ADDIS ABABA UNIVERSITY

College of Natural and Computational Science

School of Graduate studies

Department of Zoological Science

TITLE: INVESTIGATION OF EFFECTS OF INSECTICIDES ON BEEKEEPING AT SEBETA, OROMIA REGION, ETHIOPIA

A Master's Thesis Submitted to The School of Graduate Studies Of Addis Ababa University In Partial Fulfillment Of The Requirements For The Degree Of Masters Of Science In Biology (Insect Science)

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August, 2025

Addis Ababa, Ethiopia

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Declaration

I hereby declare that this thesis project entitled "**Investigation of Effects of Insecticides On Beekeeping at Sebeta, Oromia Region, Ethiopia**" has not been previously submitted for any degree in any other university and that all sources of materials used for this thesis have been dully acknowledged .

Declared by: Tejitu Tesfaye

Signature____________________

Date________________________

Advisor's approval form

College of Natural and Computational Sciences

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This is to certify that the thesis prepared by Tejitu Tesfaye entitled that "INVESTIGATION OF THE IMPACTS OF PESTICIDES ON BEEKEEPING AT SEBETA, OROMIA REGION, ETHIOPIA" I recommended the thesis submitted for oral defense.

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As members of the board of examiner's, we examined this thesis entitled" INVESTIGATION OF THE IMPACTS OF PESTICIDES ON BEEKEEPING AT SEBETA,OROMIA REGION,ETHIOPIA" by Tejitu Tesfaye, we hereby certify that the thesis is accepted for fulfilling the requirements for the award of degree of Master of Science in Biology.

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ACRONYMS/ABBREVIATIONS

IPPM: integrated pest and pollinator management

GDP: Gross domestic product

FS: Family size

CSA: Central Statistical Agency

KIIs: Key Informant Interviews

FGDs: Focus Group Discussions

ABSTRACT

Beekeeping is an essential farming practice in Ethiopia with significant contributions to rural livelihoods, environmental equilibrium, and plant pollination. However, intensive use of insecticides poses a serious threat to sustainable apiculture. The present study analyses the effects of the use of pesticides on beekeeping operations and honeybee health in four purposively selected kebeles—Furi Gerabollo, Sebeta Atebela, Dimma, and Caffe Hora—in Sebeta district, Oromia Region. Data were collected through a standardized questionnaire of beekeeper households, key informants like agriculture experts from total of 180 respondents. Findings show that 81% of beekeepers reported pesticide application near their apiaries, with 77% observing increased bee mortality and 61% reporting hive colony loss or absconding in recent years. Four prevalent agrochemicals were encountered in use: Megaban 48 EC (chlorpyrifos-ethyl), Herb 720 SL (2,4-D amine salt), Matco (a general-purpose product), and Glymax (glyphosate). These pesticides, especially when sprayed at flower stage of crops, were most directly implicated in colony losses experienced. Ground spraying such as chickpea, lentils (56.1%) and aerial spraying such as wheat,teff (39.4%), methods known to increase pesticide drift to secondary locations like bee forage and hive sites, comprised most applications. Though most farmers used pesticides only 1–3 times annually, they tended to coincide with the peak activity of bees and thus insulted injury. Institutional support was also deficient since only 14% were offered technical advice, whereas 68.3% were not notified in advance before spraying. Interviews and photo data further confirmed ecological hazards and economic losses for smallholder beekeepers. The study concludes that pesticide application is a primary driver of the declining health and productivity of bees in Sebeta, and that beekeeping in the district continues to be extremely sensitive unless regulatory control, improved farmer training, and community-based protection measures are applied. Thus, the study calls to attention an urgent policy need, education of farmers, and promotion of safer alternatives like biopesticides to offer sustainable apiculture and protect pollinators in agroecosystems.

Keywords: Beekeeping, pesticides, Chlorpyrifos, Glyphosate, 2,4-D, Agrochemical drift, Honeybee mortality, Colony collapse, Sebeta, Oromia, Pollinator health, Biopesticides, Ethiopia

CHAPTER ONE

1. INTRODUCTION

1.1. Background

Beekeeping, also technically known as apiculture, is a vital agricultural practice in Ethiopia, accounting for 1.3% of agricultural GDP through generating millions of dollars in revenue each year (Degu & Megerssa, 2020). Honey and beeswax are important export commodities. Beekeeping provides a source of income for over one million practitioners, many of whom are rural inhabitants. This practice not only contributes to household income but also plays a significant role in pollination of crops, which is essential for agriculture and food production in the region (Begna, 2014; Tekle, 2018). Ethiopia is one of the top ten honey-producing nations in the world and a major producer of honey in Africa (Legesse, 2014). It is estimated that around six million bee colonies maintained by more than one million beekeepers accounted for this massive beekeeping practice (Beyene & Research, 2014; Tekle, 2018). According to Fikru (2015) Ethiopia has the largest bee population in Africa with over 10 million bee colonies, The annual honey production of Ethiopia is estimated to be 45,300 metric tons which makes the country to rank first honey producing country in Africa and ninth in the world. Beekeeping is an animal husbandry activity that can be performed without being dependent on the soil, carried out in harmony with other agricultural activities, and considered to be the second source of income for households in Ethiopia. Honey production increased from 1,172,611 tons in 1990 to 1,851,541 tons in 2018 (Merdan. *et al.* 2021).

The extensive beekeeping practice is attributed mainly to Ethiopia's diverse agro-climatic conditions, which are conducive for beekeeping, and the abundance of bee forage plants. Because beekeeping can be practiced in small area with inexpensive equipment, any individual from a young child to an elderly person including those landless peasants can manage it without special education or training. However, the apicultural sector is well below its potential due to various obstacles (Gratzer *et al.*, 2021).

Most beekeepers in Ethiopia, as in southwest Ethiopia, use hives made from natural materials, such as wood, clay, and straw, and they do not use modern beekeeping techniques. This traditional beekeeping systems, which accounts for 96% of bee farming practice, is limited to contemporary hive equipment and management techniques. This resulted poor or no management strategies and led to lower honey yields and higher colony losses (Beyene & Research, 2014; Gratzer et al., 2021;

Tesema *et al.*, 2023).

Despite the significance bee farming to the livelihood of the community, habitat loss, climate change, and extensive use of pesticides or agrochemical are posing pressing threat to honeybees. pesticides are widely used in Ethiopia to control pests, weeds and rusts/fungus, which are linked to adverse effects on pollinators, particularly to bees (Tesfaye et al., 2021). Their widespread applications of diverse pesticides such as neonicotinoids and others, poses a direct threat to bee populations. When bees come into contact with pesticides, they can be poisoned, which can lead to death. These chemicals can have lethal and sublethal effects on bees, ranging from direct mortality to impaired foraging behavior and navigational disorientation. Even low doses of pesticides can weaken bees and make them more susceptible to disease. The systemic nature of some pesticides means they can contaminate nectar and pollen in treated plants, inadvertently exposing bees to toxic residues (Crall et al., 2018; Fikadu, 2020a; Lämsä et al., 2018).

The decline of bee populations can have multifaceted consequences with far-reaching implications for both food security and the livelihoods of beekeepers. Bees are responsible for pollinating a substantial portion of the world's crops, including staples like rice, wheat, and corn, as well as nutrient-rich foods such as apples, berries, and almonds (Saleem et al., 2023). A decrease in bee populations can lead to reduced crop yields and lower-quality produce. This not only threatens the availability of food but can also impact its affordability as decreased supply often results in higher prices. In essence, the reliability of food sources and the nutritional diversity of our diets are intrinsically linked to the well-being of bee populations (Fikadu, 2020a; Mengistu & Beyene, 2014).

In addition, the livelihoods of beekeepers are intimately tied to the health of bee populations. Beekeepers rely on thriving colonies to produce honey, beeswax, and other bee-related products, which constitute a source of income. When bee populations decline, the productivity of hives is compromised, impacting the economic stability of beekeepers (Mullié et al. 2023). Furthermore, increased bee health challenges can lead to higher maintenance costs and the need for greater intervention to sustain colonies. This affects the sustainability of beekeeping as a profession and, consequently, the income and job security of those engaged in apiculture.

Beyond the scope of agriculture, the effects of pesticides on bees are show broader environmental concerns. Bees serve as indicators of ecosystem health, and any decline in their populations is often a sign of broader ecological imbalances. Understanding these effects not only helps protect bees but also contributes to the preservation of diverse ecosystems and reinforce the critical role that insects play in maintaining ecological stability. It is important to understand the effects of pesticides on beekeeping in Ethiopia as it is imperative for achieving sustainable agricultural practices and ensuring healthy environment.

1.2 Objectives of the study

1.2.1. General Objective

To investigate the potential impacts of pesticides on beekeeping in the Furi and Sebeta sub-cities.

1.2.2. Specific Objectives

1.To identify the types of pesticides used, application methods and frequency of application.

2.To assess the effect of pesticide application on bee biology behavior, productivity in Furi and Sebeta subcities.

1.3. Research Questions

What are the types of pesticides application methods and frequency of applications used in Furi and Sebeta subcities?

What is the effect of pesticide application on bee biology, behavior and productivity in Furi and Sebeta subcities?

1.4. Statement of problem

A number of studies have been conducted on the effects of pesticides in bees. These studies have shown that pesticides have a negative impact on survival of honeybee populations (Favaro *et al.*, 2023). A better understanding of the types of pesticides that are being used in Furi and Sebeta sub cities and their impact on bee population. In addition, it promotes global awareness on the complex relationship between pest control, pollinator protection, and sustainable food systems. Understanding the effects of pesticides on beekeeping is essential for the conservation of pollinators, the sustainability of agriculture, and the livelihoods of local beekeepers.

.CHAPTER TWO

2. Literature Review

2 .1 .The Honey Bee

Honeybees are social insects that belong to the genus *Apis* in the family Apidae, order Hymenoptera, class insecta, phylum Arthropoda. Honeybees are characterized by metamorphosis, change in appearance of the body at various stages of life, highly organized colonies and certain functional qualities that, to a greater or lesser extent, allow pollination services. The most recent phylogenetic study places bees into seven families and 28 subfamilies. From all species *Apis mellifera* naturally occurs in a variety of locations. The population has adjusted to the specific geographic region in accordance with the different climatic conditions. *Apis cerana* and *Apis mellifera* are the only two Apis species that humans have tamed owing to their hidden nesting behavior (Johnson, 2023, Yadav *et al.*, 2017). Honeybees, including Ethiopian honeybees, are remarkable insects with a profound impact on environment, ecosystems, and food systems. Understanding their biology, life cycle, and importance is essential to appreciating the vital role they play in our world (Johnson, 2023)

2.1.1. Social organization and life cycle of honeybees

Social insects are distinguished by a division of labor in reproduction where only one or a small number of individuals (usually queens) lay eggs while all other individuals (workers) carry out all other non-reproductive functions in the colony. At the apex of the colony is the queen, a large and powerful bee responsible for the reproduction of the entire colony. She can lay more than a thousand eggs per day and emits pheromones that regulate the behavior and harmony of the hive. The queen bee's role is critical, as she is the sole egg-layer and the matriarch of the colony (Johnson, 2023; Shpigler *et al.*, 2022). Worker bees are the females in the colony and constitute the majority of its population. Their tasks are diverse and demanding, including tending to the queen, foraging for nectar and pollen, constructing and maintaining the hive, and safeguarding it from intruders. Worker bees have a well-defined life cycle, transitioning through various roles as they age, reflecting the dynamic nature of their society. The drones are the male bees of the colony, and they serve a unique purpose—mating with queens from other colonies. Drones lack stingers and do not engage in tasks like foraging for food or defending the hive. Their sole existence is focused on their role in reproduction (Johnson, 2023; Shpigler *et al.,* 2022; Yadav *et al*., 2017).

The life cycle of a honeybee is a captivating and intricately structured process, marked by various stages. The queen laid the eggs in individual cells of comb hatches into a larva. Worker bees attend to the larvae, providing them with the necessary nourishment in the form of royal jelly, which is a protein-rich secretion. The larva is then sealed within its cell, and it undergoes a remarkable transformation into a pupa. During this stage, the body of the bee undergoes significant changes. After completing its metamorphosis, the adult bee emerges from the cell, ready to contribute to the hive's functions. The specific role of the bee is determined by its age, with young workers handling tasks such as nursing and older bees taking on responsibilities like foraging (Johnson, 2023).

2.2. The Importance of Bees and factors affecting their health

2.2.1. Economic Importance of Bees

Without honeybee pollination, crop yields would decline, resulting in reduced food availability and increased prices. Thus, honeybees, by promoting the growth and diversity of flowering plants, have a direct impact on the maintenance of ecological balance and the preservation of natural landscapes. They facilitate the sustenance of various species and play a crucial role in environmental health and stability. (Aslan *et al.,* 2016; Ollerton *et al*., 2011; Partap, 2011).

The role of honeybees is not only restricted to ecological and agricultural aspects. Honeybees produce not only honey but also beeswax, royal jelly, and propolis, which are economically valuable resources. It is estimated to contribute billions of dollars to global agricultural production annually. These hive products contribute to local economies by providing income for beekeepers, and are used in various traditional practices and industries. (Fikadu, 2019)

2.2.2. The Importance of Bee Health to the ecosystem

Bees are the main wild pollinators, making them essential for propagation of a wide range of plants, including many crops that provide food for humans and animals. They are crucial components of our ecosystems and agriculture. As a pollinators, they facilitate the reproduction of an extensive range of plants, including numerous fruit and vegetable crops. Through their pollination services, honeybees promote the diversity of plant species, which forms the foundation of many ecosystems. Thus, pollination services they provide directly influence the quantity and quality of agricultural products (Aslan *et al.,* 2016). However, bee populations worldwide have been facing numerous challenges from several factors that impact their health and well-being. These factors can interact and exacerbate each other, making the overall health of bee populations more vulnerable. Here are some of the key factors affecting bee healthy (Fikadu, 2020b; Gratzer *et al.,* 2021).

The use of pesticides, particularly pesticides, poses a substantial risk to bee health (Wim. C. MULLIE *et al.,* 2023). Neonicotinoid pesticides have garnered attention for their adverse effects on bees. These chemicals can cause direct mortality and impaired foraging behavior in bees. Habitat destruction and fragmentation due to urbanization, agriculture expansion, and deforestation reduce the availability of suitable forage and nesting sites for bees. This affects their ability to find food and reproduce. Bees require a variety of pollen and nectar sources to meet their nutritional needs. Altered weather patterns, temperature changes, and extreme weather events due to climate change can disrupt the timing and availability of flowering plants. This can affect bee foraging and breeding patterns. Pesticides, bees can encounter various chemical contaminants, such as pollutants from industrial and agricultural runoff. These contaminants can negatively affect bee health and reproductive success (Negatu *et al.,* 2021; Saleem *et al.,* 2023).

2.3. Implications for Ecosystems

Bee health is a complex issue influenced by a variety of natural and human-induced factors. The decline in bee populations poses risks to ecosystems, food security, and biodiversity. Recognizing the importance of bees and addressing the factors affecting their health is essential for the well-being of both natural environments and human societies. Conservation efforts, sustainable agricultural practices, and public awareness play crucial roles in supporting bee populations and mitigating the risks they face (Wakshuma *et al.,* 2023).

The significant implications for bee health in danger include the decline of pollinator number. The decline in bee populations can reduce the pollination of both wild plants and crops, potentially affecting the reproduction of a wide range of species. Other pollinators, such as butterflies and beetles, may not be able to compensate fully for the loss of bees. Reduced pollination services can disrupt the relationships between plants and pollinators, potentially leading to imbalances in ecosystems. This, in turn, can affect the availability of food for various wildlife species. Bees play a crucial role in supporting food webs, serving as a food source for birds and other animals. A decline in bee populations can affect the organisms that rely on bees for food.

In addition, the factors affecting bee health also have consequences for agriculture and food security. Diminished pollination services can lead to reduced crop yields and lower crop quality. This can affect the availability and cost of food for consumers. Agriculture is a major industry in many countries, and the decline of bee populations can lead to economic losses for farmers and the agricultural sector. A decrease in bee-pollinated crops can reduce the diversity of food available for human consumption. This can impact the overall nutritional quality of diets (Bauer & Wing, 2010).

2.4. Beekeeping in Ethiopia

2.4.1. Historical Perspective

Beekeeping in Ethiopia has been practiced for centuries, with some historical records dating back to ancient times to about 5000 years ago. The Hieroglyphs of ancient Egypt denote Abyssinia the origin of bee and bee waxes. The unique history and cultural diversity have contributed to the development of various beekeeping methods and traditions (Faji & Begna, 2017; Tekle, 2018). In many rural communities, beekeeping has been a source of both food and income generation, and it has been passed down through generations. Currently, this practice not only plays a significant role in the livelihoods of many Ethiopians but also contributes to the country's agricultural and economic sustainability. With a diverse range of ecosystems and climatic conditions, Ethiopia offers an ideal environment for beekeeping and it makes the practice a vital component of the nation's agricultural landscape (Tesema *et al.*, 2023). Ethiopian beekeepers do not choose a particular subspecies for beekeeping; instead, most commonly they use the first identified and the most common locally available strains of the honey bee, *Apis mellifera*. Since there are no bee breeding programs, beekeepers must either purchase fresh colonies from nearby markets, the wild, or through colony multiplication (Gratzer *et al.*, 2021)

2.4.2. Beekeeping in Oromia region

The Oromia region in Ethiopia holds immense potential for honey production. Covering a vast area of 363,315 square kilometers, which accounts for approximately 34.3% of Ethiopia's total landmass, Oromia boasts diverse agro-ecological and climatic zones, making it ideal for beekeeping. Altitude ranges from 500 meters above sea level to the highest peak, Mount Batu, at 4,607 meters. Oromia is blessed with abundant water resources, including major rivers such as Awash, Wabe-Shebele, and Genale, as well as lakes like Bishoftu, Kuriftu, and Bishoftu-Gudo. The region's flora is rich and diverse, making it an ideal habitat for bees. Tree species like Eucalyptus, Cordia africana, Acacia, Hygenia abyssinica, Croton macrostachus, Guizota scabra, Coffea arabica, Ricinus communis, and many others provide abundant sources of pollen and nectar for bees. Oromia is a significant contributor to Ethiopia's honey and beeswax production, accounting for 41-50% of the country's total output. Remarkably, this is considered only 10% of the region's potential. The high potential for bee products in Oromia can be attributed to the large number of native bee colonies, a variable climate, and an abundance of honey bee-friendly flora, including natural trees, forage plants, horticultural crops, and cultivated crops. The region is home to approximately 60% of the country's bee colonies, estimating over 6.3 million honey bee colonies (Oromia Livestock & Fishery Resource Development Bureau).

2.4.3. Different types of Beekeeping Practices:

In Ethiopia, beekeeping practices vary from region to region due to the country's diverse climatic zones. Nevertheless, most of the knowledge and skills applied in any of these places are quite traditional. Some common types of beekeeping practices in Ethiopia include traditional beekeeping using hollowed logs or baskets as beehives. These hives are usually made from materials readily available in the region, such as bamboo, clay pots, or logs (Dekebo *et al.,* 2019; Tesema *et al.,* 2023). In more developed areas, other kind of beekeeping by using modern beehives are becoming increasingly popular. These hives are designed for better management and increased honey production. They come in various types, such as Langstroth and top-bar hives. There is also other form of beekeeping practice in some regions, where beekeepers practice migratory beekeeping. In this kind of beekeeping, the local community move their hives to follow the seasonal availability of nectar and pollen sources (Gratzer *et al.,* 2021).

2.5. Advantages and challenges of beekeeping in Ethiopia

Beekeeping is not only a cultural tradition in Ethiopia but also a significant source of income for many rural households who are n small landholder farmers and landless youths. The sale of honey and other bee products, such as beeswax and royal jelly, provides an important source of revenue. The honey and beeswax markets have experienced steady growth both domestically and internationally, with Ethiopian honey being recognized for its unique taste and quality (Dekebo *et al.*, 2019; Wakshuma *et al.*, 2023). Beekeeping plays a crucial role in sustaining the environment in Ethiopia. Bees, as pollinators, contribute to the reproduction and production of potentially high yield of variety of food and forage plants. By facilitating the pollination of crops such as coffee, teff, and various fruits, beekeeping indirectly supports the nation's agriculture, food security and stabilizing the ecosystem. On the other hand, beekeeping can also directly contributes to the cosmetic and pharmaceutical industry through its outputs such as honey, bee wax, queens, and colonies, as well as pollen, royal jelly, and bee venom. (Degu & Megerssa, 2020; Dekebo *et al.*, 2019).

There are many conditions that foster and encourage the farming of bees. One of the factors that make the country an excellent location for beekeeping is abundance of honey bee, a major opportunity among all others. It is also home to a wide variety of flowering plants that provide an abundant and varied source of nectar and pollen for honeybees. This diversity not only contributes to the quality and flavor of Ethiopian honey but also ensures that bees have a constant supply of forage throughout the year. In addition, availability of water, market demand for bee products, experience and support from the government are other opportunities (Dekebo *et al*., 2019; Faji & Begna, 2017; Tekle, 2018).

While beekeeping in Ethiopia has a rich history and numerous benefits, it also faces several challenges. These challenges include pests and diseases affecting bee colonies, deforestation, and habitat loss, as well as the potential impact of climate change on bee flora and beekeeping practices. However, with proper training, disease management, and sustainable beekeeping practices, these challenges can be overcome. In recent years, there has been a growing interest in modernizing beekeeping practices in Ethiopia to improve honey production, hive management, and product quality. Organizations and government initiatives have aimed to provide training and support to beekeepers, enhancing their skills and helping them to adopt more efficient and sustainable methods (Gratzer *et al.*, 2021).

2.6. Pesticides in Ethiopian Agriculture

Ethiopia has the second highest population in Africa, where almost 80% of its populations is dependent on agriculture and pesticides are a vital component of this agriculture. They are intensively applied for many reasons including pest control, enhanced agri products, and crop quality. Insects, including pests devastate crops and result in significant yield losses and economic hardship. pesticides play a role in protecting crops from pest infestations and ensure food security by saving around 50% crops to be lost, and increase crop quality by preventing pest damage through maintaining the appearance, taste, and marketability of crops. To mitigate the problem farmers utilize them injudiciously in farm managing (Negatu *et al.*, 2021).

Their application in agriculture raises concerns related to their impact on the non-target organisms, including flagship poisoning of honeybees in the country. Pesticides are typically applied indiscriminately throughout open agricultural fields in Ethiopia, even while foraging bees are present on the same field during their visiting season. As a result, honeybee mortality and a decline in colony population have been chronicled by beekeepers. Ethiopian researchers haven't yet looked at acute toxicity tests and events involving agricultural pesticides at specific concentration levels. Striking a balance between effective pest control and environmental sustainability is an ongoing challenge for the agricultural industry.

2.6.1. Types of pesticides used for Ethiopian agriculture

Pesticide use in Ethiopia increased significantly throughout the history upon modernization of agriculture (Negatu *et al.*, 2021). Pesticides are chemicals designed to kill or control insect pests. They come in various classes, each with its mode of action and potential impact on bees. They are intensively utilized in Ethiopia, and their form comes in diverse. Some of the most commonly used type of pesticide is organophosphates, which are chemicals that target the nervous system of insects to elicit paralysis and eventual death. Pyrethroids are other kinds of pesticides that are widely in use in Ethiopian market. This pesticide affects insect nerve function and are commonly used in household insect sprays and agricultural applications. Neonicotinoids, on the other hand, are systemic pesticides which are observed by plants and spread throughout the plant's tissues. They are effective against a wide range of insect pests. In addition, some pesticides are derived from naturally occurring microorganisms or predators are used to control specific insect pests in an environmentally friendly manner (Wim C. MULLIE *et al.*, 2023; Tessema *et al.*, 2015; Yewhalaw *et al.*, 2017).

2.6.2. Effects of pesticides on bee health and colony

While pesticides are effective in pest control, their use have several consequences as they result in unintended effects to non-target organisms, including beneficial insects like pollinator bees. pesticides, particularly neonicotinoids, have been associated with pollinator declines recently. An estimated 76 billion bee colonies have been wiped out since 2019 up on application of pesticides to control locusts (Vyawahare, 2023). This can disrupt the balance of ecosystems and lead to unexpected consequences. Residues of pesticides can accumulate in soil and water, potentially leading to contamination. This can harm aquatic life and even pose risks to human health if these residues enter the food chain. Over-reliance on certain types of pesticides can lead to the development of resistance in pest population and necessitates the use of increasingly potent and potentially harmful chemicals. (Fikadu, 2020a; Negatu *et al.*, 2021).

A number of studies conducted indicated potential impacts of pesticides on bees in a number of ways. pesticides can kill bees directly, even at low doses. Through disrupting of bee foraging and navigation, pesticides can also weaken bees, both foraging worker bees and the queen, and make them more susceptible to disease (Sanchez-Bayo *et al.*, 2016; Zhao *et al.*, 2022). The impact of pesticides on bees is particularly concerns Ethiopia, where beekeeping is an important source of income and livelihoods. A study by Yetimwork *et al*. (2015) found that the use of pesticides was a major challenge for beekeepers in eastern Ethiopia. Pesticides were found responsible for the death of bee colonies and a decrease in honey production.

Besides, even if bees survive initial exposure, sublethal effects can occur. These include impaired foraging behavior, reduced navigation abilities, and difficulties in communication among hive members. Sublethal effects even at sublethal doses, neonicotinoids can also make them more susceptible to other stressors, such as disease. By doing this, they can disrupt the social structure and functioning of bee colonies. Neonicotinoids, for instance, have been linked to reduced queen production, colony growth, and overall hive health. They affect a bee's ability to forage for nectar and pollen. Some of the key findings related to neonicotinoids include reduced bee survival, sublethal effects and forage poisoning. Bees exposed to these pesticides may become disoriented and less effective at pollination. Pesticides can accumulate in nectar and pollen, potentially affecting the entire food chain. This is concerning not only for bees but also for the organisms that rely on bee-pollinated plants. (Tosi *et al*., 2022).

There have been numerous studies on the effects of pesticide use in bee colonies in Ethiopia. For instance, one study in the Central Rift Valley of Ethiopia, where pesticides are heavily used for a smaller scale horticultural activity, found that 48.3% of beekeepers gave up their profession as a result of colony losses brought on by pesticide usage.78 Similar studies in several regions of Ethiopia revealed a decline in honeybee numbers and the availability of their products as a result of pesticide use without consideration (Melisie *et al.*, 2016; Negatu *et al.*, 2021).

2.6.3. Effects on loss of bee colonies on the environment

The effects of pesticides on bees have significant implications for both agriculture and natural ecosystems. Honey bees engage in ecological interactions, particularly when gathering pollen and nectar for food. They thereby come into contact with some chemicals and environmental pollutants. In the natural world, plants absorb and sequester waste and harmful compounds, which are typically industrial gasses, car exhaust gases, pesticides, and pesticides. Due to the fact that bees gather pollen from a variety of flowers, heavy metals that are present in high concentrations inside the afflicted plants increase the concentration of harmful heavy metals in the bodies of bees and poison them. Because of this, honeybees and products made from them are employed as bioindicators of heavy metal pollution in the environment (Hristov *et al.*, 2020).

In agriculture, for instance, declines in bee populations can lead to reduced crop yields and quality and causes escalated production costs. This, in turn, can impact food availability and prices for consumers. Bees play a vital role in pollinating not only agricultural crops but also wild plants. The decline of bee populations can have cascading effects on ecosystems, potentially affecting the reproduction of other plant and animal species. Beyond crop pollination, bees contribute to ecosystem services such as maintaining floral diversity and supporting wildlife, making their conservation critical.

CHAPTER THREE

3 Materials and Methods

3.1. Description of the study area

Sebeta is situated in the heart of Ethiopia in Oromia region, 24 km to southwest of the nation's capital, Addis Ababa along the Jimma road. The town is further subdivided into administrative districts and the demographic pattern exhibits a distinctive and diverse population pattern, with the majority of its residents living in its rural areas. The total population residing in Sebeta is estimated to be more than 350,000 with an average family size (FS) of 4.8 members, and around 70,000 households. Population residing in rural area plays a central role in the region's agriculture. Sebeta encompasses a total land area of approximately 7410 km² Area (Central Statistical Agency (CSA), 2007). Sebeta's land is broadly categorized into distinct agro-ecological zones, including highlands, midlands, and lowlands and is being utilized for a variety of purposes, including urban development, agriculture, and natural landscapes. The geographical latitude and longitude of the study area is 8530 N, 8590 N and 38350 E, 38390 E, respectively (Eridadi et al., 2021).

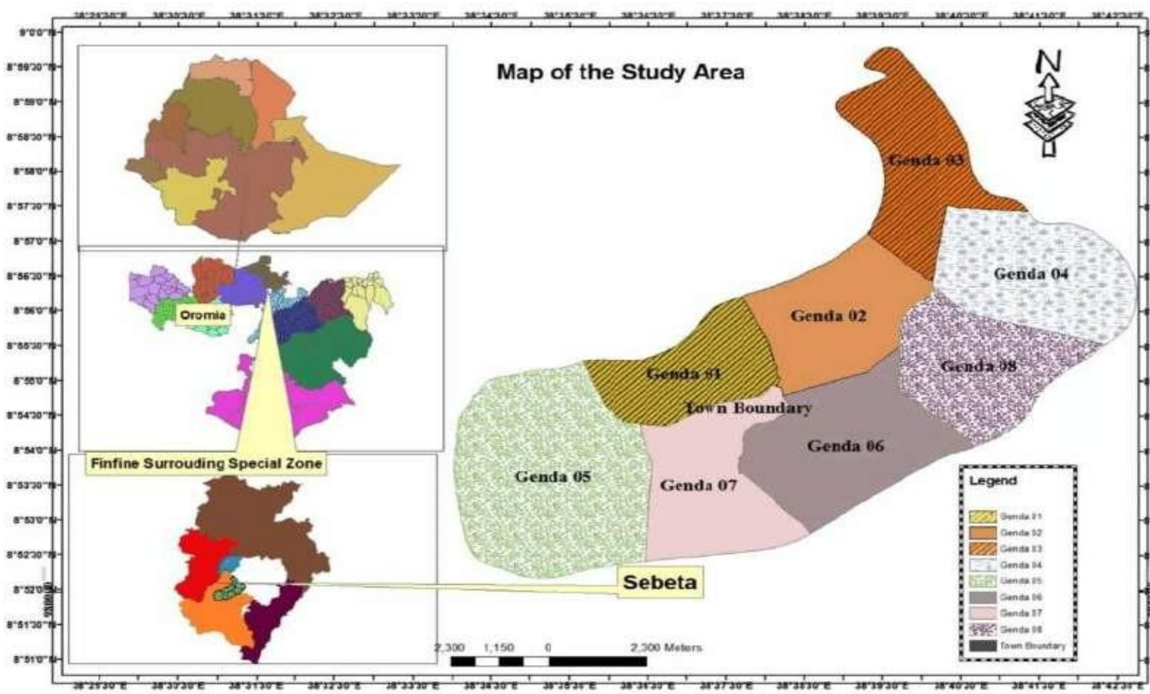

Figure 1. Map of Sebata, Oromia, Ethiopia (Eridadi et al., 2021).

3.2 .Target population

According to (Gratzer *et al.* (2021) Ethiopia has 6.01 colonies per beekeeper and 5.60 colonies per km^2, which corresponds to 0.91 beekeepers per km2 when compared to the whole population. The study area has a total land area of approximately 7410 km^2 Area. Thus, considering this data the number beekeepers in the study area is estimated to be 6,669. The area is composed of ten kebeles, namely Sebeta, Furi Gerabollo, Alemgana, Dalati, Sebeta Atebela, Walate, Furii, Dimma, Furi-Kerabu, and Caffe Hora. The estimated proportion of beekeepers in each kebele of the study area were 589 (Sebeta), 750 (Furi Gerabollo), 400 (Alemgana), 650 (Dalati), 980 (Sebeta Atebela), 300 (Walate), 250 (Furii), 1150 (Dimma), 700 (Furi-Kerabu), and 900 (Caffe Hora). This study was target populations from the listed kebele.

3.3. Sampling Methods and Sample Size determination

For the purpose of this investigation, a systematic random sampling method was employed to select respondent households from each kebeles. From the total 10 kebeles 4 kebeles namely Furi Gerabollo, Sebeta Atebela, Dimma, and Caffe Hora kebeles were intentionally chosen using purposive or judgmental sampling method based on their recognized potential for bee farming and insecticide use. The total number of populations from the sampled kebeles in the study area is 3,780 which is (750) Furi Gerabollo, (980) Sebeta Atebela, (1150) Dimma, and (900) Caffe Hora kebeles. The determination of the sample size adhered to the methodology proposed by Yamane in 1967 (1), ensuring the statistical reliability and representativeness of the collected data.

$$n = N / (1+N (e)^{2}) \quad \text{...} (1)$$

$$n = 3{,}780 / (1+ 3{,}780 (0.05)^{2})$$

$$n = 3{,}780 / (1+ 9.45)$$

$$n = 378$$

Where, n is sample size, N is number of households in the zone which is 3,780 and e is the desired level of precision at 5%.

Although the initially proposed sample size was 378, which was proportionally distributed across the four kebeles using Yamane (1967) formula, only 180 respondents were available for data collection. The reduction was due to the unavailability of respondents and disruptions caused by displacement activities around Addis Ababa and ongoing construction which limited access to some households.

Table 1. Application of Proportionate method for sample determination

Stratum	Population	Proportionate sample size	Actual samples present and data collected
Furi Gerabollo	750	75	25
Sebeta Atebela	980	98	50
Dimma	1150	115	65
Chaffe Hora	900	90	40
Total	**3,780**	**378**	**180**

3.4. Study design

A cross-sectional study was conducted to investigate the potential impacts of pesticides on beekeeping. Data collection was performed through a questionnaire. A purposive sampling method was employed to select a total of four kebeles (villages) and key informants. The primary units of sampling were beekeeping households actively engaged in keeping honeybee colonies around agricultural lands.

3.5. Surveys and Interviews with Local Beekeepers

To comprehensively investigate the effects of pesticides on beekeeping in the study area, it is essential to gather data directly from the beekeeping community. Through investigation into the types and quantities of pesticides commonly used in the past and in the present in the study locations was required access to official records. Thus, information pertaining to various aspects of beekeeping, such as pesticide usage records was obtained from agricultural cooperatives and relevant government agencies to determine the use of pesticides, types of pesticides, pest control practices, their application rates, timing, quantity and the crops on which they are used against around apiary location was collected. In addition, information related number of hives, hive management, land size in hectares, land held by households, labor, socioeconomic status, the number of bee colonies maintained in the past and present, the purposes for keeping honeybees, honey production, rates of absconding and swarming, and the methods employed for harvesting and processing hive products, as well as other major challenges encountered in beekeeping, was collected and examined through structured interviews utilizing structured questionnaire.

Semi-structured interview was also conducted with a subset of beekeepers. These interview was provide deeper insights into the beekeepers' experiences, challenges, and the context in which they operate. The data will provide data on their perceptions of the impacts of pesticides on bee health and their understanding of sustainable beekeeping practices.

3.6. Data analysis

Data from these records was subjected to quantitative and qualitative analysis to determine the prevalence and intensity of pesticide usage in the study area. Descriptive statistics was used to transform raw data into a more comprehensible format, providing clear insights. Once the relevant data related to the study area are gathered, they were subjected to analysis and interpretation tailored to their inherent characteristics.

Ethical Considerations

This section was addressed ethical considerations regarding the treatment of bee colonies, obtaining informed consent from participating beekeepers for interviews and data collection, and ensuring that the research adheres to ethical standards and guidelines.

CHAPTER FOUR
4. Results and Discussion

4.1. Demographic and Socioeconomic Characteristics

The table shown that Majority of the respondents (61%) were between the ages of 31 and 50 suggesting that beekeeping in Sebeta is largely practiced by active-working-age adults. This demographic group has the physical capability and community experience to manage beekeeping effectively and provide insight into environmental and agricultural changes. Educational level varied, with 38.9% completed primary education, 30% reaching secondary education, and only 17.2% holding a college diploma or higher. This is that while most beekeepers possess basic literacy many may lack the advanced understanding to grasp the advanced impacts of chemical pesticides, which indicating a potential gap in risk awareness.

From the household size of the study area 50% of beekeepers came from families with 1 to 4 members. This smaller household size suggests limited labor availability for managing beekeeping activities. But it also implies that these families may rely more heavily on beekeeping as a source of income or substenance, increasing their vulnerability to external shocks like pesticide exposure. The majority (89.4%) of respondents reported mixed (modern and traditional) farming as primary occupation, by integrating crop production with beekeeping. These dual engagements indicate pesticides applied to crops could inadvertently harm bee colonies, especially when farmers are unaware of the toxicity of applied chemicals to pollinators. About 38.3% of the respondents have over 10 years of beekeeping experience, strengthening the reliability of their reported observations. Their long-term experience provides valuable context for interpreting trends in colony health and productivity (Table 2).Based on demographic the data of the study area the majority of beekeepers was included in the age of (31-40) and had the primary educational background with(1-4) household size that practice mixed farming which had above ten years beekeeping experience.

Table 1. Demographic and Socioeconomic Characteristics

Variable	Categories	Frequency	Percentage
Age	21–30	30	16.7
	31–40	55	30.6
	41–50	54	30.0
	>50	41	22.8
Educational Background	No formal education	25	13.9
	Primary	70	38.9
	Secondary	54	30.0
	College diploma and above	31	17.2
Household Size	1–4	90	50.0
	5–8	61	33.9
	9–12	29	16.1
Primary Occupation	Beekeeping	1	0.6
	Crop farming	18	10.0
	Mixed farming (Crops and animals)	161	89.4
Beekeeping Experience	1–3 years	40	22.2
	4–6 years	25	13.9
	7–10 years	46	25.6
	>10 years	69	38.3

4.2. Beekeeping Practice

This table shown small-scale beekeeping dominates in Sebeta in that 52.2% of respondents managing 1 to 5 hives. The small hive count implies a high dependency on each individual colony. This low redundancy system (few hives per household) reflects limited adaptive capacity and increased ecological fragility at the household level.

The predominance of modern hives (57.2%) comparing to traditional hives indicates encouraging trend toward the adoption of improved technologies, which is possibly driven by extension programs, training institutions, or non-governmental organizations promoting transitional and Langstroth hive systems. However, the continued reliance on traditional hives by 25% of beekeepers can exposes critical socioeconomic barriers likely related to initial capital cost, limited technical support, and lack of awareness according to the respondents. Traditional hives, often hung in trees or mounted on high structures, are difficult to inspect, harvest from, or shield from pesticide drift, which may exacerbate colony mortality and reduce productivity.

The primary motivation for beekeeping, according to 88.9% of respondent, was honey production, followed by income generation of 8.9%. This show that beekeeping is both a cultural and economic activity but still underutilized for diversified income generation. Honey production contributes directly to household food security and indirectly through monetary income, often used to meet basic needs such as school fees, healthcare, and agricultural inputs. Yet, the low percentage of respondents citing income as their primary motivation suggests potential gaps in market linkages, value chain development, and post-harvest handling, which are essential to transition beekeeping from subsistence to commercial viability.

About 57.1% of the participants received formal training in beekeeping which suggested the availability and uptake of capacity-building efforts. Training programs likely focus on hive management, colony health, queen rearing, and harvesting techniques. However, the persistence of pesticide-related challenges despite such training coverage suggests that training interventions may not sufficiently address external environmental risks, particularly agrochemical threats (Table 3).On the area the majority of the beekeepers (52.2%) owned 1-5 beehives, use modern hives (57.2%) ,produce honey (88.9 %) and beekeeping training. (Table 3)

In beekeeping practice (37.7%) of the study area finding, the beekeepers had moderate a number of beehives with a majority of them used modern hive types for the purpose of honey production. According to (Serda *et al* 2015)high number of beekeepers used traditional beekeeping practice ,this finding contradict with my study result due to factors of urbanization level of the study area.

Table 2. Beekeeping Practices in the study area.

Variable	**Categories**	**Frequency**	**Percentage**
Number of Beehives	1–5	94	52.2
	6–10	65	36.1
	11–15	21	11.7
Type of Hive Used	Traditional	45	25.0
	Modern	103	57.2

	Mixed	32	17.8
Purpose of Beekeeping	Honey production	160	88.9
	Pollination	2	1.1
	Wax or hive production	2	1.1
	Marketing	16	8.9
Beekeeping Training honey and wax production	Yes	100	57.1
	No	86	43

4.3. Pesticide Exposure and Use

As table 3 shown findings revealed that 55.6% of beekeepers in Sebeta reported pesticide applications near their apiaries, placing bee colonies at considerable risk of acute and chronic exposure to harmful agrochemicals. This proximity is of significant concern in apicultural ecology, as bees forage widely—up to 5 km from their hives—and thus regularly come into contact with chemically treated environments. The presence of pesticides near apiaries undermines the ecological safety required for sustainable pollinator health and violates principles of agroecological zoning and pollinator-friendly farming. Observation indicated that 38.9% of the beekeepers attribute the pesticide use to nearby commercial farms. This indicates that a significant portion of beekeeping activity is negatively impacted by external land management decisions, over which the beekeepers have limited or no control. This scenario reflects a spatial and institutional disconnect between crop production systems and pollinator-based livelihoods, which can be explained by the lack of land-use regulation, pesticide buffer zones, and inter-farm coordination mechanisms. From a policy and governance standpoint, this calls for integrated pest and pollinator management (IPPM) frameworks, which emphasize collaboration between farmers and beekeepers, as well as regulatory agencies.

4.5. Toxicological Profile of Pesticides

The photograph show four agrochemical products that were mostly applied in the local farming, which reflect a strong dependency on traditional chemical methods in weed and pest control. Figure 2, which is the first product, is Megaban 48 EC, a pesticide containing 49% chlorpyrifos-ethyl, a broad-spectrum organophosphate compound applied extensively to manage chewing and sucking insect pests. Even though chlorpyrifos is effective, it has been found to be extremely toxic to non-target organisms, particularly pollinators such as honeybees, and is of great health concern to humans through exposure in the environment. Figure 2B. Herb 720 SL which is a herbicide with 2,4-

D amine salt in 720 g/L is applied mainly for the control of broadleaf weeds according to the seller. 2,4-D is a synthetic auxin analog plant growth inhibitor widely criticized for drift and devastation of sensitive non-target plant material. Figure 2C, or Matco, is a powder formula pesticide marketed for use on horticultural crops of grapes, tomatoes, and onions. As no active ingredient is named, by its broad-spectrum application one might assume it was used as a fungicide or general pesticide. Figure 2D, Glymax, is the most frequently applied glyphosate herbicide for non-selective weed control, specifically pre-plant or post-harvest, the pesticide responsible for the widespread use, as claimed by the supplier. Their extensive application reflects extensive reliance on chemical inputs, with resultant ecological and environmental implications, including pollinator health, soil biodiversity, and agricultural long-term sustainability, it adds. The observations highlight the need for safer, more environmentally friendly alternatives such as nanopesticides to mitigate against the adverse impacts of conventional pesticides. Even at low concentrations, these compounds can synergize with other stressors (e.g., diseases like Nosema, poor nutrition), leading to colony collapse. Organophosphates disrupt the acetylcholinesterase enzyme, affecting nerve function. While typically less persistent than neonicotinoids, they are often applied in large quantities and pose immediate toxic threats to bees, especially when applied during flowering periods.

Megaban 48 EC a pesticide containing (49%) chloriphyritos ethyl applied to manage chewing and su cking insect pests, Herb 720SL a herbicide with 24D amine salt in 720g applied to control broad leaf weeds, matco a powder formula pesticide used on horticultural crops of grapes , tomato and onion, glymax is the most frequently applied glyphosate herbicide for non-selective weed control.

Figure 2: Type of pesticides used in the study area

Widespread scientific consensus on the risk profile of these chemicals, their continued use in close proximity to apiaries reflects regulatory gaps and inadequate pesticide stewardship. It also highlights the urgency of promoting bee-safe alternatives, such as biopesticides, botanical extracts, and mechanical pest control techniques, especially during sensitive periods of the bee foraging calendar.

Application Frequency and Methods

Although 88.9% of respondents report pesticide application only 1–3 times per year, it does not necessarily indicate low risk. The application time (e.g., during flowering or peak foraging hours), chemical formulation, and route of exposure (oral, contact, or systemic) are critical of bee mortality and colony stress. The cumulative and synergistic effects of sporadic pesticide events can result in sublethal impacts, such as immune suppression, decreased brood rearing, and disoriented foraging.

The fact of spraying (56.1%) and aerial spraying (39.4%) are the dominant application methods raises additional concerns. Both methods are reason to pesticide drift especially when windy or dry conditions are present which lead to off-target deposition on flowering weeds, apiary areas, or water sources. Aerial spraying has been linked to mass bee kills in several parts of the world, especially when done without prior notification or environmental risk assessment. (Mc laren.n.d).

4.5. Target Crops and Exposure Pathways

The main crops treated with pesticides in the area are cereals (45%) and cash crops (27.2%). While cereals such as maize and wheat are not always attractive to pollinators, they often coexist with flowering weeds (e.g., Bidens, Trifolium) in the fields or field margins. These plants serve as unintended pesticide carriers, contaminating foraging routes and food stores within the hives. Cash crops, depending on their type (e.g., vegetables, oilseeds, or fruits), may be highly attractive to bees and thus pose a direct oral route of pesticide exposure through nectar and pollen. Lack of pre-spray notifications—reported by 68.3% of beekeepers-greatly impedes the effectiveness of protective actions. In the absence of early warning systems or community-based spray calendars, beekeepers are unable to seal hives, relocate colonies, or coordinate with applicators to minimize exposure. This finding reflects a communication breakdown among agricultural stakeholders, which could be mitigated by mandatory notification laws, mobile alert systems, or joint cooperative management plans.

Despite the challenges, a large number of respondents (90%) of beekeepers report taking protective measures during spraying events. These may include covering hives with nets or tarpaulins, relocating them temporarily, or limiting hive openings. However, such actions are often reactive and insufficient in the face of unannounced or widespread pesticide applications. In addition, these methods may induce thermal stress and reduced ventilation, especially in warm climates, potentially compounding the colonies' health challenges (Table 3).

These individual efforts, while important, cannot substitute for system-level coordination and structural safeguards, such as:

Establishment of buffer zones (e.g., 2–3 km pesticide-free belts around major apiaries)

Designation of pollinator protection times (e.g., early mornings or evenings)

Promoting pesticide label reform to include bee toxicity warnings

National pesticide use audit systems to track compliance and drift events

In the study area (55.6%) of pesticide is spray near to apray, (38.9 %) applied by commercial farmers and (39.4 %) used neonicotinoid pesticide type ,(88.9%) it was applied 1-3 times per year,(45%) on cereals and (27.2%) on cash crops are treated with pesticides,(56.1 %) by hand spraying application method, the majority of respondents (90 %) took protective measure during spray.(Table 3). Based on respondents the majority of response shown the application frequency of pesticides per year was within the maximum of three times. This finding shown the exposure of bee for pesticides was high.

Based on this survey the degree of exposure of honeybee to pesticide is high, this survey was the same as the survey by (Fikadu 2020). According to him the majority of beekeepers don't use any control measure for chemical poisoning to honeybee.

Table 3. Pesticide Exposure and Use

Variable	Categories	Frequency	Percentage
Pesticide Use Near Apiary	Yes	100	55.6
	No	80	44.4
Who Applies Pesticides	Yourself	45	25.0
	Neighbor	31	17.2
	Commercial farmer	70	38.9
	Government/NGO	34	18.9
Types of Pesticides Used	Neonicotinoids	71	39.4
	Organophosphates	59	32.8
	Pyrethroids	31	17.2
	Unknown/Other	15	8.3
Application Frequency (per year)	1–3	160	88.9
	4–6	16	8.9
	7–9	4	2.2
Application Method	Spraying	101	56.1
	Aerial spraying	71	39.4
	Seed treatment	8	4.4
Crops Treated with Pesticides	Cereals	81	45.0
	Cash crops	49	27.2
	Legumes	29	16.1
	Vegetables	21	11.7
Advance Notification Received	Yes	57	31.7
	No	123	68.3
Protective Measures Taken	Yes	162	90.0
	No	18	10.0

4.6. Observed Impacts of Pesticides

Table 4 shows the impacts of pesticides on bee colonies the data presented reveal an alarming trend of pesticide-induced harm to honeybee health and productivity in Sebeta. A majority (64.4%) of surveyed beekeepers reported increased bee mortality following pesticide application. This strong temporal association between spraying and death events supports previous toxicological and field studies that highlight the acute toxicity of commonly used agrochemicals especially neonicotinoids and organophosphates to both adult bees and larvae. Field-realistic exposures to these chemicals can result in rapid-onset mortality, either through direct contact during spraying or indirect ingestion of contaminated nectar, pollen, or water. Furthermore, 66.7% of respondents reported behavioral abnormalities, including disorientation, lethargy, and reduced foraging activity which is consistent with sub-lethal effects of neurotoxic pesticides. These symptoms are similar with from global literature where sub-lethal pesticide exposure impairs bees nervous systems, leading to: Impaired learning and memory, affecting foraging efficiency and floral preference, reduced navigation ability, leading to forager losses and hive starvation, decreased grooming and hygienic behavior, increasing vulnerability to pathogens and parasites.

Such behavioral dysfunction are not just temporary disturbances: they often indicate cascading effects on colony homeostasis, including reduced brood care, queen failure, and eventual colony collapse or absconding, as reported by 61.1% of beekeepers in the past two years. The reported rates of colony collapse and absconding point to a critical threshold of stress beyond which bee colonies can no longer maintain social coherence and reproduction. Absconding, in particular, is a stress-induced escape response in which bees abandon the hive en masse, typically in response to: Persistent chemical exposure overheating and poor ventilation (linked to protective measures like covering hives during spraying)

These result is not only ecological loss (reduced pollination services) but also significant economic costs for beekeepers, who lose honey harvests, breeding stock, and future productivity. 35.6% of beekeepers reported reduced honey yields, a direct consequence of decreased foraging, weakened colonies, and queen dysfunction. The 44.4% who reported no change may represent those who adopted effective hive protection strategies or were geographically distant from major pesticide use zones. The variability may also reflect different floral calendars, with some apiaries foraging predominantly in pesticide-free areas during flowering. Colony strength:-37.2% reported a decline, indicating reduced worker populations, fewer brood, and weakened queen output. 25% saw an increase, reflecting improved management or favorable environmental conditions. 37.8% reported no change, again highlighting site-specific variation in pesticide exposure and hive resilience. This variability underlines the importance of site-specific exposure risk mapping, which could inform strategic hive placement, seasonal migration, and chemical use planning. Although while pesticides are a major driver of bee health decline, 55.6% of beekeepers cited pests and diseases as additional pressures. These biotic stressors are often synergistic with pesticide exposure. For example, the pesticide exposure has been shown to: Suppress immune gene expression, making bees more susceptible to pathogens, alter gut microbiota, increasing vulnerability to disease, reduce metabolic activity, compounding pesticide toxicity(PLoS One,2017). In addition, 22.8% of beekeepers identified habitat loss, such as deforestation, urbanization, and monoculture expansion, as key stressors. Loss of floral diversity and nesting habitat deprives bees of nutrition and shelter, further reducing their resilience to chemical stress. This point to a broader landscape-level degradation that threatens pollinator health (Table 4).

On the observed study area the impact of pesticides,(66.7%) cause unusual bee behavior, (64.4%) increase bee mortality (61.1%) cause colony collapse, based on the response of respondent (35.6%) decrease honey production,(37.8 %) shown no change in colony strength and (55.6%) cause major stress factors such as disease. (Table 4). Based on the response of the majority respondents the impact of pesticides cause behavioral abnormality, this shown the use of pesticides with less awareness and proper management on the amount and site of application cause negative behavioral change.

Based on the finding of (Alemu *et al*, 2020) honey bee produced was indicated that the bee shown aggressiveness symptoms and anomalous behavior beside the observed death during and after pesticides spray.

Table 4. Observed Impacts of Pesticides

Variable	Categories	Frequency	Percentage
Increased Bee Mortality	Yes	116	64.4
	No	64	35.6
Unusual Bee Behavior	Yes	120	66.7

	No	60	33.3
Colony Collapse or Absconding	Yes	110	61.1
	No	70	38.9
Change in Honey Production	Increased	36	20.0
	Decreased	64	35.6
	No significant change	80	44.4
Change in Colony Strength	Increased	45	25.0
	Decreased	67	37.2
	No change	68	37.8
Other Major Stress Factors	Pests/Diseases	100	55.6
	Habitat Loss	41	22.8
	Poor Management	24	13.3
	Other	15	8.3

4.7. The integration of Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs)

The integration of Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) into this study provided a rich, multi-layered understanding of the complex dynamics surrounding pesticide use and its effects on apiculture in the study area. Qualitative narratives serve not only as validation for the survey results but also reveal contextual subtleties, behavioral patterns, institutional gaps, and socioecological linkages that might not emerge from quantitative data alone. As shown in the figure below (Figure 3), the district-level expert provided valuable insight into the challenges local beekeepers face due to pesticide usage. The discussion focused on demographics related to bee keepers, the linkage between agricultural pesticide use and its effects on beekeeping in the area. He explained that although awareness programs have occasionally been delivered, implementation remains inconsistent and monitoring of pesticide application practices is minimal. He also emphasized that there is a lack of strong coordination between plant protection units and the apiculture development desk, which hinders efforts to protect bee colonies in the area.

Figure 3. Interview with the Sebeta District Agriculture Office representative.

Another interview was conducted with a key informant female and male beekeeper, as shown in the (figure 4 and 5, respectively). The informant shared challenges related to pesticide exposure despite adopting improved apiculture practices. She explained that although she had adopted improved hive technology, her bees often experienced stress during the spraying season. Her primary concern was the use of pesticides on nearby vegetable plots and the lack of notification when spraying occurs. Despite practicing better hive management, she noted recurring reductions in honey yield, especially in the spring season when pesticide activity increases.

Figure 4: Interview with a local woman beekeeper who uses modern hives in close proximity to nearby farms.

Figure 5. A beekeeper shared firsthand experiences of declining colony strength and reduced honey yields, attributing the changes to pesticide exposure from nearby vegetable farms.

The below photo (Figure 6) of a field interview with a local beekeeper in Sebeta, Oromia, Ethiopia, reveals a row of beehives traditionally made from locally available materials and standing on wooden pedestals under the shade. These are the types of hives commonly used by local beekeepers in the nation and reflect the traditional apiculture dominant in most rural Ethiopian beekeeping. His account highlights how even small-scale, home-based beekeeping operations are not insulated from the broader agricultural practices that pose risks to bee health. The openly casual environment highlights the grassroots level of beekeeping in Sebeta, where apiculture is not only a cultural tradition but also a source of income for most. The informant explained how increased use of pesticides in surrounding farm fields has affected the health and productivity of his bee colonies from one year to the next. According to him, the decline in bee populations and hive productivity has increasingly been noticeable over the past few years, particularly during crop flowering seasons intensively cultivated like other respondents. He described that bees that expose themselves to pesticide-contaminated plants rarely return to the hives, and the ones who survive become lost and weak. As observed during the field visit, there was minimal activity in some of the hives, suggesting potential colony loss or swarming of bees—matters he attributed to exposure to pesticides.

Figure 6: A row of beehives traditionally made from locally available materials and standing on wooden pedestals under the shade. This another interviewed informant suggested other perspective that augments the broader quantitative data obtained from the study. It is a witness to local beekeepers actual-day plight, and proof of the confluence of environmental degradation through the use of chemicals and loss of sustainable rural ways of life. The narrative of the interviewee underlines the importance of integrated pest management measures and greater regulation of pesticide usage surrounding apiary fields.

4.7.1. Triangulation of Chemical Risk: Consistency Across Data Sources

The survey's finding that 55.6% of beekeepers experience pesticide exposure near their hives was strongly raised in the KIIs and FGDs. Participants repeatedly identified pesticides as the most prevalent pesticide classes used in the area—chemicals widely documented in the literature for their acute and chronic toxicity to bees (Sánchez-Bayo & Goka, 2014; Woodcock *et al.*, 2017).

4.7.2. Pesticides act through different mechanisms:

Neonicotinoids are systemic, persisting in plant tissues, nectar, and pollen, and causing impaired navigation, memory loss, and colony collapse even at sublethal doses. Organophosphates, by inhibiting acetylcholinesterase, cause neuroexcitation, leading to bee tremors, paralysis, and death.
Pyrethroids, though generally less toxic, still cause repellence, altered foraging, and reduced thermoregulation in bees, particularly when applied repeatedly or synergistically with other compounds. (P. RIETH & D.LEVIN.2018). Community-level observations from FGDs regarding aerial and boom spraying reaffirm the survey's findings and align with well-established risks of pesticide drift, which have been shown to affect non-target insects several kilometers away from the application site. The problem of non-notification before spraying, emphasized by 68.3% of survey respondents, was deeply felt in qualitative narratives and is recognized globally as a major barrier to pollinator protection (EFSA, 2018). The qualitative data vividly described neurological symptoms in bees—disorientation, circling, failure to return to the hive—which precisely match neuroethological evidence from toxicology research. (Al Jafar.n.d) Chronic exposure reduces colony thermoregulation, alters circadian rhythms, and delays larval development, ultimately impairing population dynamics. The fact that 61.1% of beekeepers observed colony absconding or collapse aligns with what is classified in the literature as Colony Collapse Disorder (CCD)-like events, though the term is now more broadly attributed to multi-stressor declines rather than a singular phenomenon.

4.8. Economic Impacts and Ecological Feedback Loop

Qualitative insights further validate survey reports of declining honey yields (35.6%) and weakened colonies (37.2%), adding first-person economic testimonies to the data. Beekeepers detailed reduced harvests and income losses, particularly in years with poor coordination between spraying schedules and flowering seasons. Such misalignment exacerbates phenological risk, whereby bees are more likely to encounter contaminated floral resources. This observation is consistent with agroecological models that stress the importance of synchronizing pest management with pollinator-safe flowering windows. Moreover, these declines trigger feedback loops: weaker colonies mean less pollination, which in turn leads to lower crop yields, possibly prompting increased pesticide use in a vicious cycle of agricultural intensification and pollinator decline. FGDs referenced these cycles, noting that some farmers increase chemical inputs after observing reduced fruit set or pest outbreaks, unaware that they may be exacerbating pollination deficits caused by their own chemical practices. While 96.1% of survey respondents received beekeeping training, the qualitative accounts expose a critical disconnect between training content and actual risk preparedness. KIIs with beekeepers and agricultural experts revealed that most training programs focus narrowly on hive construction, honey harvesting, and colony inspection, without integrating modules on: pesticide risk communication, toxicity classifications, protective protocols during spraying seasons, intersectoral coordination mechanisms. This narrow approach reflects a broader structural bias in agricultural extension systems, which tend to prioritize yield-enhancement for crops over ecosystem service protection, a pattern documented in studies across Sub-Saharan Africa (FAO, 2019). The agricultural agents themselves admitted in KIIs that pollinator protection is not yet institutionalized within national pest management programs, and cross-departmental collaboration between plant protection units and apiculture divisions is minimal or non-existent. FGDs called attention to this disjunction and proposed more holistic training models, including participatory learning approaches, hands-on field demonstrations, and integrated farmer-beekeeper workshops. These align with best practices in agroecological extension, which emphasize co-production of knowledge and local adaptation. Both KIIs and FGDs generated practical, community-based recommendations that closely align with globally endorsed pollinator protection protocols (e.g., the FAO's Global Action on Pollination Services for Sustainable Agriculture). Suggested solutions included: mandatory advance notification systems using mobile alerts or community spray calendars, buffer zones and pesticide-free corridors near apiaries. Time-of-day spraying regulations, such as prohibiting application during peak foraging hours (8 a.m. – 5 p.m.). The call for prohibiting aerial spraying near apiary zones is particularly significant, as this method is known to maximize drift, and its regulation remains weak in many developing regions.

CHAPTER FIVE

5.1. Conclusion

The findings of the research provide strong evidence that beekeeping in Sebeta is greatly impacted by the excessive use of pesticides and the poor extent of institutional support to the local cultivators. Beekeeping remains one of the significant sources of livelihood for the households of the locality, yet the sector continues to be dominated by traditional practices with minimal movement towards modern hive technology or improved management practice. Most of the respondents reported spraying of pesticides in close proximity to their apiaries, most commonly during sensitive periods of bee activity such as crop flowering. This is followed by high observed bee mortality, hive absconding, and poor honey production,

The expert and key informant interviews revealed the existence of policy-practice gaps in the regulation of pesticide use and the safeguarding of pollinators. Most farmers were unaware of pesticide types or protection regulations, and most had no access to formal training or advisory services. The field report and photographic records also supplemented the quantitative data by showing the realities of both modern and traditional beekeepers who continued to bear the brunt of uncontrolled chemical use on surrounding farms. Even those who employed improved technology, like modern hives, continued to record stress in their bee colonies, highlighting that technology alone is not sufficient without external support and environmental safeguards. Moreover, records of widely used agrochemicals—including Megaban (chlorpyrifos), Herb 720 SL (2,4-D), Matco, and Glymax (glyphosate)—indicated the ongoing use of harmful chemical inputs in agriculture with disastrous implications for pollinators and ecosystem health.

5.2. Recommendation

Collectively, these findings underscore the need for an intensive pest and pollinator management plan, enhanced regulatory enforcement, and increased farmer training for the promotion of both agricultural productivity and sustainable beekeeping and based on the findings of the study the following are recommended:

The study concludes that pesticide application without significant awareness and lack of proper pesticide management was a primary driver for the declining health and productivity of bees in

Sebeta, and that beekeeping in the district continues to be extremely sensitive unless regulatory control, improved farmer training, and community-based protection measures are applied. Thus, the study calls attention to an urgent policy need, education of farmers, and promotion of safer alternatives like biopesticides to offer sustainable apiculture and protect pollinators in agro ecosystems.

- Promote farmer training on pollinator-friendly pesticide use, including proper timing and safer alternatives.
- Agricultural extension workers should receive strong and extensive training in Apiculture, and the ministry should follow up their work progress actively.
- Establish collaboration between plant protection officers and apiculture development units at the local level.
- Enforce mandatory pre-spray notifications to nearby beekeepers to allow for hive protection.
- Encourage the adoption of biopesticides and integrated pest and pollinator management (IPPM) strategies.
- Develop and implement strict regulations on aerial spraying and pesticide use near apiaries, including buffer zones and pesticide-free corridors.

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Appendix

Questionnaire for Research on Effects of Pesticides on Beekeeping in Sebeta, Oromia, Ethiopia

<u>Section I:</u> Semi-Structured Questionnaire for Beekeeper Households

Demographic and Socioeconomic Information

1. Age: __________
2. Educational Level: a. No formal education b. Primary c. Secondary d. College and above
3. Household Size: __________
4. Your Primary Occupation:
   a. Beekeeping b. Crop farming c. Mixed farming d. Other (specify): __________
5. Years of Beekeeping Experience: __________ years

Beekeeping Practices

6. Number of Beehives you Maintained:
   a. 1–5 b. 6–10 c 11–20 d. More than 20
7. Type(s) of Hives you Used:
   a. Traditional b. Transitional c. Modern d. Mixed
8. Primary Purpose of Beekeeping:
   a. Honey production b. Pollination c. Wax/hive products d. Marketing Other: __________
9. Have You Received Formal Beekeeping Training?
   a. Yes b. No

Pesticide Exposure and Nearby Use

10. Are pesticides applied near your apiary?
    a. Yes b. No
11. Who applies the pesticides?
    a. Yourself b. Neighboring farmers c. Commercial farms d. Government/NGOs
12. What types of pesticides are used? *(Check all that apply)*
    a. Neonicotinoids b Organophosphates c. Pyrethroids c. Unknown d. Other:_
13. Estimated number of pesticide applications near your apiary per year:
    a. 1–2 b. 3–5 c. 6–10 d. More than 10 e. Not sure
14. What method(s) of application are commonly used? *(Check all that apply)*
    a. Hand spraying b. Seed treatment c. Aerial spraying d. Other: __________
15. What crops are typically treated with these pesticides? __________
16. Do you received advance notice before nearby pesticide applications?
    a. Yes B. No
17. Do you take any measures to protect your bees during pesticide application?
    a. Yes (specify): __________B. No

Observed Impacts on Beekeeping

18. Have you observed increased bee mortality following pesticide application?
    a. Yes a. No

19. Have you noticed unusual changes in bee behavior (e.g., disorientation, inactivity)?
    a. Yes (specify): __________ b. No
20. Have you experienced colony collapse or absconding in the past 2 years?
    a. Yes b. No
21. How has your honey production changed recently?
    a. Increased b. Decreased a. No significant change
22. Has your colony strength (population size) changed over the past year?
    a. Increased a. Decreased c. No change
23. How has pesticide use affected your honey yield? (e.g., kg per hive) _____________
24. What other major factors are affecting your bees? *(Check all that apply)*
    a. Pests/diseases b. Habitat loss c. Poor management d. Other (specify): __________

Section II: Key Informant Interview With
Beekeeper-Farmers

1. Have you observed any changes in bee health, colony mortality, or honey yield that you associate with pesticide use?
2. What types of pesticides are commonly used near your apiaries, and how are they applied?
3. Have any changes been made in local farming or pesticide practices to reduce harm to bees?
4. What strategies have you personally adopted to manage pesticide risks?
5. What are the main challenges you face in keeping your bees safe and productive?
6. Do you receive any advice or support from cooperatives, agricultural agents, or institutions?

agricultural Experts, Government Officials, & Cooperative Leaders

1. Which insecticides are most commonly used in this area, and for which crops?
2. Are there any training programs or guidelines for safe pesticide use near beekeeping areas?
3. What trends have you observed in honeybee health, colony losses, or production levels?
4. How is your office or organization supporting pollinator-friendly farming practices?
5. What policies or practices do you recommend to improve coexistence between agriculture and beekeeping?

Focal Group Discussion (FGD)-Used with groups of beekeepers, farmers, and local leader

1. What types of insecticides are commonly used, and on what crops?
2. Have you observed any collective changes in bee behavior, mortality, or honey production?
3. What methods are local beekeepers using to minimize the impact of pesticide exposure?
4. How helpful have agricultural cooperatives or agents been in supporting safe beekeeping?
5. What improvements are needed in pesticide regulation, awareness, and pollinator protection?