted with wax. Cornicles cylindrical and longer than cauda, cauda elongate (Photo 12)
Damage part: Flower stalks and pods
Locality: Dana, Kabre (Myagdi)
Altitude: 1472 m, 1690 m

13. *Lipaphis erysimi* (Kaltenbach, 1843)
Common name: Mustard aphid
Order: Hemiptera
Family: Aphiididae
Collected host plant: Broad leaf mustard
Damage pattern: Leaves, stem
Diagnostic characters: Wingless adult is pale olive green with a white waxy bloom covering the body with two rows of dark bands on the thorax and abdomen, antennae with six segments, cornicles are paler than the cauda and have dark tips. Cauda elongate and triangular with hairs (Photo 13)
Locality: Ghasa, Larjung (Mustang), Timang, Danaque (Manang)
Altitude: 1948-2774 m

14. *Brevicoryne brassicae* (L., 1758)
Common name: Cabbage aphid

Order: Hemiptera
Family: Aphididae
Collected host plant: Cabbage
Diagnostic characters: Body covered with a greyish white mealy wax. The head, tips of the antennae and the legs are dark. Cornicles are thick and very short. The cauda is triangular and broad (Photo 14)
Damage part: Leaves
Locality: Dana, Ghasa
Altitude: 1472 m, 1948 m

15. *Myzus persicae* (Sulzer, 1776)
Common name: Green peach aphid
Order: Hemiptera
Family: Aphididae
Collected host plant: Potato
Diagnostic characters: Wingless adult oval-bodied, mainly yellowish green but may vary from whitish to rose-pink or red. Antennal tubercles converging. Cornicles slightly curved and longer than cauda (Photo 15)
Damage part: Leaves and flowers
Locality: Larjung (Mustang), Chame, Syarkhu (Manang)
Altitude: 2559 m, 2724 m, 2691 m

16. *Riptortus* sp.
Common name: Pod sucking bug
Order: Hemiptera
Family: Alydidae
Collected host plant: Green Bean
Diagnostic characters: Adults dark brown. Head is broad. Antennae filiform and four segmented. The femora of the hind legs with several strong spines; the tarsus has three segments (Photo 16)
Damage part: Pods of Bean
Locality: Dana (Mustang), Dharapani (Manang)
Altitude: 1472 m, 1904 m

17. *Eurydema* sp.
Common name: Shield bug
Order: Hemiptera
Family: Pentatomidae
Collected host plant: Cauliflower and Cabbage
Diagnostic characters: Body length 8mm. Bright red colored with black markings. Head is rounded and body is flattened. Antenna black and five segmented, legs black. Tarsi 3 segmented (Photo 20)
Damage part: Fruits and leaves
Locality: Dana, Ghasa, Lete (Mustang)

Altitude: 1506 m, 1948 m, 2536 m

18. *Nezara* sp.
Common name: Green stink bug
Order: Hemiptera
Family: Pentatomidae
Collected host plant: Green Bean
Diagnostic characters: Body length 12mm. Body brightly green and shield shape. Scutellum triangular. Three parallel white spots on the scutellum (Photo 22)
Damage part: Leaves
Locality: Chame, Thanchok (Manang)
Altitude: 2724 m, 2691 m

19. *Melanoplus* sp.
Common name: Spur – throated grasshopper
Order: Orhtoptera
Family: Acrididae
Collected host plant: Green Bean
Diagnostic characters: Body color pale gray and light brown, bottom of thorax and abdomen usually bright yellow. Antenna short and stout. The hind tibiae are red, tarsi three segmented (Photo 7)
Damage part: Leaves
Locality: Kabre (Myagdi)
Altitude: 1690 m

20. *Monolepta signata* (Olivier, 1808)
Common name: Flea beetle
Order: Coleoptera
Family: Chrysomelidae
Collected host plant: Green Bean
Diagnostic characters: General appearance oblong-ovate, moderately convex and dorsa, surface shiny with fine punctures. Head, pronotum and abdominal sternites reddish brown, antennae long and blackish with three basal segments brown, elytron brown to black, with two spots on each elytra (Photo 18)
Locality: Chame (Manang)
Altitude: 2724 m

21. *Epilachna* sp.
Common name: Lady Bird beetle
Order: Coleoptera
Family: Coccinelidae
Collected host plant: Green Bean

Diagnostic character: Body widely ovate, mainly red-brownish; metathorax black; dorsum covered with short hairs. Pronotum without spots; each elytra with 8 black points (Photo 21)
Locality: Dharapani (Manang)
22. *Bagrada* sp.
Common name: Painted bug
Order: Hemiptera
Family: Pentatomidae
Collected host plant: Cauliflower
Diagnostic characters: Adult black in color with red and yellow markings. Body shield shape, pronotum and the scutellum have an obvious longitudinal marking down the center. Antenna five segmented (Photo 17)
Locality: Danaque (Manang)
Altitude: 2270 m

23. *Aulacophora lewisii* Baly, 1886
Common name: Pumpkin beetle
Order: Coleoptera
Family: Chrysomelidae
Collected host plant: Sponge gourd
Diagnostic characters: Body length 6 mm. Elytron shiny, generally blue black, covered with very small punctures; ventral surfaces brownish. In male, fifth abdominal sternite with median lobe oblong, longitudinally elevated and with a long deep sulcus in middle (Photo 19)
Locality: Kabre (Myagdi)
Altitude: 1690 m

4.2 Relative abundance of reported insect pest

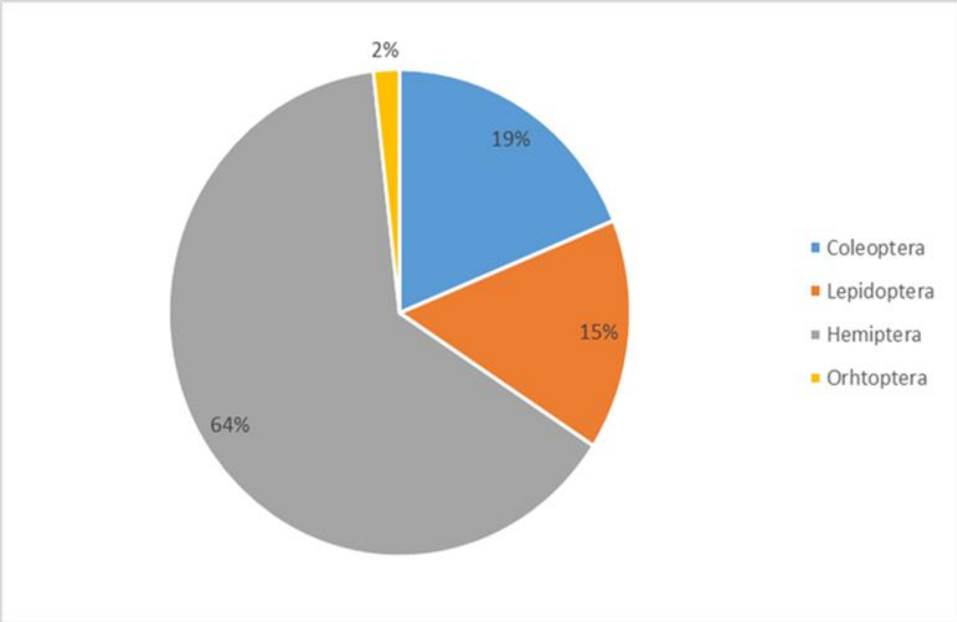

Figure 2: Order wise composition of insect pests in study area

Four insect orders: Hemiptera, Lepidotpera, Orthoptera and Coleoptera are reported in the study area. Among four insect orders, Hemiptera order was must abundant (64%) and the order Orthoptera (2%) was least abundant.

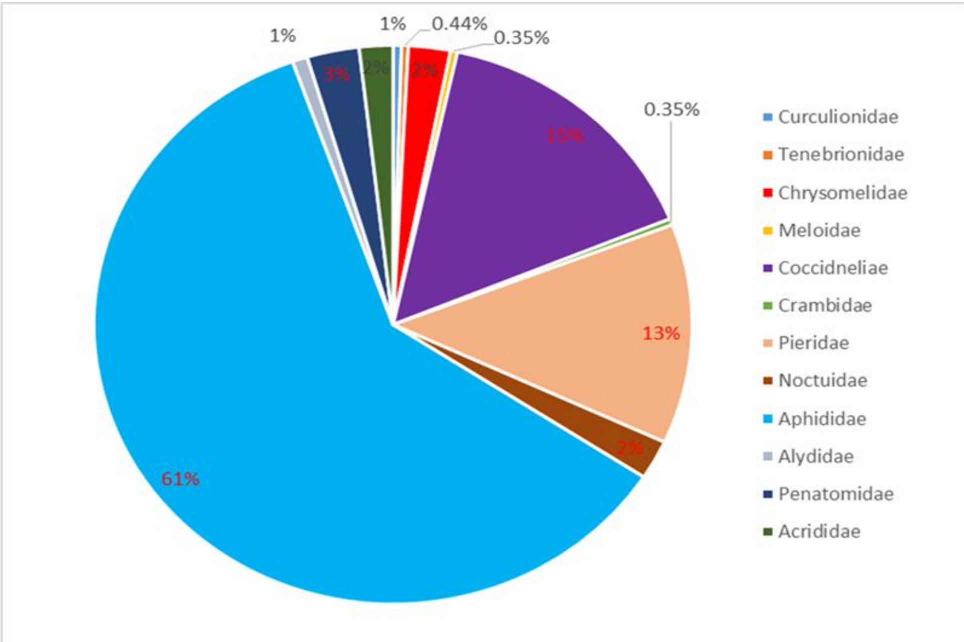

Fig 3: Family wise composition of insect pest in study area

12 families of insects were found in the study area. Among them, family Aphididae was most abundant (61%) and the family Meloidae (0.35%) and Tenebrionidae (0.35%) were least abundant.

4.3 Diversity of insect pest species

Table 3: Diversity of insect pest species in Kaligandaki and Marsyangdi river basin area

	Total number of species (S)	Shannon Wiener diversity index (H)
Kaligandaki	19	2.07
Marsyangdi	13	1.88

Shannon diversity index (H) is higher (2.07) in Kaligandaki river basin system than in Marsyangdi river basin system (1.88). It means the diversity of insect pest species is high and equally distributed in Kaligandaki river basin as compared to Marsyangdi river basin area.

4.4 Relation of insect pest abundance with family of insect pests

In order to find the relation of frequency of pest with family of insect pest one way ANOVA was used.

Table 4: Relation of insect pest abundance with family of pests

Variables	Df	Mean sq	F	Pr(>F)
Family	11	1342	4.82	**0.0001**

Significant codes: 0.000= highly significant 0.001= moderately significant 0.01= significant 0.05= marginal significant

The abundance of insect pests showed significant relation (P<0.0001) with the family of pest. It means family wise, the abundance of insect pest was different.

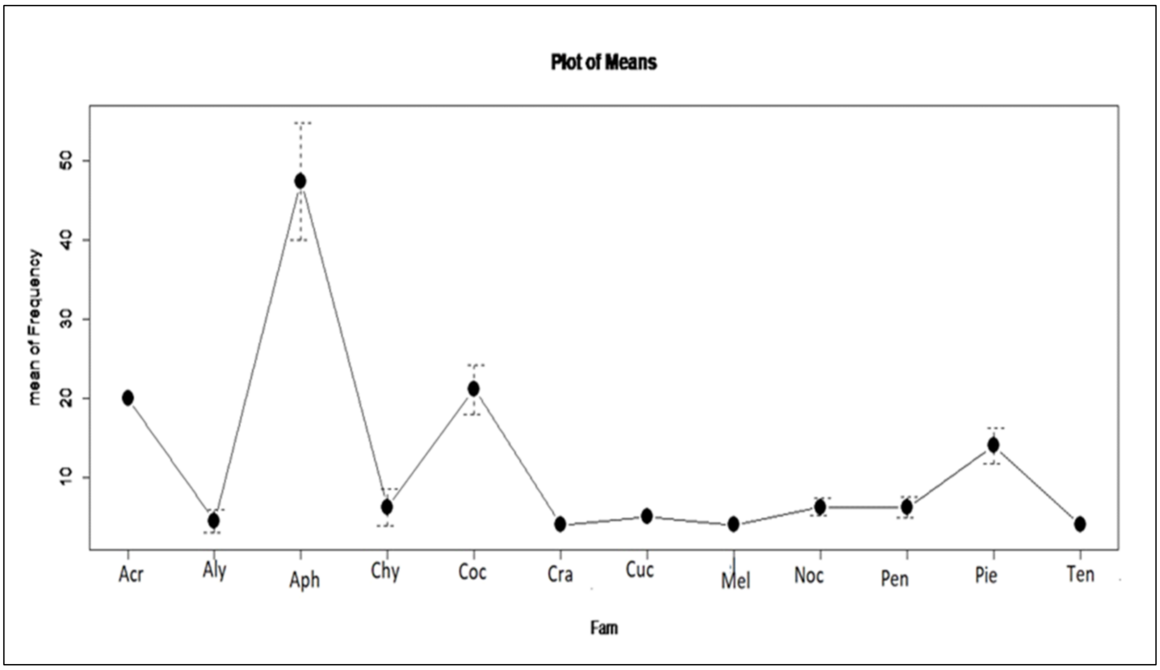

Fig 4: Mean plot showing abundance of insect pests in different families

Abbreviations: Acr= Acrididae, Aly= Alydidae, Aph= Aphididae, Chy= Chrysomelidae, Coc= Coccinelidae, Cra= Crambidae, Cuc= Curculionidae, Mel= Meliodae, Noc= Noctuidae, Pen= Pentatomidae, Pie= Pieridae, Ten= Tenebrionidae

The highest mean frequency of insect pests were found from the family Aphididae and the least mean frequency of insect pests were from the family Tenebrionidae.

4.5 Relationship of insect pest species with physical parameters (temperature, humidity and altitude)

In order to find out the relation of insect pest species with physical parameters temperature, humidity and altitude, multivariate analysis i.e. PCA (Principal Component Analysis) was performed. It was found that frequency of insect pest species had positive correlation with temperature and altitude while negative correlation with humidity.

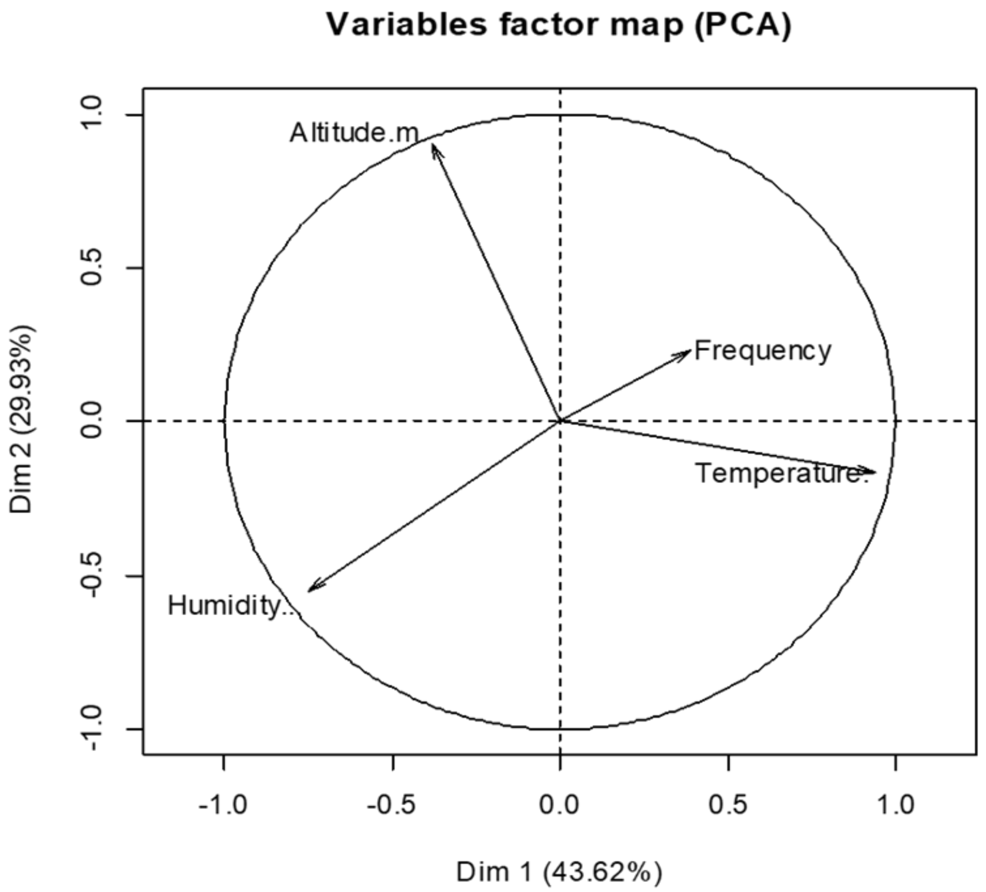

Fig 5: PCA diagram showing the relationship between temperature, altitude, humidity and frequency of insect pest species. First canonical axis explain 43.62% and second axis explain 29.95% of total variance of data set.

4.6 Abundance of insect pests in different host plants

Table 5: Generalized linear model performed to find the abundance of insect pests in different host plants

Coefficient	Estimate	Std. error	T- value	P-value
Host plant(CPB)	0.09	0.03108	2.895	**0.00606**
Host plant(BLM)	-0.08944	0.03109	-2.877	**0.00635**
Host plant(CAB)	-0.08832	0.0311	-2.84	**0.00699**
Host plant(BLB)	-0.07954	0.03129	-2.542	0.01489
Host plant(GRB)	-0.08964	0.03109	-2.883	**0.00624**
Host plant(CAU)	-0.08878	0.03111	-2.854	**0.00674**
Host plant(LIB)	-0.0275	0.05142	-0.535	0.59565
Host plant(POT)	-0.08729	0.0311	-2.807	**0.00763**
Host plant(PUM)	-0.05	0.04272	-1.17	0.24861
Host plant(SPG)	-0.0275	0.05142	-0.535	0.59565
Host plant(TAR)	-0.08408	0.03186	-2.639	0.0117
AIC	399.51			

Abbreviations: CPB=Cowpea Bean, BLM=Broad Leaf Mustard, CAB= Cabbage, CAU=Cauliflower, GRB= Green Bean, BLB=Black Bean, LIB= Lima Bean, POT=Potato, PUM= Pumpkin, SPG= Sponge gourd, TAR=Taro

Significant codes: 0.000= highly significant, 0.001= moderately significant, 0.01= significant, 0.05= marginal significant.

Generalized Linear Model (GLM) was performed to find the abundance of insect pest in different host plant. The results showed that abundance of insect pest was significantly different in host plant Cowpea Bean, Broad Leaf mustard, Green Bean, Cabbage, Cauliflower and Potato there is variation in abundance of insect pests.

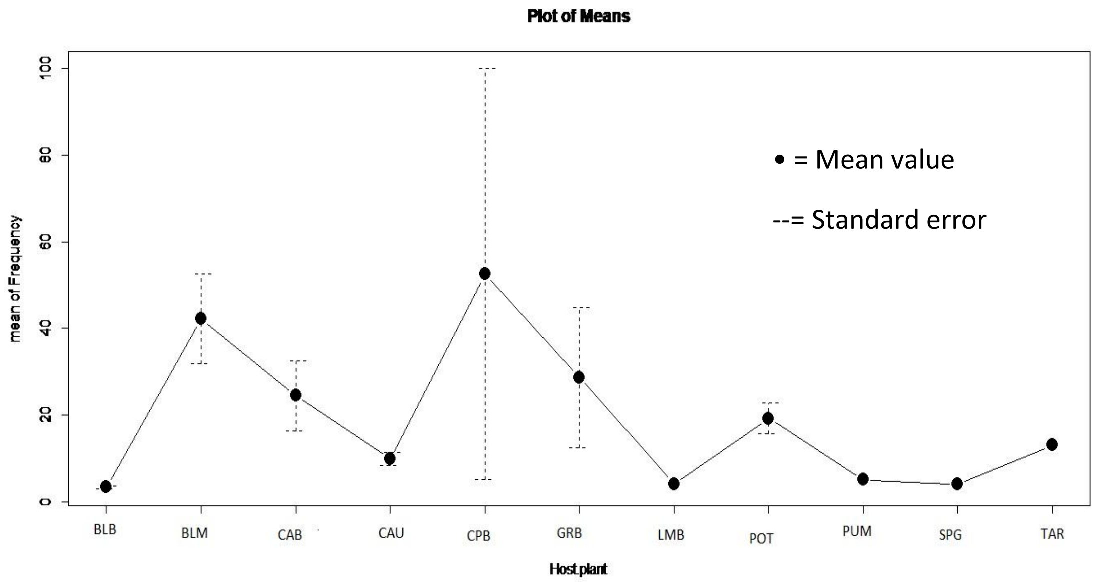

Fig 6: Mean plot showing insect pest abundance with host plant.

The mean frequency of insect pests was highest in Cowpea bean and the mean frequency of insect pests was lowest in Lima bean.

4.7 Pest management practices

The study found that most of the farmers grow vegetables for household consumption. Only few famers grow vegetables commercially. By using questionnaire method and informal discussion with farmers, the pest management status was assessed in the study area (Appendix vii). The total number of respondent were 66. Out of which 59.09% were female and 49.90% were male. Maximum percentage of people (54.54%) had the education of primary level, 30.30% had education of lower secondary level and only 15.15% had secondary level education. Agriculture and hotel business were the major source of income of the respondents.

Pest management practices followed by the farmers include use of chemical pesticides, bio-pesticides, tillage, crop sanitation and hand picking of insect pests. It was found that farmers seldom use traditional as well as the newly commercialized bio-pesticides as practice of insect pest management. Moreover, they preferred to use chemicals pesticides. The study found that 52% farmers use chemical pesticides and 27% farmers use bio-pesticides and 21% farmers adopt other pest control method in their field. More than half of them had knowledge about IPM but they do not practice in their field because according to them, IPM requires a lot of labor, time and pesticides are cheaper.

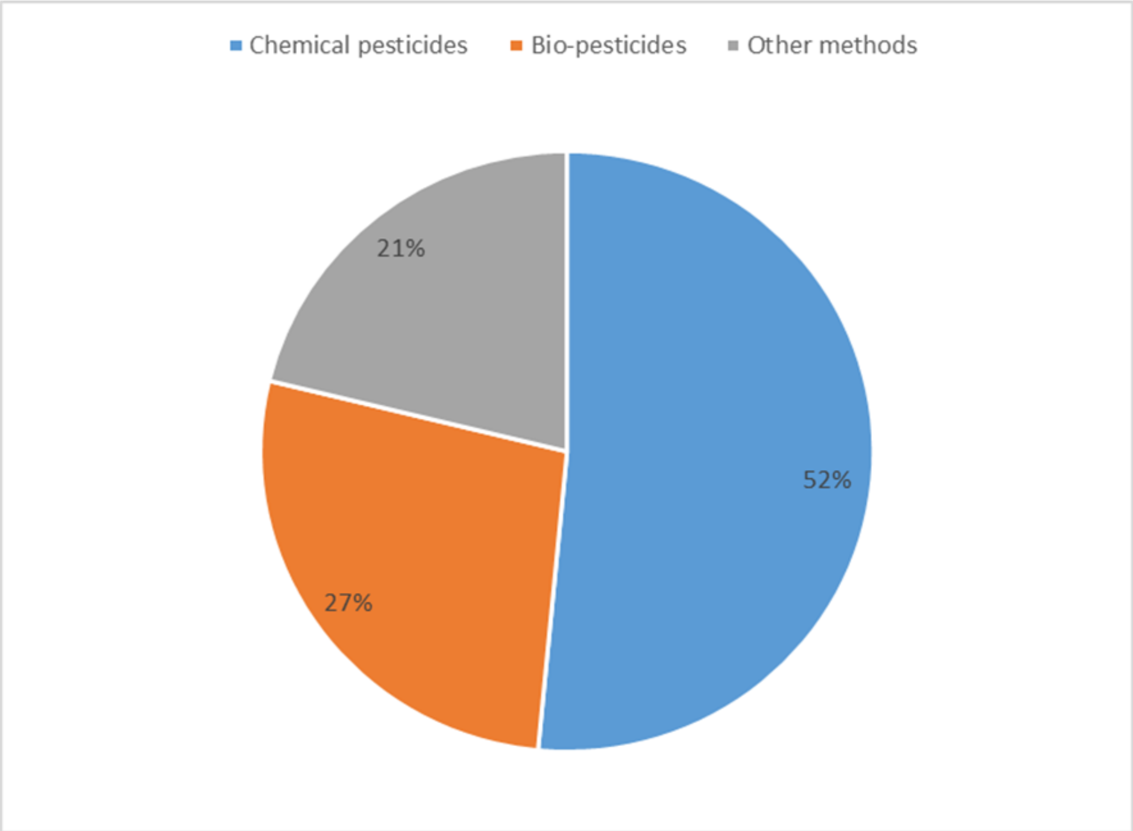

Fig 7: Methods of pest management adopted by the farmers

Table 6: Methods of pest management adopted by farmers

	Frequency of farmers	Total no of respondents
Chemical pesticide user	34	66
Bio-pesticide user	18	
Other methods	14	

4.7.1 Chemical pesticides used for the control of pests

The study found that 52% farmers use chemical pesticides to control insect pests in vegetables. Most of the famers used chemical pesticides to control the insect pests and disease. Only few farmers used chemical pesticide to increase productivity. Chemical pesticides used in the study area were: Dichlorovus, Carabaryl, Malathion, Endosulfan, Dimethoate, Mancozeb, and Cypermethin. Most of the vegetables are sprayed with Nuvan, Thiodane and cypermethin to control aphid and biting insect caterpillars. G-van Dichlorovous was used to control caterpillars and whiteflies. Malathion dust was used to kill insect pests of potato.

Table 7: Chemical pesticides used in study area

Trade Name	Common name	Pesticide group	WHO class	Physical state
DD-76	Dichlorovous	Organophosphates	IB	Liquid
Nuvan	Dichlorovous 76% EC	Orgnaophophates	IB	Liquid
Rogar plus	Dimethoate	Organophophates	II	Liquid
Cropstar	Carbaryl	Carbamates	IB	Solid
Malathion 50% EC	Malathion	Organophophates	III	Liquid
Endos-35	Endosulfan	Organochlorine	II	Solid
Super-D	Cypermethrin 5%	Synthetic Pyrethroids	II	Liquid
Surya M-45	Mancozeb	Fungicide	U	Solid
Uthane M-45	Mancozeb	Fungicide	U	Solid

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

4.7.2 Bio-pesticides used for the control of pests

The study found that 27.28% farmers use bio- pesticides to control insect pests of vegetables in the study area. Most of the farmers prepared bio-pesticides by themselves and only few farmers purchased bio-pesticide such as Derisom, Neem oil and Green verticill from the market. While preparing local bio-pesticides, they use mixture of animal urine, neem leaves (*Azadirachta indica*), titepaati leaves (*Artemisia vulgaris*), banmara (*Eupatorium* spp.) and bakaina (*Melia azadarach*). Besides use of bio-pesticides, farmers also reported use of ash, soap water, garlic and animal urine to control insect pests and diseases. Among them, mostly used was ash followed by animal urine and soap water.

Table 8: Bio-pesticides used in study area

SN	Bio-pesticides	Target pests
1	Neem oil	Armyworm, Aphids, Caterpillar of Cabbage butterfly
2	Green verticill	Aphids, mealy bug and other sucking insect pests
3	Garlic	Thrips
4	Banmara leaves	Aphids, Mites
5	Titepati leaves	Caterpillars, Aphids
6	Ash	Beetle, aphids, thrips
7	Derisom	Scale insects, thrips, whiteflies
8	Animal urine	Aphids

4.7.3 Equipment used for the application of pesticides

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

4.7.4 Farmers perception on pesticides

Most of the respondent reported that the use of chemical pesticides and chemical fertilizer in the vegetables has increased the production. Majority of farmers 51.5 % used pesticides to control pest, 15.2 % used pesticides to increase productivity and 33.3% used pesticides to control disease. They revealed that the disease name “Daduwa” is prevalent in the area which destroyed the potatoes and without the use of pesticides, vegetables in that area cannot be grown well. According to them, local bio-pesticides are time consuming, nuisance to prepare and readymade bio-pesticides are expensive and not as effective as chemical pesticides. This forced them to use chemical pesticides as chemical pesticides are cheaper and easily available at market. Majority of the farmers are unaware of pesticide types, level of poisoning, safety precautions and potential hazards on health and environment. Most of the respondents about 70% have the knowledge of adverse health hazards of pesticides and 30% did not have knowledge about adverse health hazards of pesticides.

Table 9: Reason of using pesticide by farmers

Reasons	Frequency of farmers
To control pest	34
To increase production	10
To control disease	22
Total no of respondent=66	

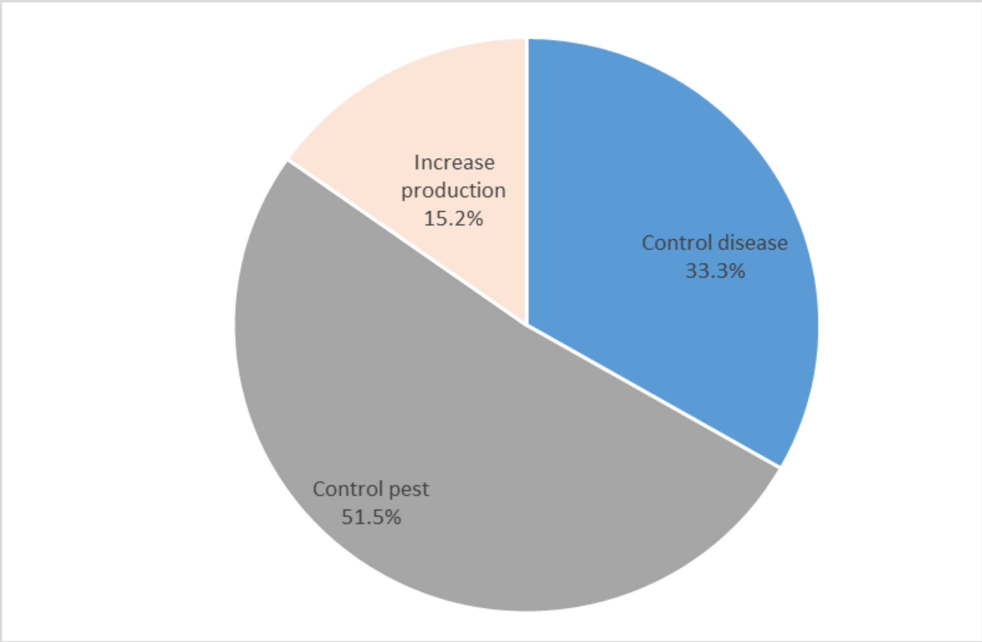

Fig 8: Reasons of using pesticides by the farmers

4.7.5 Protective measures adopted during use of pesticide

Very few farmers used protective clothing or other safety measures during insecticide application. The study found that 21.21% of total respondents (14) did not use any safety measures at all. No farmer used glasses or other form of protective devices to protect their eyes during pesticide application. This may put them in the risk of acute and chronic health hazards due to the inhalation, ingestion and contamination of pesticides. The reason for not using protective measures was lack of knowledge and not having the habit of wearing. Due to unsafe practices, vegetable growers are more vulnerable to expose with toxic pesticides and are in higher health risks as there has been use of pesticides with too little or no protection.

Table 10: Use of personal protective equipments and maintenance of hygiene (Total no of respondent=66)

Items	Yes (%)	No (%)
Gloves	35%	65%
Mask	90%	10%
Shoes	75%	25%
Hat	40%	60%
Glasses	-	100%
Change clothes	95%	5%
Wash hands and feet	80%	20%

4.7.6 Disposal techniques

Most of the farmers (45.5%) did not dispose pesticides bare container properly. They throw the pesticide containers anywhere they like. 15.5% buried in the fields and 24.5% disposed by burning. 14.5% of the respondents throw them in dumping sites.

4.7.7 Health hazards experienced by the farmers while using pesticide

In this survey, 52% respondent replied that they did not experience any health effect, 23% experienced headache and nausea. Similarly, 25% experienced skin problems like itching, skin rashes, burn and allergies.

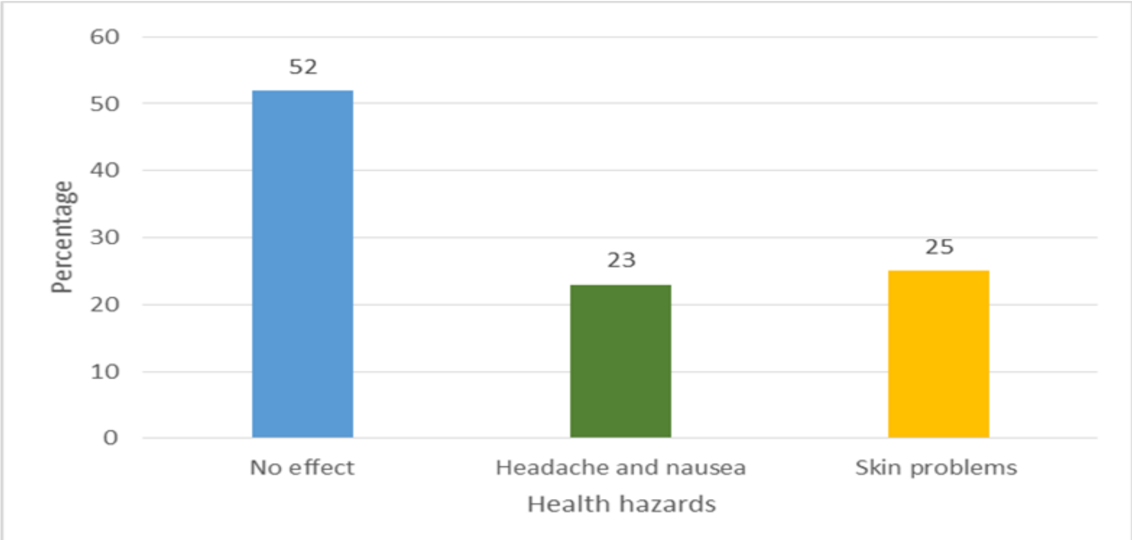

Fig 9: Health hazards experienced by the farmers

5. DISCUSSION

5.1 Abundance and diversity of insect pests

The present study found 23 insect pest species belonging to four insect orders (Lepidotera, Hemiptera, Coleoptera and Orthoptera) 12 families (Coccinellidae, Pentatomidae, Aphididae, Noctuidae, Chrysomelidae, Pieridae, Acrididae, Curculionidae, Tenebrionidae, Meloidae, Crambidae and Alydidae) and 21 genera. Family Aphididae of the order Hemiptera was most abundant. This study result shows resemblance with the study result of Bhat and Ahangar (2018) who had reported family Aphididae as the most abundant insect pest family in the research conducted on vegetable crops in Kashmir valley, India. Among the pests documented in the present study, some have been reported in some literature as major pests, in terms of causing damage to the host crops. These included, *Pieris brassica*, *Lipaphis erysimi*, *Epilachna vigintioctopunctata*, *Aplosonyx chalybeaus,* and *Myzus periscae. Pieris brassicae* was reported as the major pest of Cabbage in India that had caused 69% of yield loss (Rai *et al*., 2014.) Similarly, Mustard aphid (*Lipaphis erysimi*) was reported as the major pest of mustard in Nepal (Kafle, 2015). *Aplosonyx chalybeaus* was reported as the the major pest of Taro in Nepal (Joshi, 1994). *Epilachna vigintioctopunctata* was reported as the the major pests of Potato in Nepal especially in Hilly region (Joshi, 1994).

The abundance of insect pests was significantly different in different host plants. The highest abundance of insect pests was found in the host plant Cowpea Bean, followed Broad Leaf Mustard, Potato and Cabbage. The least abundance of insect pests were found on the host plant Lima Bean followed by Sponge Gourd and Pumpkin. Occurrence of pest depends on host suitability and climatic condition, therefore, occurrence and infestation of pest differ in different host plants and due to variation of management practices in the study area (Khan and Talukder, 2017).

The species diversity index of insect pests found in Kaligandaki and Marsyangdi river basin were 2.07 and 1.88. It means the diversity of insect pest species is high in Kaligandaki river basin as compared to Marsyangdi river basin which may be due to the variation of climates and fertility of soil pattern, particularly, usage of pesticides and organic manure by farmers.

5.2 Relation of insect pest with physical parameters

Insect population is regulated both by biotic and abiotic factors. Among the abiotic factors temperature, relative humidity and rainfall play the most important role (Soultani *et al*., 2012). In this study, it was found that the frequency of insect pest species had positive correlation with temperature. The abundance of insect pest species had increased with increase in temperature. This result is in agreement with the findings of (Vidya *et al*., 2011) in which abundance of insect pests of cruciferous vegetables had increased with the increase in temperature in Nilgiri district of India. This is an indication that temperature has a profound effect on the abundance of insects as earlier reported by several studies that temperature greatly affects the distribution and abundance and diurnal activity of insects (Young, 1982; Hill, 1987).

The relative humidity also directly or indirectly affects the life of insects, increasing or decreasing the development processes and reproductive activities (Chang *et al*., 2008). Frequency of insect pests showed negative correlation with relative humidity in this study. That means the frequency of insect pest decreased as the relative humidity increased. Increase in humidity has a negative effect on arthropod population as it increases fungal pathogens of arthropods when humidity increases which results into decrease their population (Sharma, 2014). This would have been one of the reasons why insect pest population decreased as relative humidity increased.

5.3 Pest management practices

For the management of insect pests on vegetables, pest management practices followed by the farmers include use of chemical pesticides, bio-pesticides, tillage, crop sanitation and hand picking of insect pests. It was found that farmers seldom use traditional as well as the newly commercialized bio-pesticides as practice of insect pest management. Moreover, they preferred to use chemicals pesticides. The study found that 52% farmers use chemical pesticides, 27% farmers use bio- pesticides and 21% farmers use other of pest control in their field. High dependence on chemical pesticides in vegetable production was also reported in the Chitwan districts of Nepal (Rijal *et al*., 2018) in which the majority of the farmers (80%) used chemical pesticides solely to control insect pests in their vegetable crops. Only 16% of the farmers used other methods (biological, cultural, and mechanical) for insect pest control. Farmers used chemical pesticides to control the pest, to control disease as well as to increase productivity.

Different types of chemical pesticides used in the study area were Dichlorovous, Dimethoate, Carabaryl, Malathion, Endosulfan, Mancozeb and Cypermethrin. 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 Endosulfan and Dichlorovous were also found in the field. Use of similar chemical pesticides were reported by Koirala *et al*., 2010 on the commercially grown vegetable pockets in five districts Tanahun, Chitwan, Kavre, Dhading and Bhaktapur of Nepal.

This study found that 27% of farmers use biopesticdes to control insect pests. Most of them prepare biopesticides by locally available plants and animal urine. Only few of them purchase biopestiicdes from the shop. Majority of them used animal urine and ash as the alternative methods of pesticides in this area. Similar findings was reported by (Ghimire, 2016) in Nawalparasi districts of Nepal. Adoption of safety precaution during and after pesticide application is very important to prevent harmful impact of pesticides. The various safety measures could be use of mask, gloves, use of long sleeved clothes, glass, shoes, hat, etc. During this study it was found that very few farmers used protective clothing or other safety measures during insecticide application. The reason for not using protective measures were lack of knowledge, not having easy access of safety measure equipment and not having the habit of wearing. This may put them in the risk of acute and chronic health hazards like cancer, birth defects, reproductive problems, tumors, and damage of liver, kidney and neural organs (Sharma *et al*., 2012). In many developing countries like Nepal, most pesticides are associated with adverse effects on human health and environment due to inappropriate use and handling of pesticides by inadequately trained farm workers (Naidoo *et al*., 2010). Various studies in Nepal reported the huge use of chemical pesticides in vegetable growing areas have raised problem of health risks (Atreya, 2007).

Acute health problems experienced by the farmers in the study were: skin rashes, itching dizziness, nausea, difficulty of breathing, headache, eye irritation, blurred vision and irritation of nose and throat. They use home remedies such turmeric water, oil massage, salt water gargle and eating mint (*Mentha* spp) to cure the acute symptoms of pesticides infection as described by Thapa, 2014. Majority of farmers had poor knowledge about pesticides use and its bad impact on non-target organisms due to the misuse of pesticides. Lack of knowledge about pesticide, its composition and its formulation made more misuse of pesticides. Misuse of insecticides is common in Nepal. Unregistered and illegal products, open air sales, sales of banned products, cases of decanting and reweighing, fake pest control products using counterfeit labels, sales of expired products with modified expiry dates are among the misuse cases that have been reported in Nepal (Sharma *et al*., 2012). Palikhe (2002) reported that misuse and overuse of pesticides particularly among commercial farmers pose a health risk to the public and have numerous cases caused serious poisoning. There are numerous reports on pesticide residues in food in Nepal. A recent survey conducted by Department of Food Technology and Quality Control (DFTQC) indicated that Nepalese people are at alarming threat of pesticides in their diets. Commodity-wise detection of pesticides showed the highest level of residues in root vegetables (11.9%) followed by leaf vegetables (10.9%) (Koirala *et al*., 2009). The vegetables sold in the markets of Nepal contain large amounts of pesticide residues which are harmful to human health (Thapa 1997). Pesticide pollution not only affects human health, but also other ecological assets, such as soil surface and ground water, micro and macro flora and fauna (Pimental, 2005).

Integrated Pest Management is the best method for long term pest control as it is eco-friendly, lowers cost, guarantees yield and contributes to the sustainability of agriculture.

During this study we did not found anyone practicing IPM in their fields because they did not have knowledge of integrated pest management. Maximum percentage of people (54.54%) had the education of primary level only. This could be the reason for the low level of knowledge of IPM and safety precaution while applying pesticides. Also they have not received any training programs of IPM. So, government should provide training and awareness programs regarding integrated pest management in this region to reduce the application of chemical pesticides.

6. CONCLUSION AND RECOMMNEDATION

6.1 Conclusion

This study found 23 insect species of 12 families and four orders in the study area. The highest abundance of insect pest was from the family Aphididae. The highest abundance of insect pests were found in the host plant Cowpea Bean. The least abundance of insect pests were found on the host plant Lima Bean followed by Sponge Gourd and Pumpkin. This may be due to the high use of pesticide in Lima bean, pumpkin and sponge gourd than other vegetable crops. It was found that the abundance of insect pests show positive correlation with temperature and altitude while negative correlation with humidity. This is because temperature and relative humidity affect in the regulation of insect population. For the management of insect pests, most of the farmers use chemical pesticides in this area. Chemical pesticides used in the study area were Dichlorovous, Dimethoate, Carabaryl, Malathion, Endosulfan, Mancozeb and Cypermethrin. Very few farmers used protective clothing or other safety measures during insecticide application. The reason for not using protective measures were lack of knowledge, not having easy access of safety measure equipment and not having the habit of wearing. Most of them did not have knowledge of IPM. Therefore, it is urgent to provide training on integrated pest management, training on pesticides handling, disposal and dissemination of alternative technology through field demonstration to reduce the chemical risks in future.

6.2 Recommendation

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

- Detailed study of insect pests in vegetable crops in CHAL is needed covering more agriculturally important sites.
- Training should be provided to the farmers on integrated pest management to reduce the application of insecticide.

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APPENDICES

Appendix i

Insect pest abundance along with host plant, temperature, humidity and altitude

Date	Village	Altitude	*Species*	Common name	Order	Family	Host plant	Fre	Temp	Rh	Longi	Lalti
1-Jun	Tatopani	1320	*Maruca* sp.	Legume pod borer	Lepi	Cram	LMB	4	27.6	60	83.66213	28.51715
2-Jun	Dana	1472	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAB	15	30.6	55	83.64615	28.51767
2-Jun	Dana	1472	*Brevicoryne brassicae*	Cabbage aphid	Hemi	Aphididae	CAB	30	30.4	73	83.64615	28.51767
2-Jun	Dana	1472	*Aphis* spp.	Cowpea aphid	Hemi	Aphididae	CPB	60	30.6	55	83.64615	28.51767
2-Jun	Dana	1472	*Alcidodes* sp	Bean gall weevil	Cole	Curculionidae	GRB	5	30.6	55	83.64615	28.51767
2-Jun	Dana	1472	*Riptortus* sp	Pod sucking bug	Hemi	Alydidae	GRB	6	30.6	55	83.64615	28.51767
2-Jun	Dana	1472	*Lagria* sp.	Darkling beetle	Cole	Tenebrionidae	GRB	4	30.6	55	83.64615	28.51767
2-Jun	Dana	1472	*Aulacophora* sp.	Pumpkin beetle	Cole	Chrysomelidae	PUM	5	30.4	73	83.64615	28.51767
3-Jun	Dana	1506	*Eurydema* sp.	Shield bugs	Hemi	Pentatomidae	CAB	6	30.4	73	83.64691	28.51767
3-Jun	Dana	1506	*Aplosonyx chalybaeus*	Taro corm borer	Cole	Chrysomelidae	TAR	9	30.4	73	83.64691	28.51767
4-Jun	Kabre	1690	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAB	13	34.4	46	83.63577	28.51767
4-Jun	Kabre	1690	*Aphis* spp.	Cowpea aphid	Hemi	Aphididae	CPB	100	34.4	46	83.63577	28.51767
4-Jun	Kabre	1690	*Melanoplus* sp.	Grasshopper	Ortho	Acrididae	GRB	20	34.4	46	83.63577	28.51767
4-Jun	Kabre	1690	*Mylabris* sp.	Banded blister beetle	Cole	Meloidae	SPG	4	34.4	46	83.63577	28.51767
4-Jun	Kabre	1690	*Aulacophora lewisii*	Pumpkin beetle	Cole	Chrysomelidae	SPG	4	34.4	46	84.35845	28.52995
5-Jun	Ghasa	1948	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	80	29.5	55	84.31945	28.52995
5-Jun	Ghasa	1948	*Brevicoryne brassicae*	Caabbage aphid	Hemi	Aphididae	CAB	35	29.5	55	83.64288	28.51767
5-Jun	Ghasa	1948	*Eurydema* sp.	Shield bug	Hemi	Pentatomidae	CAU	5	29.5	55	84.31945	28.52995
5-Jun	Ghasa	1948	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAU	20	29.5	55	83.64288	28.51767
5-Jun	Ghasa	1948	*Agrotis* sp.	Black cutworm	lepi	Noctuidae	POT	7	29.5	55	83.64288	28.51767
5-Jun	Ghasa	1948	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	18	29.5	55	83.64288	28.51767
6-Jun	Lete	2536	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAB	30	30.9	47	83.61387	28.51767
6-Jun	Lete	2536	*Eurydema* sp.	Shield bugs	Hemi	Pentatomidae	CAU	8	30.9	47	83.61387	28.51767
6-Jun	Lete	2536	*Thysanopulsia* sp.	Cabbage looper	Lepi	Noctuidae	CAU	5	30.9	47	83.61387	28.51767
6-Jun	Lete	2536	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	21	30.9	55	83.59916	28.51767
7-Jun	Larjung	2559	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	35	30.3	53	84.30365	28.52974
7-Jun	Larjung	2559	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAB	17	30.3	53	84.30365	28.52974
7-Jun	Larjung	2559	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	18	30.3	53	83.61387	28.51767
7-Jun	Larjung	2559	*Myzus persicae*	Potato aphid	Hemi	Aphididae	POT	10	30.3	53	84.30365	28.52974
8-Jun	Nesyang	2774	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	26	29	40	84.22973	28.55582
8-Jun	Nesyang	2774	*Pieris brassicae*	Cabbage butterfly	Leppi	Pieridae	CAU	5	29	40	84.22973	28.55582
9-Jun	Chame	2724	*Monolepta signata*	Spotted leaf beetle	Cole	Chrysomelidae	GRB	3	25.9	60	84.22973	28.55582
9-Jun	Chame	2724	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	12	25.9	60	84.24081	28.5504
9-Jun	Chame	2724	*Nezara* sp.	Green stink bug	Hemi	Pentatomidae	POT	3	25.9	60	84.24081	28.5504
9-Jun	Chame	2724	*Myzus persicae*	Green peach aphid	Hemi	Aphididae	POT	47	25.9	60	84.22973	28.55582
9-Jun	Chame	2724	*Agrotis* sp.	Black cutworm	Lepi	Noctuidae	POT	9	25.9	60	84.22973	28.55582
10-Jun	Thanchok	2722	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAU	11	24.8	60	84.24081	28.5504
10-Jun	Thanchok	2722	*Nezara* sp.	Green stink bug	Hemi	Pentatomidae	BLB	4	24.8	60	84.24081	28.5504
11-Jun	Syarkhu	2691	*Myzus persicae*	Green peach aphid	Hemi	Aphididae	POT	39	28	53	84.29865	28.54092
11-Jun	Syarkhu	2691	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	23	28	53	84.24081	28.5504
12-Jun	Timang	2633	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	34	22.6	69	84.29865	28.54092
12-Jun	Timang	2633	*Thysanopulsia* sp.	Cabbage looper	Lepi	Noctuidae	CAB	4	25.6	63	84.29492	28.51356
12-Jun	Timang	2633	*Pieris brassicae*	Cabbage white butterfly	Lepi	Pieridae	CAU	8	22.6	69	84.30365	28.52974
12-Jun	Timang	2633	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	30	22.6	69	84.29492	28.51356
13-Jun	Danaque	2270	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	65	28.4	59	83.59916	28.51767
13-Jun	Danaque	2270	*Brevicoryne brassicae*	Cabbage aphid	Hemi	Aphididae	CAB	90	28.4	59	84.31945	28.52995
13-Jun	Danaque	2270	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAU	11	28.4	59	83.59916	28.51767
13-Jun	Danaque	2270	*Bagrada* sp.	Painted bug	Hemi	Pentatomidae	CAU	5	28.4	59	83.59916	28.51767
13-Jun	Danaque	2270	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	34	28.4	59	84.31945	28.52995
13-Jun	Lete	2536	*Lipaphis erysimi*	Mustard aphid	Hemi	Aphididae	BLM	13	30.9	55	83.59916	28.51767
14-Jun	Dharapani	1904	*Epilachana* sp.	Spotted beetle	Cole	Coccinellidae	BLB	6	24.5	70	83.64288	28.51767
14-Jun	Dharapani	1904	*Phyllotreta* sp.	Cabbage flea beetle	Cole	Chrysomelidae	CAB	4	24.5	70	84.35845	28.51751
14-Jun	Dharapani	1904	*Pieris brassicae*	Cabbage butterfly	Lepi	Pieridae	CAU	10	24.5	70	84.35845	28.51751
14-Jun	Dharapani	1904	*Riptortus* sp.	Pod sucking bug	Hemi	Alydidae	GRB	3	24.5	70	83.64288	28.51767
14-Jun	Dharapani	1904	*E. vigintioctopunctata*	Epilachana beetle	Cole	Coccinellidae	POT	7	24.5	70	84.35845	28.51751
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Appendix ii

List of insect pests of vegetables in Kaligandaki river basin area

SN	Common name	Scientific name	Family	Host plant
1	Legume pod borer	*Maruca* sp.	Crambidae	Lima bean
2	Large cabbage white butterfly	*Pieris brassicae*	Pieridae	Cauliflower, Cabbage
3	Black cutworm	*Agrotis* sp.	Noctuidae	Potato
4	Cabbage looper	*Trichopulsia* sp.	Noctuidae	Cabbage, Cauliflower
5	Bean gall weevil	*Alcidodes* sp.	Curculionidae	Green Bean
6	Darkling beetle	*Lagria* sp.	Tenebrionidae	Green Bean
7	Pumpkin beetle	*Aulacophora* sp.	Chrysomelidae	Pumpkin
8	Taro corm- borer	*Aplosonyx chalybaeus*	Chrysomelidae	Taro (pidalu)
9	Banded blister beetle	*Mylabris* sp.	Meloidae	Sponge gourd
10	Epilachna beetle	*Epilachna vigintioctopunctata*	Coccinellidae	Potato
11	Cowpea aphid	*Aphis* sp.	Aphididae	Cowpea
12	Mustard aphid	*Lipaphis erysimi*	Aphididae	Broad leaf mustard
13	Cabbage aphid	*Brevicoryne brassicae*	Aphididae	Cabbage, cauliflower
14	Potato peach aphid	*Myzus persicae*	Aphididae	Potato
15	Spur-throated grasshopper	*Melanoplus* sp.	Acrididae	Green Bean
16	Pod sucking bug	*Riptortus* sp.	Alydidae	Green Bean
17	Shield bug	*Eurydema* sp.	Pentatomidae	Cauliflower, cabbage
18	Green stink bug	*Nezara* sp.	Pentatomidae	Bean, potato
19	Pumpkin beetle	*Aulacophora lewisii*	Chrysomelidae	Sponge gourd

Appendix iii

List of insect pests of vegetables in Marsyangdi river basin area

SN	Common name	Scientific name	Family	Host plant
1	Epilachna beetle	*Epilachna vigintioctopunctata*	Coccinellidae	Potato
2	Green stink bug	*Nezara* sp.	Pentatomidae	Poato, bean
3	Potato peach aphid	*Myzus persicae*	Aphididae	Potato
4	Black cutworm	*Agrotis* sp.	Noctuidae	Potato
5	Large cabbage white butterfly	*Pieris brassicae*	Pieridae	Cabbage , cauliflower
6	Mustard aphid	*Lipaphis erysimi*	Aphididae	Broad leaf mustard
7	Cabbage aphid	*Brevicoryne brassicae*	Aphididae	Cabbage, cauliflower
8	Pod sucking bug	*Riptortus* sp.	Alydidae	Bean
9	Cabbage looper	*Trichopulsia* sp.	Noctuidae	Cauliflower, cabbage
10	Flea beetle	*Phylloterta* sp.	Chrysomelidae	Cabbage
11	Flea beetle	*Monolepta signata*	Chrysomelidae	Cauliflower
12	Painted bug	*Bagrada sp*	Pentatomidae	Caulliflower
13	Spotted beetle	*Epilachana sp*	Coccinelidae	Black Bean

Appendix iv

List of insect pests found in different vegetables in study area

Host plant	Species	Total frequency
Cabbage	*Pieris brassicae*	75
	Eurydema sp.	6
	Brevicoryne brassicae	120
	Thysanopulsia sp.	4
Cauliflower	*Pieris brassicae*	65
	Bagrada sp.	5
	Eurydmea sp.	13
	Thysanopulsia sp.	5
	Brevicoryne brassicae	35
Potato	*E. vignintioctopunctata*	163
	Myzus periscae	96
	Agrotis sp.	16
	Nezara sp.	4
Green Bean	*Riptortus* sp.	9
	Alcidodes sp.	5
	Lagria sp.	4
	Melanoplus sp.	20
	Monolepta signata	3
Cowpea Bean	*Aphis* sp.	160
	Nezara sp.	3
Taro	*Aplosonyx chalybaeus*	9
Sponge gourd	*Aulacophora lewisii*	4
	Mylabris sp.	4
Pumpkin	*Aulacophora* sp.	5
Broad leaf mustard	*Lipaphis erysimi*	253
	Phyllotreta sp.	4
Lima Bean	*Maruca vitrata*	4
Black Bean	*Epilachna* sp.	6

Appendix v

Shannon- Wiener diversity indices (H) of Kaligandaki river basin

Species	Ni	Pi	lnpi	Pi*lnpi
Maruca vitrata	4	0.006269592	5.072043922	0.031799648
Alcidodes sp.	5	0.007836991	4.848900371	0.038000787
Aphis sp.	160	0.250783699	1.383164468	0.346875102
Riptortus sp.	6	0.009404389	4.666578814	0.043886321
Pieris brassicae	95	0.148902821	1.904461392	0.283579674
Lagria sp.	4	0.006269592	5.072043922	0.031799648
Aulacophora sp.	5	0.007836991	4.848900371	0.038000787
Brevicoryne brassicae	65	0.101880878	2.283951013	0.232690934
Aplosonyx chalybaeus	9	0.014106583	4.261113706	0.060109754
Eurydema sp.	19	0.029780564	3.513899304	0.104645904
Melanoplus sp.	20	0.031347962	3.46260601	0.108545643
Mylabris sp.	4	0.006269592	5.072043922	0.031799648
Myzus periscae	10	0.015673981	4.15575319	0.065137197
Agrotis sp.	7	0.010971787	4.512428134	0.0495094
Epilachna vigintioctopunctata	57	0.089341693	2.415287016	0.215785831
Lipaphis erysimi	128	0.200626959	1.606308019	0.322268694
Thysanopulsia sp.	5	0.007836991	4.848900371	0.038000787
Aulacophora lewisii	4	0.006269592	5.072043922	0.031799648
				2.074235407
H= 2.07				

Appendix vi

Shannon- Wiener diversity indices (H) of Marsyangdi river basin

Species	Ni	pi	lnpi	pi*lnpi
Epilachana vigintioctopunctata	106	0.215010142	1.53707008	0.330485656
Nezara sp.	7	0.014198783	4.254599025	0.060410128
Myzus persicae	86	0.174442191	1.746161878	0.304604303
Agrotis sp.	9	0.018255578	4.003284597	0.073082275
Monolpeta signata	3	0.006085193	5.101896885	0.031046026
Pieris brassicae	45	0.09127789	2.393846684	0.218505275
Lipaphis erysimi	125	0.253549696	1.372195437	0.347919735
Brevicoryne brassicae	90	0.182555781	1.700699504	0.310472526
Phylloterta sp.	4	0.00811359	4.814214813	0.039060566
Riptortus linearis	3	0.006085193	5.101896885	0.031046026
Thysanopulsia sp.	4	0.00811359	4.814214813	0.039060566
Bagrada sp.	5	0.010141988	4.591071262	0.046562589
Epilachana sp.	6	0.012170385	4.408749705	0.053656183
				1.885911855
H= 1.8				

Appendix vii

Questionnaire

Central Department of Zoology

Kirtipur, Kathmandu

INSECT PESTS OF VEGETABLES AND THEIR MANAGEMENT PRACTICES IN KALIGANDAKI AND MARSYANGDI RIVER BASIN ACROSS CHITWAN ANNAPURNA LANDSCAPE (CHAL), NEPAL

Date of interview: Survey ID number:

Name of the respondent: Gender:

Age: Education:

Village: District:

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

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

6. What are the major insects that are harmful to the vegetable plant?

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

S.N.	Name of the insect pest	Pesticides used

12. Where do you get pesticides from?
    a. From local shop
    b. From authorized shop/ retailers
    c. Other places
13. How do you determine the amount of pesticides you use?
    a. Information as per on label
    b. According to retailer
    c. According to neighbor

14. How do you mix the pesticides?

a. With bare hand
b. With stick but bare hand
c. With hands wearing gloves
d. With stick and wearing gloves

15. Do you wear mask while spraying pesticides?

a. Yes
b. No

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

a. Yes
b. No

17. Protective gears used during application.

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

18. Do you change clothes after application of pesticides?

a. Yes
b. No

19. If yes, what do you do?

a. Take a bath
b. Clean hands and feet only
c. Yes
d. No

20. How do you dispose pesticides usually?

a. Burn
b. Burry in field
c. Throwing in dumping sites
d. Used for household purpose

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

a. Yes
b. No

22. What health hazards have you experienced after handling pesticides?

a. No effect
b. Headache and nausea
c. Skin problems

23. Do you have any knowledge about integrated pest management?

a. Yes
b. No

24. If yes, do you currently use any IPM practice method?

a. Yes
b. No

25. Which method do you use?

a. Smoke
b. Rotation of crop
c. Light trap
d. Pheromone trap
e. Biological control

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

a. Pesticides are cheaper
b. IPM requires lot of labor
c. Lack of knowledge about IPM

PHOTOPLATES

Photo 1: Larva of legume pod borer (*Maruca* sp.)

Photo 2: Larva of *Pieris brassicae* on cauliflower leaf

Photo 3: Black cutworm (*Agrotis* sp.) Photo 4: Larva of *Thysanopulsia* sp.

Photo 5: *Alcidodes* sp. Photo 6: *Lagria* sp.

Photo 7: *Melanoplus* sp. on leaf of bean

Photo 8: *Aplosonyx chalybaeus*

Photo 9: *Phyllotreta* sp. on mustard leaf

Photo 10: *Mylabris* sp.

Photo 11: *Epilachna vigintioctopunctata*

Photo 12: *Aphis* sp. on cowpea bean

Photo13: *Lipaphis erysimi* on mustard leaf

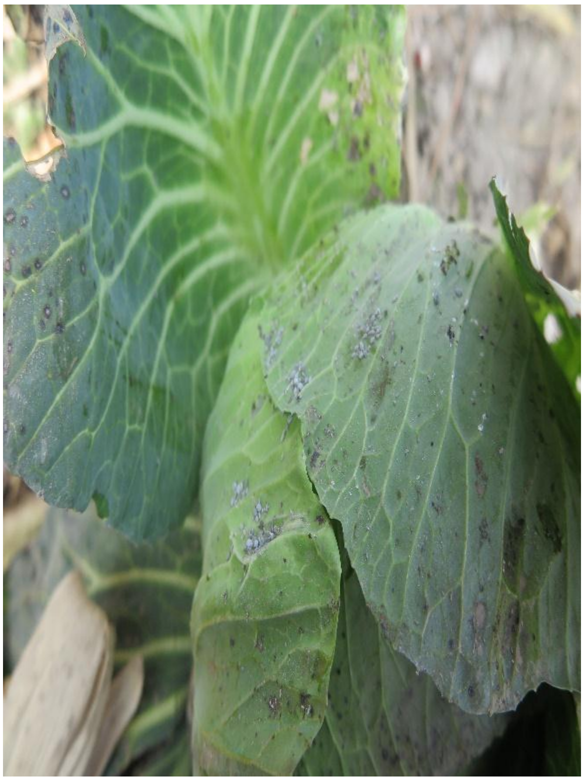

Photo 14: *Brevicoryne brassicae* on cabbage

Photo 15: *Myzus periscae* on Potato

Photo 16: *Riptortus* sp. on pod of bea

Photo 17: *Bagrada* sp. on cauliflower leaf

Photo 18: *Monolepta signata* on potato leaf

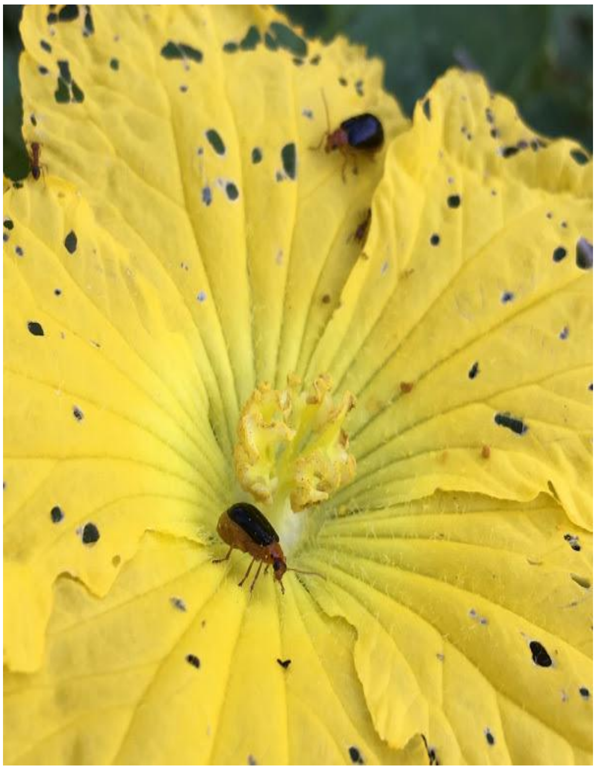

Photo 19: *Aulacophora lewisii* on flower

Photo 20: *Eurydema* sp. on leaf of host plant

Photo 21: *Epilachana* sp.

Photo 23: *Aulacophora* sp.

Photo 24: Antennal tubercle of *Myzus periscae*

Photo 25: Researcher on lab

Photo 26: Researcher on field with farmer