

**ASSESSMENT OF AVOCADO (*Persea americana*) PESTS
IN DHANKUTA MUNICIPALITY, NEPAL**



Entry
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Submitted to

Central Department of Zoology

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Tribhuvan University

Kirtipur, Kathmandu

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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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RECOMMENDATION

This is to recommend that the thesis entitled “*Assessment of Avocado (Persea americana) pests in Dhankuta Municipality, Nepal*” has been carried out by Miss Ashma Bogati for the partial fulfilment 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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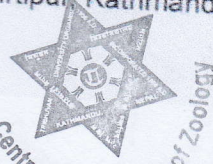
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LETTER OF APPROVAL

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CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Miss Ashma Bogati entitled “**Assessment of Avocado (*Persea americana*) pests in Dhankuta Municipality, Nepal**” has been accepted as partial fulfilment for the requirements of Master’s Degree of Science in Zoology with special paper Entomology.

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LIST OF ABBREVIATION

CDZ	Central Department of Zoology
CDZMTU	Central Department of Zoology Museum of Tribhuvan University
TU	Tribhuvan University
CABI	Centre for Agriculture and Bioscience International
IPM	Integrated pest management
DDT	Dichlorodiphenyltrichloroethane
BVOCs	Biogenic volatile organic compounds

ABSTRACT

The cultivation of avocado is increasingly popular among farmers in Dhankuta Municipality as it contributes to their economic growth. In this study, we assessed pest abundance and diversity along with pest infestation in five selected avocado orchards from the pocket area of the 27 avocado farming in this region. Pest abundance and diversity were estimated using specific pheromone and light trapping techniques from Nov- Dec, 2022. Total 1,693 individual were collected from the study area. Among the five orchards that were sampled, the fifth orchard had notably high abundance of species while, the fourth orchard exhibited a higher level of species diversity, as indicated by Shannon H value 1.61. The highly abundant pest species is Fruit fly *Bactrocera dorsalis* from the Dipteran family Tephritidae but the most diverse species were from the Coleopteran family Scarabaeidae. *Anomala dimidiata* and *Xylotrupes gideon* were found to be the major pest of avocado in this area. A significant association was observed between damage to leaves and the presence of insects. The relationship was analyzed using a chi-square test, resulting p-value of 0.007233. For the control of pest species in avocado orchards their local farmers were observed implementing cultural techniques over other.

1. INTRODUCTION

1.1 Background of the study

Globally, insect pests inflict significant harm to agricultural crops and their natural environment. Agricultural crop contains food or fiber grown which comprises fruits, vegetables, cereals, grains, pulses etc. Nepal has progressed significantly in developing horticultural technologies and become cult in recent days (Pradhan et. al. 2016). Avocado has been a major commercial fruit crop in Nepal. However, insect pests are significant hindrance to agricultural output (Oerke 2006) and their impact is expected to increase as the global demand for food grows (Godfray et al. 2010). The pests cause significant economic losses and therefore, it is crucial to carefully consider the pros and cons of pest management since the economic significance of pests is complex and multifaceted. Researchers have investigated the effects of various insect pests on avocado fruit worldwide.

The avocado (*Persea americana*) is an evergreen tree of the Lauraceae family with 50 genera and 3000 species, known as oldest flowering plant to mankind, which is originated in South Mexico (Storey et al. 1986). It is found naturally in tropical and subtropical regions of the world. Avocado is widely grown in Mexico, South America, Australia and South Africa, from where it is dispersed around the world, including Nepal. Avocado was first planted in Nepal in 1979 AD (BS 2035) in horticulture farms with five varieties (Atreya 2020). Recently, Dhankuta has designated as an avocado capital by the local authorities as its cultivation has become a major source of revenue in Dhankuta. It produce 80 tons of avocado fruit each year, as well as a large number of sampling (Atreya 2020).

The major insect pests for avocado are from insects order Thysanoptera, Lepidoptera, Hemiptera, Coccidae, Diaspididae, Pseudococcidae and Diptera (De Villers & Van den Berg 1987). Sucking insects, borers and defoliating caterpillars, thrips and Persea mites are reported as key pests because natural enemies are unable to control these pests and are also frequently reported in significant economic losses. In Africa, the main pests that cause damage to avocado fruits by leaving scars on their pericarps are fruit flies, false codling moths (Schwartz 1987) and coconut bugs (Vilijeon1986). Fruit quality is degraded when sucking insect pests attack the fruits, trees those are

under stressed, are susceptible to sunlight and may produce less because of premature yield loss due to Persea mites. Although many potential pests are classified as secondary and sporadic, they can still cause harm to avocado trees if their natural enemies are eliminated or disrupted (Subhagan et al. 2020).

Tephritid species, such as *Ceratitis capitata*, *Ceratitis cosyra*, and *Ceratitis rosa*, are recognized for causing damage to avocado during their early stages. But in 2003, a novel species of *Bactrocera* was identified in Kenya that affect avocados (Lux et al. 2003) and Tanzania reported it shortly after (Mwatawala et al. 2006). Numerous species of fruit flies known to attack various types of crops grown for commercial purposes, leading to significant damage. This is a cause for concern, particularly because of the negative impact it has on the production of fruits and vegetables (Schutze et al. 2015). More than 300 species of wild and edible hosts are attacked by the polyphagous pest *Bactrocera dorsalis* (CABI 2020). *Bactrocera dorsalis*, which is commonly referred to as the oriental fruit fly, accounts for the majority about 90% of the pest insects captured in avocado farms in Kenya and Tanzania (Odanga et al. 2018). Tephritidae fruit flies are frequently encountered pests in the United States that can result in quarantines. These pests can have a substantial economic impact, causing direct yield losses and raising the cost of production. Depending on the country, fruit flies can also be of quarantine significance. In survey conducted in 2016, Ambrosia beetles were identified as a significant emerging pest of avocado due to their potential to transmit plant infection to avocado tree (Carillo et al. 2016). Additionally, the *Euwallacea fornicates*, also known as the tea shot hole borer and belonging to the Coleoptera order, has been found to attack avocado tree in various regions such as Israel, California and recently Florida. This group of species is cryptic and shares morphological similarities with the ambrosia beetle (Garcia et al. 2016). For the first time in 2012 *E. fornicates* was identified in commercial avocado at south Florida (Carillo et al. 2012). The avocado lace bug, scientifically known as *Pseudacysta perseae* was initially identified as *Acysta perseae* in 1908 from specimens collected in Florida (Mead & Pena 2013). The infestation of lace bugs is typically associated with the appearance of brown necrotic patches on avocado leaves, as they tend to attack the underside of leaves during the dry winter and spring months (Wolfe et al. 1939). Avocado thrips infestation, caused by *Scirtothrips perseae* from the Thysanoptera order and Thripidae family, resulted in 50 to 80% of crop loss in

Ventura Country orchards in 1997. Fruit that was damaged by thrips feeding became either unmarketable or was reduced during the packing house process (De Graaf 2009). The natural enemies of certain avocado pests such as the omnivorous looper, avocado brown mite and green house thrips have been successful in keeping them from reaching levels that would cause significant economic harm.

Insect pests damaging avocado fruit increased in economic importance, due to effective natural enemy control up until the late 1980s, avocado orchards were relatively free of major insect pests (De Villers & Van den Berg 1987). Since avocado production has expanded over the past ten years, insect pest's populations and their effects on the avocado business have also increased (Erichsen & Schoeman 1992). Monitoring avocados pest have been done in different areas with a project for these pest and done by monitoring device or tools, such as black light trap or pheromones trap (Grove & De Beer 2012). In context of Nepal there has not been serious study about the pest of avocado, but studied about its economical and nutritional value. In terms of avocado fruit value, it has been classified as a functional food by the Academy of Nutritional and Dietetics (1999) for over a decade due to their high nutritional value and beneficial effects on human health.

This research aimed to determine the diversity of avocado's insect pest species and their abundance. Since there is lack of information on the Avocado pests in Nepal, this study will provide the baseline information for avocado farmers, agriculturists and policy makers.

1.2 Objectives of the study

General objective of this research is to find occurrence of insect pest species of avocado. The specific objectives are to;

- i. detect pest species diversity and their abundance in avocado orchard.
- ii. assess severity level of pest infestation in avocado plants.
- iii. document control measures applied by local farmers.

1.3 Rationale of the study

Avocado was first introduce in Nepal in 1979 AD (BS 2035) in horticulture farms with the cultivation of five varieties (Aterya 2020). Avocado is considered one of the

five emerging fruit in Nepal and high demand fruit (Adhikari 2018) due to this increasing demand, commercial farming of avocado has expanded in Nepal. Avocado cultivation is done at Trisuli, Kirtipur, Sarlahi and Dhankuta. Dhankuta district is leading in Avocado farming due to its popularity, the local government has declared Dhankuta, as capital of avocado. The cultivation of avocados has become a significant source of income in Dhankuta. Dhankuta currently has approximately 3,700 mature avocado trees, and over the last few years, more than 26,000 sapling have been planted. Every year, Dhankuta produces around 80 tons of avocado fruit, in addition to a significant number of avocado sapling (Adhikari 2018). The growth of avocado farming is being hindered from achieving its full potential due to numerous barrier in its value chain (Mwaura, 2021) one of the top challenges is infestation by pests, resulting in significant losses of around 30% (Kimaru et al. 2020). Since this fruit is new to Nepal, farmers could face many problems in its cultivation as lack of knowledge about its disease and pest problems. It is important for farmers and pest manager to understand insect activity in their crops and field before they can make it cost-effectiveness. Avocado farming has the potential to be profitable commercial venture due to its high productivity. However, to effectively control pests and optimize yields, it is essential to understand the dynamics of insect populations in avocado plantations, including the best timing and choice of control measures (Tonnang et al. 2017). Identification of pest is essential to gather information about its biological, ecological, behavioral and monitoring population level of pest. All these pest related information will be very helpful for the management of its problem.

This study enables to target the pest problem and avoid injury to beneficial organism, which help farmers to upgrade the quality and quantity of fruits. Knowing the signs and symptoms of pests can enable one to more effectively address and control the situation.

1.4 Research questions

- i. What are the pest species found in avocado orchard at Dhankuta?
- ii. How severe the pest infestation seen in plant?
- iii. What are the control measures used by local farmers to eradicate pest?

1.5 Hypothesis

H0= There is no association between the presence of insects pest and leaves damage.

H1= There is a significant association between the presence of insects pest and leaves damage.

2. LITERATURE REVIEW

Avocado (*Persea americana*) is one of the five emerging horticultural fruits in Nepal with Pomegranate, Kiwi, Dragon fruit and Grapes (Atreya 2020). Avocado has found spreading across the mid hills from east to west. Under our soil, geographical and climatic circumstances all of the above developing high value fruits have a lot of potential. Commercial farming of these emerging fruits have enormous potential for the economic growth of Nepalese farmers. However, there are number of difficulties that must be overcome in order to improve their optimum production.

There are four types of genotypes of avocado fruit in eastern Nepal and they have various sizes PAKAV012 (143.4g), PAKAV005 (144.4 g) and PAKAV009 (403.3 g), PAKAV010 (346.8 g) (Poudel et al. 2018).

Poor Avocado fruit quality caused by Tephritid fruit flies (*Tephritidae*) and the false codling moth, *Thaumatotibia leucotreta* (Meyrick) infestations makes it difficult to enter profitable export markets. *Ceratitis cosyra* (Walker) was the most common pest produced from fruit, with *Pachycrepoideus vindemniae* (Rondani) and *Toxemorpha nigricola* being the most common parasitoids (Toukem et al. 2020)

Subhagam et al. (2020) In 1989, thrips outbreaks in avocado caused some producer to lose up to 80% of their fruit, while in 1997, orchards highly infested with avocado thrips suffered 50-80% crop losses. New pest are constantly being discovered in avocado farming which is still relatively new in many areas of the world. This study concluded that avocado being an emerging crop with several nutritional, environmental, social and economic benefits, it's past time to protect natural enemies while also being cautious of sucking pests of avocado, which might become a serious problem in the future.

Gilligan et al. (2011) during their research found a new species from Mexico and Guatemala, is described and illustrated. They provide characteristics to distinguish this pest from *Stenomacrus catenifer*, the most prevalent avocado fruit pest in the region, as well as a key to identify Lepidoptera larvae attacking avocado in California. In addition, they gave a comprehensive list of tortricids found in various avocado type across the world.

Monitored fruitfly in avocado orchard using biolure containing putrescine, ammonium acetate and tri-methylamine. Fruit flies were observed for a year after traps were placed in the orchards in September. *Ceratitis rosa* was the most common species collected, followed by *Ceratitis capitata* and *Ceratitis casyra*. Female flies were collected in greater numbers than male (Grove & De Beer 2012)

Dennill and Erasmus (1992) conducted a survey of insect damage to avocado fruits, 16256 avocado fruits were evaluated on arrival to packhouse in 36 samples from 32 farms. The most common pests were the coconut bug (*Pseudotheraptus wayi*) Coreidae two thrips species (*Heliothrips haemorrhoidalis*) and (*Selenothrips rubrocinctus*) Thripidae, fruitfly (*Pterandrus rosa*) Tephritidae and stink bug were the most significant pests, causing culling of 4%, 7%, 9% and 8% of fruits respectively.

Spatial distribution map of *B. dorsalis* and *T. leucotreta* in avocado, the two pests were monitored by using their respective parapheromone lures for two years between August 2012 and July 2014. Their results indicated that the mean number of *B.dorsalis* per trap per day different significantly across elevation and the percentage of infestation of ground collected fruits by *B. dorsalis* varied with altitude, being lowest at highlands above 1500 m.a.s.l , whereas the mean number of *T. leucotreta* did not vary with altitude in either study (Odanga et al. 2018).

In interactions between integrated pest management and pollinator introduction it resulted that 941% fruit set increase and up to 97% fruit abscission within the high vegetation productivity class. In comparison to farms without IPM, pest abundance significantly decreased on farms using IPM, increasing final fruit weight by 6%. Overall, integrating pest and pollinator management did not increase the final avocado yield in a synergistic way, but it did present a potential method for reducing pest densities while preserving wild visitors and reaping the rewards of honeybee colonies' secondary products (Toukem et al. 2022).

Avocado Lace bug, its host are known to be Avocado *Persea americana* and *Cinnamomum camphora*. Yellowish or brownish necrotic areas in the leaves are the indication of the presence of avocado lace bug. For identification, place a few infested leaves and a paper towel in a plastic bag, tie securely, and ship in a mailing tube with

collection data. Sprays should be directed to the underside of leaves and repeat twice a week (Mead & Peña 2016).

Scirtothrips perseae (Thysanoptera: Thripidae): a new avocado pest in California. The developmental and reproductive biology of *Scirtothrips perseae* Nakahara, was determined in the laboratory at five constant temperatures, 15, 20, 25, 27.5 and 30°C. At 20°C, *S. perseae* exhibited greatest larval to adult survivorship (41%), An upper developmental threshold was estimated at 37.6°C with an optimal temperature of 30.5°C for egg to adult development Feeding damage by adult and larval *S. perseae* to young leaves causes distortion, and brown scarring along the midrib and veins on the leaf underside becomes increasingly visible as leaves mature. Thrips larvae and adults also feed on developing fruit. (Hoddle 2002).

The detection in August 2015 of the Oriental Fruit Fly. Post harvested treatment was given which include treatments that combine methyl bromide, fumigation and cold storage periods six avocado varieties were tested from Florida. Damage was attributed to the fumigation component of the treatment, but the six varieties tolerated the cold portion of the treatment. Damage by fumigation ranged from 26% - 100%. In general, the longer the fumigation period worse would be the effect on fruits (Carrillo et al. 2017).

In Florida, avocado were attacked by two to three key pests which are currently controlled through the use of chemical products. This practice continues despite the presence of several native biological control agents for some insect pests such as mirids, avocado lace bug, and several attempts to introduce exotic biological control agents. Timid efforts on the development of IPM include determining economic thresholds for the avocado mite and sampling techniques for mirids and loopers (Peña et al. 2003).

Susceptibility of avocado to infest by oriental fruit fly. Laboratory, field no choice cage test were done, risk of infestation was negatively correlated with fruit firmness, about 50% of mature hard fruit exposed immediately after harvest became infested. Field sampling of fallen 'Malama' fruit over two seasons showed no natural infestation by *B. dorsalis* which make Malama avocado to export from Hawaii to the continental United State (Follett et al. 2022)

A survey of insect damage to avocado fruits of five cultivars, was conducted at eight pack houses in the Nelspruit/Hazy view region. Stink bugs, coconut bug, fruit fly and thrips and false codling moth were the most important pests responsible for 84.10% of the damage recorded. It confirms the importance of the above five pests and the seasonal variation in pest attacks between cultivars. Hass showed the greatest overall incidence of insect pest attack. The insect pest-complex was increased with the addition of three new pests recorded as damaging, or present on, avocado fruit (Erichsen & Schoeman 1992).

The *Latania* scale is considered a significant insect pest of avocados in California. Its population has experienced a rapid increase in recent years, leading to damage in numerous orchards. Typically, the scale infests branches and twigs in large numbers, but as the infestation progresses, it can also affect the leaves and fruit. In severe cases, heavily infested smaller branches may die off. The presence of scales on the fruit's rind negatively impacts its market quality. As the fruit ripens, the insects create protrusions that extend from the rind into the flesh. Consequently, when the rind is removed, corresponding depressions are left in the flesh (McKenzie 1935)

3. MATERIALS AND METHODS

3.1 The Study Area

Dhankuta is located in Eastern Nepal. Dhankuta is a hill town, located in the middle of the country. It has co-ordinates of 26°59'0" N and 87°20'0" E. The district has a total area of 888.7 sq.km and is situated between 243 m and 629 m above sea level. The district vegetation zones range from subtropical sal forests along the Tamor and Arun rivers to colder temperature forests on parts of the district's high peaks, which serve as a watershed between the two catchments. The elevation varies between 300 m and 250 m. Agriculture employs the majority of people. Dhankuta has been known for its oranges and other citrus fruits for a long time. The trend, however has shifted in the last decade, with avocados taking the lead. Farmers in Dhankuta have been progressively focusing on avocado cultivation and production, encouraged by the potential financial benefits of avocados in recent years. Dhankuta's local government designated the district the 'Avocado Capital' of Nepal in 2018 (Adhikari 2018).

This research will focus specially on the pest found on avocado trees, degrading the quantity and quality of fruit and plant. Study on the severity of pest infestation in different parts of plants, which will be helpful to target the pest problem and put forward the most relevant pest management policies for better productivity. This research can also be helpful for those who are interested in related field.

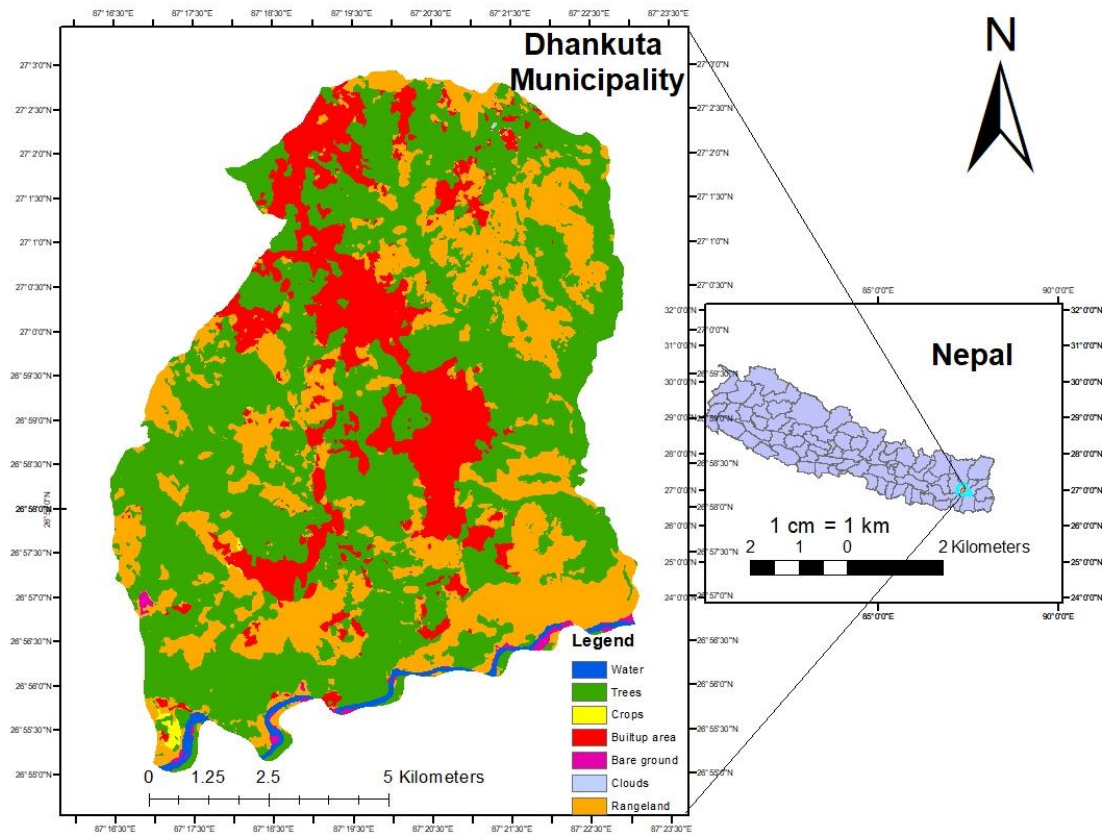


Figure 1. Map of Dhankuta Municipality.

3.2 Materials

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

3.3 Research Design

Avocado pocket area of the Dhankuta Municipality was selected for the study. There were total 27 commercial orchards altogether. 20% of it was chosen for the sampling unit, which consists of five orchards. Five orchards selected were on the basis of largest, smallest, oldest, and newly formed and orchard at the center. Insect samples was collected from both pheromone and light traps with their respective lures in the fruiting period (Nov to Dec).

3.4 Field Techniques

3.4.1 Pest's Detection

Direct and close observation of sample trees and affected plant parts (leaves, twigs, tree trunk, flowers, buds, fruits) signs and symptoms of damage

(defoliation/skeletonizer, leaf mining, leaf rolling, borers, mud galleries, gall producing, seed feeding, sap sucking) timing of the infection was noted in the field datasheet. General pest status information of avocado orchards were gained from direct observation method.

3.4.2 Pheromone Trap

Yellow bucket trap was used which is an attractant for monitoring of the oriental fruit fly by placing commercial lure. The trap was placed at the middle of the orchard, two meter above the ground level. Trap was set for one month and 15 days (Nov 1 to Dec 15, 2022) and insect samples was collected from the trap in every 15 days. Collection was done three times.

3.4.3 Light Trap

In addition to the pheromone trap, other method light trapping for insect collection was also used. Florescence bulb of 30 watt was used in light tapping tool. Tool was set in the middle of the five sampled avocado orchards at first canopy of the tree for overnight time period from sunrise to sunset. Light trapping method was used to collect insects during fruiting period (Nov 21-25, 2022). Insect trapped in the trap was caught in a killing bottle. Once killed, insects was transferred to either paper bags/envelope moths) and container with 90% ethanol (bugs, beetles and other insects) along with data label.

3.4.4 Infestation Assessment

Randomly five infected trees were selected for the experiment, from which each of its single branch's leaves were counted with the categorization of total leaves, damaged leaves, defoliation and discolouration of leaves. Branch was selected on the basis of its damaged level.

3.4.5 Questionnaire Survey

All 27 head of the orchards were interviewed using semi-structured questionnaire to get the information on the pest infestation and yeild loss, local control measures.

3.4.6 Sample preservation and Identification

Collected sample was preserved by both dry and wet method according to the requirement of species for further identification and study. Sample was collected in a killing jar and preserved in ethyl alcohol. Species whose requirement was dry preservation was preserved in a paper fold. Further the preserved sample was kept in refrigerator. The preliminary examination for the identification of specimen was done by using the standard taxonomic. Further examination was done by studying their morphological characteristics under the microscope (stereoscope) in CDZ laboratory. Family level of identification was done by using Borror and DeLong's Introduction to the study of insects (Borror and DeLong's, 2004). The confirmation of the pest identification on genus/ species level were done by comparing the characteristics of the samples with the original description (Sarkar et al. 2014; Britton, 1978; Wunderer, 1990; Chen et al. 2022 & Knight, 1918).

3.5 Statistical Analysis

The raw data collected was initially recorded in MS Excel (2013) and subsequently imported into other statistical software for advanced analysis. (PAST v 4.03) software and R programming (R Core Team 2022) was used to analyze the data. PAST was utilized to compute diversity indices from Shannon- Weiner Index whereas R programming was used to analysis the level of pest infestation data. Chi-square test was done for evaluating the data. Furthermore, the relative abundance of each organism was calculated, indicating the percentage composition of an organism relative to the total number of organisms present in the study area. It was calculated by using the formula,

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

Where,

n= Number of each individuals

N=Total number of individuals

4. RESULTS

4.1 Insect Pest Abundance in Sampled Avocado Orchards.

Altogether 1,693 individual were collected from both pheromone and light trapping technique in which four order of insects were trapped Diptera (1,465), Coleoptera (111), Hemiptera (62) and Lepidoptera (55). Highly abundant insects order were found Diptera in avocado orchards of Dhankuta.

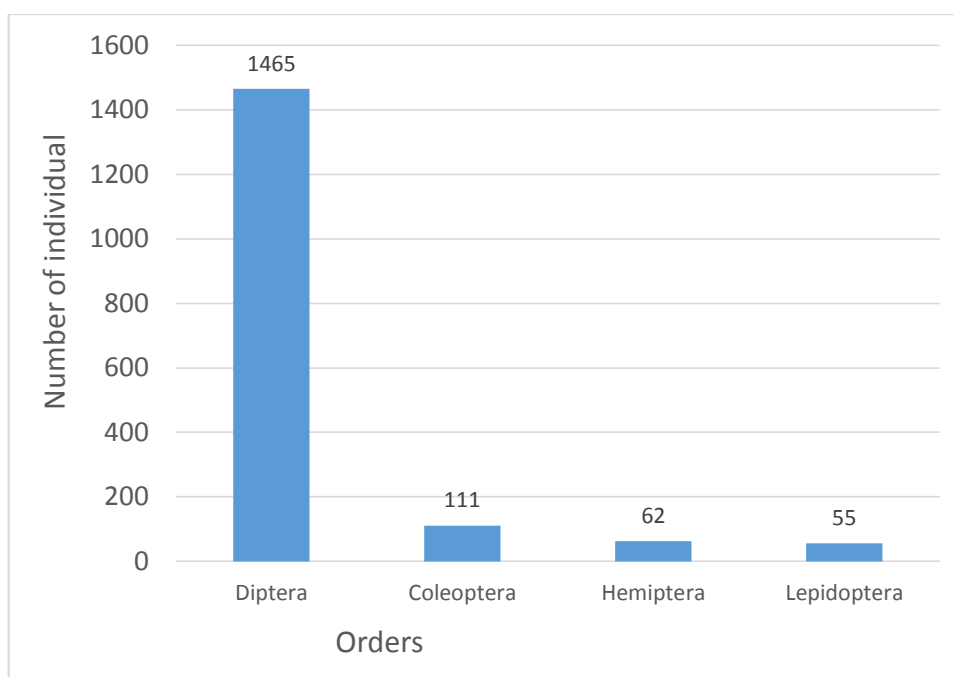


Figure 2. Abundance of insect order in five sampled avocado orchards

From the calculation of Relative abundance (%) Fifth orchard shows high abundance in order Diptera, Coleoptera and Lepidoptera whereas fourth orchard shows high abundance in order Hemiptera (Table 1.)

Table 1. Relative abundance of insects order of five sampled avocado orchards

Order	Relative abundance (%)				
	Orchard 1	Orchard 2	Orchard 3	Orchard 4	Orchard 5
Diptera	18.36	20	22.18	16.86	22.59
Coleoptera	13.51	18.91	24.32	15.31	27.92
Hemiptera	14.51	20.96	17.74	27.41	19.35
Lepidoptera	12.72	23.63	14.54	20	29.09

4.2 Insect Pest Species Diversity in Sampled Five Avocado Orchards

From the statistical analysis (Shannon-Weiner diversity index) high level diversity of species were seen from all five orchards but in comparison the most species diversity were observed from fourth orchard with H value 1.61 and lowest species diversity was observed from third orchard with H value 1.49.

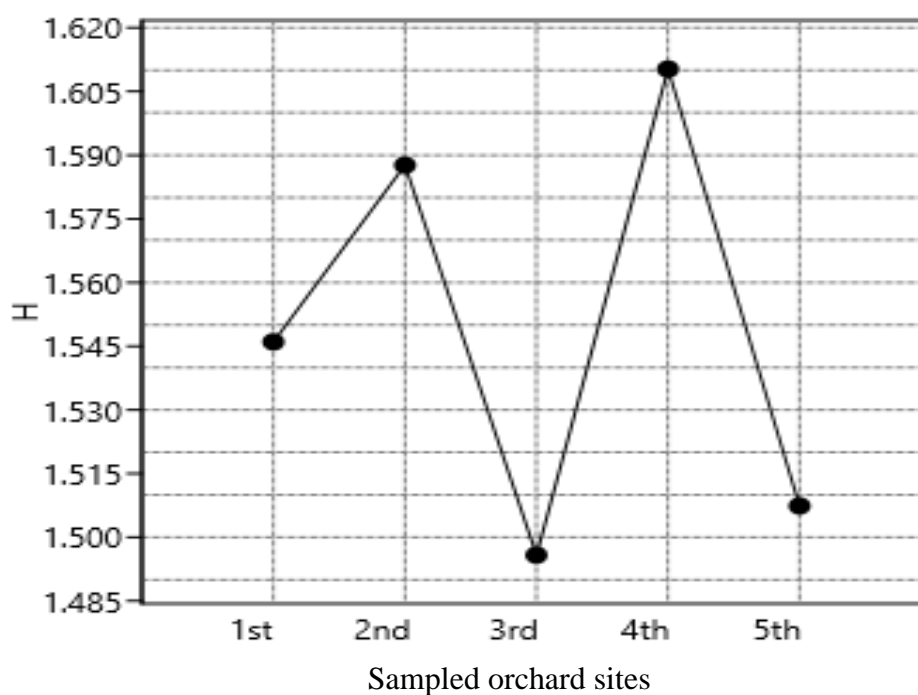


Figure 3. Species diversity of five sampled avocado orchards.

4.3 Assess Severity Level of Pest Infestation in Avocado Plants.

Table 2. Experimental data of assessment of the pest infestation.

S.N	Total leaves	Damaged leaves	Defoliation	Discoloration
1.	123	56	38	18
2.	183	94	59	35
3.	96	61	28	33
4.	148	71	46	25
5.	84	49	20	29

Analysis showed that there is significant association between the presence of insect pest and leaves damage as the chi-square statistic is 14.02, with 4 degrees of freedom and a p-value of 0.007233.

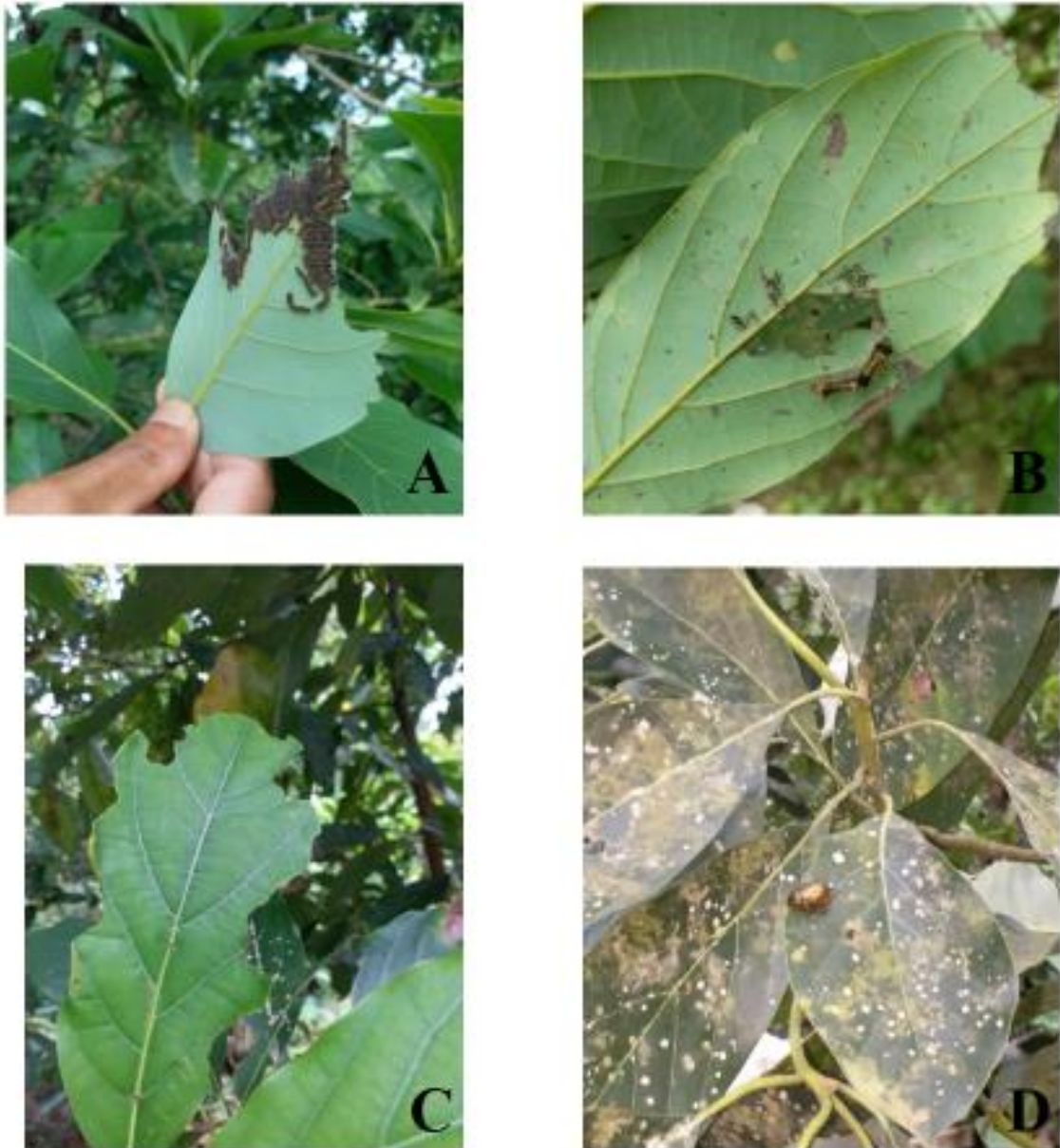


Figure 4. Insects pest damaging avocado leaves (A) Larva feeding on young avocado leaf (B) Larva defoliating avocado leaf (C) Defoliation of leaf (D) *Anomala dimidiata* feeding on upper side of avocado leaf.

4.4 Control Measures Applied by Local Farmers

From the questionnaire survey, control measures used by local farmer's data were collected in which farmer's preferable control measure were cultural method followed by Chemical and Biological methods.

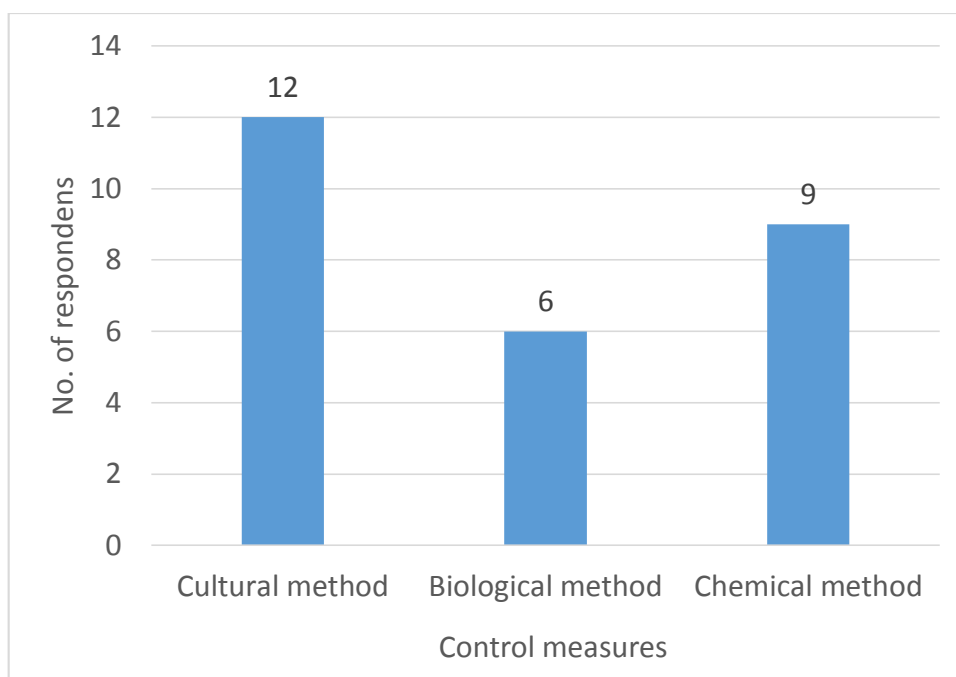


Figure 5. Control measure used by local farmers.

Table 3. List of Pest species

Order: Coleoptera/ Family: Scarabaeidae		
S.N	Name of species	Diagnostic features
1.	<i>Anomala dimidiata</i>	Apple green in color, ventral surface and legs black or blue green, broadly oval.
2.	<i>Xylotrupes gideon</i>	Shiny dark brown in color, they have two chitinous bifurcated horns, a thick thoracic horn and smaller cephalic horn.
3.	<i>Cyphochilus</i> sp.	Whitish in color, elongated and slightly flattened body shaped, robust legs.
4.	<i>Maladera affinis</i>	10-12 mm in length, shiny metallic appearance, elytra may have distinctive patterns, segmented antennae, pronotum is often wider than head.
5.	<i>Canthidium</i> sp.	Elongated body, black or dark brown exoskeleton, chewing mouthparts, segmented antennae.

Family: Cerambycidae		
6.	<i>Apriona germari</i>	Elongated and cylindrical body, 2-4 cm in length, brown in color, long antennae, pronotum wider than head, and have yellowish margin.
7.	<i>Monochamus</i> sp.	Dark brown or black exoskeleton, elytra may exhibit patterns or marking, antennae longer than their body, presence of long and spiky appendages on their thorax.
Family: Tenebrioninae		
8.	<i>Leprocaulus</i> sp.	Medium in size, yellowish in color, antennae usually long than body size.

Order: Hemiptera/Family: Miridae		
9.	<i>Deraeocoris</i> spp.	Medium sized bug, green brown or grey tone or cryptic color, antennae long and slender.
10.	<i>Psallomorpha</i> sp.	Elongated and flattened body, medium sized, green, brown or grey in color.
11.	<i>Lygus</i> sp.	Small sized, brown or grey in color, they have distinctive marking or patterns on their body.
Family: Pentatomidae		
12.	<i>Aeschrocoris</i> sp.	Brown in color, having stout in both side of pronotum, body contain black marking.
Family: Aradidae		
13.	<i>Aradus</i> sp.	Medium sized, brown, black or grey in color, distinctive pattern in their body or wings, antennae long and slender.
Family: Flatidae		
14.	<i>Siphanta</i> sp.	10 mm in length, green in color, short antennae.

Family: Cicadellidae		
15.	<i>Aphrodes</i> sp.	Small sized, green in coloration, pronotum elongated.
Family: Corixidae		
16.	<i>Corixa</i> sp.	Medium sized, streamlined body shape, gray or green in color, short antennae.
Order: Lepidoptera/ Erebidae		
17.	<i>Cretonotos transiens</i>	20-30 mm in length, forewings narrow and elongated, grayish brown with dark patterns or band, broader hindwings, filamentous antennae.
18.	<i>Miltochrista linga</i>	25-30 mm in length, narrow forewing with pointed tip, brown in color, wings have pale or whitish marking.
19.	<i>Miltochrista</i> sp.	Medium sized, brown color with distinct pattern, spots or lines on wings.
20.	<i>Anomis</i> sp.	Small sized, triangular in shape, reddish in color, body generally stout, filamentous antennae.
Family: Noctuidae		
21.	<i>Amphipyra</i> sp.	Have broad forewings and narrow hindwings, gray, brown or reddish in color, abdomen have specific pattern.
22.	<i>Eupterote</i> sp.	Have broad, triangular forewings and narrower hindwings, brown, gray, white or red in color.
Order: Diptera/ Tephritidae		
23.	<i>Bactrocera dorsalis</i>	Medium sized, 5-8 mm in length, has yellowish brown thorax and abdomen,
24.	<i>Bactrocera correcta</i>	6-8 mm in length, wings have characteristic pattern of dark and light spots.

25.	<i>Bactrocera scutellaris</i>	Abdomen contain distinctive marking or pattern, yellowish in color, 6-8 mm in length.
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Figure 6. Insect pests of avacado (A) *Anomala dimidiata* (B) *Cyphochilus* sp. (C) *Miltochrista linga* (D) *Cretonotos transiens* (E) *Aradus* sp. (F) *Aeschrocoris* sp.



Figure 7. Identified species (A) *Stenolophus* sp. (B) *Lygus* sp. (C) *Leprocalus* sp.
(D) *Amphipyra* sp. (E) *Aphrodes* sp. (F) *Dromius* sp.

Table 4. List of Non pest species

Order: Coleoptera/Family: Carabidae		
S.N	Species	Diagnostic character
1.	<i>Harpalus</i> sp.	Elongated and flattened body, robust leg, body narrower than pronotum, black brown or metallic in color.
2.	<i>Dromius</i> sp.	Elongated and narrow body shaped, short elytra, black or brown in color.
3.	<i>Stenolophus</i> sp.	Flattened body, head narrower than pronotum, brown and black to metallic in color.
Order: Diptera/ Family: Diptera		
4.	<i>Musca domestica</i>	Oval shaped body, 7 mm in length, eyes are reddis brown in color, body grayish in color.

5. DISCUSSION

A total of 1,693 individuals were captured from the field area using pheromone and light trapping techniques. The fruit fly species trapped in the pheromone trap were *Bactrocera dorsalis*, *B. correcta* and *B. scutellaris* among these three species *B. dorsalis* were the most abundant species with total 978 individual. Coleoptera, Hemiptera and Lepidopterans insects order were trapped in the light trap. Species diversity was observed from the Coleoptera order with 11 species in it. *Anomala dimidiata* were the pest found most abundant in comparison to other. Experiment was held in five selected orchard were the abundance of species were observed in fifth orchard while the species diversity were observed in fourth orchard. Infestation level was also calculated in which leaves infestation were found to have significant association between the presence of insect pest and leaves damage with p-value 0.007233. For the control measures of avocado pests farmers were recorded using cultural method in which included sanitation and pruning techniques.

The fruit fly species *Bactrocera* was caught in pheromone trap in the avocado farm for one and half month. Three species *B. dorsalis*, *B. correcta* and *B. scutellaris* were trapped in which most abundant species found was *B. dorsalis*. This shows that avocado is at high risk to get infest by *B. dorsalis* and should receive considerable control efforts. Higher abundance of the oriental fruit fly in this research supports the study by (Grove 2018) Natal fruit fly species were trapped in very low number whereas higher number of Oriental fruit fly were trapped in all the orchards with Invader-Lure™ and producers are advised to use the male annihilation technique for the Oriental fruit fly, to monitor fruit fly species and inspect fruit for lesions. *B. dorsalis* and *Ceratitidis* spp. was included as major pest of avocado (Ekesi et al. 2006). As in this survey fruit flies were trapped from the elevation of 1,200 m, further supports the study of (Ekesi 2008) in which *B. dorsalis* were characterized as lowland pest. Vegetation involves in medium and low landscape are at high risk infestation area from *B. dorsalis*. It was the dominant species reared from avocado in Taita Hills (Kenya), thus making avocado the main host plant for *B. dorsalis* (Odanga et al. 2018). Orchard sanitation has been promoted as part of integrated pest management (IPM) for the suppression of *B. dorsalis* in East Africa by (Ekesi et al. 2016). Fruit flies not only lead to direct loss of fruit but also result in significant export losses due to non-traffic trade barriers. The presence of quarantine

pests like *B. dorsalis* in avocado fruit has led to phytosanitary restrictions on their export, thereby reducing market opportunities for Kenyan avocado exports to the EU. This information has been reported in studies conducted by (Johnny et al. 2019; Wanjiku et al. 2020).

Insect species collected from light trapping technique in five avocado orchard which was placed overnight. Insect order coleoptera, hemiptera and lepidoptera were trapped in which most abundant order found was coleopteran. (Holguin & Mira 2021) conducted nocturnal inspections at various sampling sites and observed that *A. pygidialis* was feeding on small fruits, young shoots and leaves. The researchers confirmed in the laboratory that the feeding injury was caused by this species. Along with *P. obsoleta*, *P. menetriesi*, *A. undulata* and *A. cincta* (Holguin & Mira 2021) identified *Astaena* aff as one of the scarab beetles (melothinae) responsible for damaging fruits and leaves. In this study Scarabaeidae family beetles were trapped which could be the major cause for the damage of avocado leaves and fruits. *Anomala dimidiata*, *Xylotrupes gideon* species were most collected. Not only in leaves and fruits but also beetles hold the capacity to damage its flowers, tender buds and stem too (Valencia et al. 2019). Our result concluded that Coleopteran species *Anomala dimidiata* is causing much damage in avocado plant at orchard located in Dhankuta. *C. xyliana* species was observed feeding on pollen and nectar causing a significant damage (Carabali et al. 2016). Here in this study Coleopteran family Scarabaeidae, Melothinae, Cerambycidae and Tenebrioninae were found as pest of avocado. Our finding contrast with other studies that report a Coleopteran complex causing damage to avocado fruit and leaves. *Xylophagous* longhorn beetles are documented as attacking avocado. In Hawaii, the invasive longhorn beetle *Acalolepta aesthetica* is an emerging pest of avocado (Matsunaga et al. 2019). *Monochamus* sp. and *Apriona* sp. recorded from Dhankuta's avocado orchard which was categorized as an important polyphagous pest (Ernstson et al. 2021).

Here, six families of Hemipteran were found in avocado orchard Miridae, Pentatomidae, Aradidae, Flatidae, Cicadellidae and Corixidae (García-Palacios et al. 2016) In Colombia, there are three types of whiteflies that are known to cause damage to avocado fruit. These whiteflies are likely to be indigenous to Latin America, specifically the Caribbean, Central America, Florida and Mexico, as evidence by the presence of specimens from regions (Nakahara 1995). In Dhankuta whiteflies were not

recorded during the research cause may be due to the difference of continent and climatic condition. (Joubert & Claasen 1994) identified seven species of Pentatomidae and two species of Coreidae pest causing damage in fruits of avocado which supports this study were Pentatomidae pest species were found in most abundant among the Hemipteran order, this highlight that fruits damage like darkening of skin, scars in fruits may have been caused by these pests. Through light trapping less number of Lepidopteran species were trapped may be due to the season (winter) of research periods limited this study. Moreover, the most abundant family found were Erebidae followed by Noctuidae and Eupterotidae. From Erebidae family a tussock moth, *Bracharoamixta* (Snellen), is reported for the first time on avocado trees, scarring fruit and defoliating leaves. Feeding damage by the larva results in corky tissue development, making the fruit unsuitable for export (Bara & Laing 2020). Majority of lepidopteran species are considered economically important due to phytophagous larvae (Feng et al. 2010). Despite the insect pest other animals were also found causing damage to the avocado fruits like squirrel, monkey, bat and crow. These animals were observed feeding on avocado fruits causing different kinds of damage in its fruits.

Different insect pest species were found from the avocado orchard which damages the plants part in various ways, the infestation seen in the plants were defoliation in the leaves, discoloration of the leaves, scars on fruits, damage on stem and so on, as these problems were observed an experiment was held to know the severity level for pest infestation in plants. Analysis were done with the data and was concluded that there is strong association between damage of plants parts and insect pests. According to the findings of (Rioja et al. 2016) when mite populations are more abundant and continuously feed on shoots, the level of infestation in the shoots increases. Several other studies have also discovered that avocado fruits as well as various parts of the tree such as leaves, petioles and branch sections, emit certain volatile organic compounds (BVOCs). These studies specifically investigated the Melendez cultivar, as well as the Criollo and Drymifolia varieties (Torres-Gurrola et al. 2011). Avocado leaves were examined to know various level of feeding injury caused by the avocado brown mites and concluded that mites feed from the upper leaf surface that reduce the photosynthesis rated by 56% (Sances et al. 1982). For the eradication of pest farmers have been using some of the control measures like cultural method, irrigation management and chemical pesticides in which most commonly used method is cultural method because it is cost

effectiveness and well known among the farmers. In the context of avocado pest control, conventional methods involving spraying and fumigation with chemical pesticides have been employed. However, reports have indicated that excessive use of pesticides, such as DDT can lead to the elimination of natural enemies of pests. Consequently, there has been a shift towards prioritizing biological and cultural methods for pest control, which rely on non-chemical means. This shift is driven by the recognition of the negative impacts of chemical pesticides on the ecosystem and the importance of preserving natural pest control agents (Fleschner 1954).

Detecting the pest species, evaluating its infestation level in the plants part and looking for the control measures of the pest. All these observation and assessment are interlinked with each other and the information gained from the assessment can be very beneficial for the pest detection and management.

6. CONCLUSION AND RECOMMEDATION

Dhankuta is declared as the capital of Avocado by the local government. The types of avocados that are primarily cultivated in the research area hold great significance. The avocado insect pests in Dhankuta were dominated by fruitflies followed by beetles, bugs and moths. Three Fruit fly species *Bactrocera dorsalis*, *B. correcta* and *B. scutellaris* were found among which the *B. dorasalis* was most abundance species. *Anomala dimidiata* species from order coleoptera was also observed as key pest in this region. More than chemicals pesticides cultural methods are used to control insect pest. Also there is significant association between the damage of avocado leaves and insect pest.

Based on the results of the entire study following recommendations are made:

- More exploration on the pest status of avocado is required.
- Farmers should get knowledge about current pests, their mode of destruction, possible measures to restrict pest population growth etc.

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APPENDICES

Appendix I: Materials required

- Commercial Pheromone traps
- Light trapping tool
- Alcohol, ethyl acetate
- Cotton, gloves, forceps
- Killing jar
- Vials
- Stationary (Notebook, pen, pencil)

Appendix II: Diversity indices of insect pests of five avocado orchard.

	Orchard 1	Orchard 2	Orchard 3	Orchard 4	Orchard 5
Taxa_S	16	20	17	19	21
Individuals	310	340	372	292	393
Dominance_D	0.3066	0.3422	0.357	0.3398	0.3999
Simpson_1-D	0.6934	0.6578	0.643	0.6602	0.6001
Shannon_H	1.546	1.588	1.496	1.61	1.507
Evenness_e	0.2933	0.2446	0.2625	0.2634	0.215

(Source: PAST v 4.03)

7. If yes, can you please list the problem?

- a)
- b)
- c)
- d)
- e)
- f)

8. Have you seen any animals, birds or insects damaging Avocado's tree, flower, fruit etc?

Name of Animal	Types of damage	Stage of damage	Timing of damage	Remarks

9. Does any kind of natural or climatic condition affect the growth of avocados tree? If yes what are those conditions:

.....
.....
.....

10. Have you seen any new animal or pest you have not seen earlier? If yes, give details

.....
.....

11. Have you ever faced any major loss in cultivation?

.....

12. Do you get any technical/ financial support from any organization for avocado's cultivation/ marketing?

.....

13. Any kind of pest control method you are using?

.....

.....

.....

Avocado Insect Pests: Symptoms and Severity

Name of Insect Pest	Symptoms of Insect attack	Severity of Impact	Emergence time	Remarks
	1. Defolitation 2. Sap sucking 3. Leaf mining 4. Leaf roller 5. Gall producing 6. Bud eating 7. Tuber 8. Fruit eating 9. Fruit decay	1. Very low (0-5%) 2. Low (6-10%) 3. Medium (11-20%) 4. High (21-30%) 5. Very high (>30%)		

PHOTO PLATES



Photo plates: (A) Preserved sampled, (B) Preserved sampled, (C) Pheromone trap (D) Light trap (E) Light trapping tool (F) Mites infected avocado leaves.