EVALUATING THE VIABILITY OF INTRODUCING (*Metarhizium anisopliae*), A FUNGAL BIOPESTICIDE, INTO THE INVENTORY OF AGRODEALERS IN KIRINYAGA COUNTY, KENYA.

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A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Master of Science Degree in Agribusiness Management of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this university or any other for the award of a degree

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Recommendation

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DEDICATION

I dedicate this work to my lovely parents and my family members who have shown me love, emotional support and understanding throughout this entire process.

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ABSTRACT

Trading in chemical pesticides has proved to be inefficient even though agrodealers have heavily invested in them. Apart from their high cost of production, these chemicals pose a significant threat to human health and the environment. Biological control measures such as biopesticides have been recommended as a more sustainable alternative to synthetic chemicals. Thus, the objective of this study was to assess the feasibility of stocking a fungal based biopesticide (ICIPE 20) for the management of Tomato leaf miner *(Tuta absoluta)* by agrodealers in Kirinyaga County, Kenya. The study was conducted in two sub-counties, namely Mwea East and Mwea West. A census of agrodealers in the two sub-counties was conducted during a preliminary visit with the help of sub-county agricultural officers. The list comprised of 141 agrodealers who were all included in the survey. Primary data was obtained through observations, interviews, and semi-structured questionnaires. Descriptive statistics, principal component analysis, binary probit model, and cost-benefit accounting techniques were employed to analyze the study's objectives. The results revealed that about 43% of the respondents were aware of the specific non-pesticide practices that could be used to control the tomato-infested insect pest, and 79% of the respondents stated crop rotation with a non-host crop as the primary control measure. Based on the principal component analysis employed to analyze knowledge and perception, the extracted components had the first one contributing the highest percentage (35%) to the variance. The second and third components contributed 15% and 13%, respectively. The components represent effectiveness, general effect on human health and the environment, and the aspect of commercialization, respectively. The survey results further depict that the most used pesticide for managing *Tuta. absoluta* is Coragen at an average price of Ksh 622 per litre**.** Eighty-two (82%) of the agrodealers were willing to stock and resell a fungal based biopesticide at the same price as Coragen. On average, the willingness to stock was 64% higher than the cost of Collagen. The regression results indicate that willingness to stock ICIPE 20 was negatively related to the agrodealer’s age but positively influenced by agrodealer’s access to a social network, years of schooling, access to credit facilities, and information. Thus, there is a need to improve agrodealers access to social networks, credit facilities, and information. These institutional factors are likely to enhance their knowledge, perception, and willingness to stock new products such as ICIPE 20. There is also a need to limit synthetic Certification that inhibits the dominance of Biopesticides.

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LIST OF ABBREVIATIONS AND ACRONYMS

BT	*Bacillus thuringiensis*
BC	Biological control
COMESA	Common Market for Eastern and Southern Africa
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
HCDA	Horticultural Crops Development Authority
ICIPE	International Centre of Insect Physiology and Ecology
IPM	Integrated Pest Management
NBS	National Bureau of Statistics
NGOs	Non-Governmental Organizations for Biopesticides and biocontrol Agents
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Science
STATA	Statistics and Data
USD	United States Dollar

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

New products create excitement to consumers since they provide broader alternatives and profits to retailers, including increased customer traffic, points of differentiation and a signal that the retailer is stocking and supplying the best products. They are also responsible for the firm's long-term success since they are depended on to revive old products while enhancing customer loyalty. Suppliers and retailers always aim to maximize returns and achieve efficiency (He *et al.*, 2019). Therefore, given that competition of a variety of new products and already existing products exists in the market, introducing a new product is crucial to both agrodealers and the farmers. To maximize returns, agrodealers are compelled to stock in large volumes pesticides that are effective and highly demanded by tomato farmers in crop protection against the invasive tomato leaf miner *Tuta absoluta*, which is capable of causing between 80 to 100 percent yield loss if no control measures are executed (Wafula *et al*., 2018a).

Since the invasion of *Tuta. absoluta* in Kenya, agrodealers have been stocking in large volumes, synthetic chemical pesticides in the agrovets, thus promoting their use and farmers relying much on them in crop protection. Cultural methods for managing the pest have also been previously reported from Kirinyaga county, including uprooting infected tomato plants, crop rotation, baiting and killing the adult moth (Nderitu *et al*., 2018). Farmers use conventional synthetic pesticides since they are considered readily available, increase production as they protect the crop from pests and diseases, solve risks associated with farming, unpredictable weather conditions, and save time and effort used in farming (Duran *et al*., 2020). The contribution of synthetic chemical pesticides to increase agricultural production cannot be underscored. However, these chemical pesticides have caused unprecedented ecological damage, induced severe health hazards among workers during their manufacture, formulation, handling in the agrovets and field application in crop protection (Ankit *et al*., 2020). Continuous application has also led to pest resistance and residues in food substances harmful to human health and the environment. The chemicals are often associated with long term health impairments such as cancer and, therefore, not sustainable for producing food crops such as tomatoes.

Previous studies have demonstrated that biopesticides are specific to the pest organism with a correspondingly low risk to the non-target organism. They constitute a particular group of active

substances and several living organisms that occur naturally for plant protection. They are derived from naturally occurring materials such as animals, plants and bacteria, and mainly constituted in fungi, protozoa, nematodes, baculoviruses and bacteria, such as the widely used *Bacillus thuringiensis* (Bt) in the United States of America, to regulate the population of insect pests (Wilson *et al.,* 2019). Thus, effective and efficient in pest management, for instance, in the management of potato tuber moth, rice ear head bug and oriental army worm for wheat sorghum and corn. The corresponding yield increase in these crops has been reported due to the use of sustainable biopesticides and safe for human health (Seenivasagan & Babalola, 2021). Biopesticides, therefore, hold promises to replace chemical pesticides soon since they prove to be sustainable.

The increasing demand for organic food products due to the adverse effects of synthetic chemical pesticides has stimulated the growth of organic farming, which is now the fastest growing industry in agriculture in the world (Ummyiah *et al.,* 2017). Organic farming combines both indigenous practices and science to produce crops that flourish without synthetic pesticides and herbicides. It also incorporates integrated pest management packages such as mass trapping of insects, orchard sanitation and biological control (Wafula *et al*., 2018b). Biological control (BC) considers the use of biopesticides and other living organisms such as parasitoids or a beneficial insect that destroys the harmful one. Biological control replaces chemical pesticides, thus reducing chemical residues in food substances for consumers. Kenya has recognized the importance of promoting biopesticides as an alternative to chemical pesticides for agricultural purposes (MALF, 2021). Several policies and strategies have been implemented to encourage the adoption and use of biopesticides. These include: National Biopesticide Policy: The ministry of Agriculture, Livestock, Fisheries and cooperatives has developed a National Biopesticide Policy that aims to promote the use of biopesticides and other environmentally friendly pest management practices. The policy provides a framework for regulating, promoting, and supporting the production, importation, distribution, and use of biopesticides. Additionally, Capacity Building and Training has also been laid up. The government, in collaboration with research institutions and international organizations, conducts capacity-building programs and training sessions to educate farmers, extension workers, and other stakeholders about the benefits and proper use of biopesticides. These initiatives enhance awareness, knowledge, and skills related to biopesticide application and management. Therefore, biopesticides are a sustainable alternative for the management of *Tuta. absoluta* in the tomato fields (Ummyiah *et al.,* 2017). A study on biopesticides in Kirinyaga

County is thus justified to promote sustainable agricultural practices, reduce chemical pesticides use, and safeguard human health and the environment.

The International Centre of Insect Physiology and Ecology (ICIPE), in collaboration with its partners, are introducing a fungal based biopesticide (ICIPE 20) for combating the tomato leaf miner (*Tuta. absoluta*) in an integrated pest management approach. This pesticide is to be sold to farmers through agrodealers. Since the ICIPE 20 is a new product, it will have to compete with existing products, synthetic pesticides, for shelf space in agrovets. This study, therefore, aims to determine the feasibility of stocking ICIPE 20 by agrodealers.

1.2 Statement of the Problem

Agrodealers are compelled to stock chemical pesticides that are often demanded by tomato growers for controlling the invasive tomato leaf miner (*Tuta. absoluta).* The pest could cause 80 to 100% crop loss if not managed. Frequent exposure to synthetic chemical pesticides, however, poses health risks to humans and the environment. Their continuous manufacturing, formulation, and incorrect mixing ratios that involve direct handling by the agrodealers may also result to diseases such as cancer. The use of a fungal-based biopesticide (ICIPE 20) has been proposed as one of the IPM components in managing *Tuta. absoluta*, as an alternative to the toxic and high-costing chemical pesticides. However, the knowledge and perceptions of agrodealers on the fungal based biopesticide are not clearly understood. Furthermore, factors influencing their willingness and the capacity to stock the fungal based biopesticide and potential costs and benefits associated with the commercialization of the biopesticide have also not been adequately established. This study, therefore, seeks to fill this gap using the case of Kirinyaga County, where tomato production is predominant.

1.3 Objectives

1.3.1 General Objective

The general objective of this study was to contribute towards increased returns of agrodealers through the stocking of profitable Biopesticides.

1.3.2 Specific Objectives

i. To analyze the knowledge and perception of agrodealers towards the use of biopesticides to manage pests in Kirinyaga County.

ii. To assess the agrodealers' capacity to stock the fungal based biopesticide in Kirinyaga County

iii. To determine the factors influencing the agrodealers willingness to stock a fungal based biopesticide (ICIPE 20) for management of *Tuta. absoluta* in Kirinyaga County.

iv. To determine the potential costs and benefits of stocking a fungal based biopesticide among agrodealers in Kirinyaga County, Kenya.

1.4 Research Questions

i. What are the knowledge and perceptions of agrodealers towards the use of biopesticides for management of pests in Kirinyaga County?

ii. What capacity do the agrodealers have towards stocking a fungal based biopesticide in Kirinyaga County?

iii. What are the factors influencing agrodealers willingness to stock the fungal biopesticide for management of *Tuta absoluta* in Kirinyaga County?

iv. What are the potential costs and benefits associated with stocking of a fungal based biopesticide among agrodealers in Kirinyaga County?

1.5 Justification of the Study

There is a need for more significant investment in alternative pest management to replace the expensive and hazardous broad-spectrum chemicals for managing invasive pests such as *Tuta absoluta.* Therefore, agrodealers need to shift from investing in chemical pesticides to biopesticides since they are safe for humans, the environment, and sustainable. The change of stocking decisions aims to open broader markets hence increased participation among agrodealers in local and international markets. This will lower the rate of poverty and hunger with corresponding job creation to the fast-growing human population and improved returns to agrodealers. Products from biopesticides are also of high quality and meet the set standards of maximum chemical residues in food substances for the trading blocks, such as the common market for Eastern and Southern Africa (COMESA). Access to international markets generates foreign exchange to the country thus contributing to economic growth. This is aligned with the sustainable development goals (SDGs) number 1, 2, and 3 of no poverty, zero hunger and good health and well-being, and conforms to the economic pillar of vision 2030.

Assessing the feasibility of stocking the fungal based biopesticide by agrodealers in Kirinyaga County aids in determining the potential costs and benefits associated with the commercialization of the biopesticide and the factors influencing agrodealers willingness and capacity to stock the fungal based biopesticides, which is not only important for development agencies but also the policy makers in decision making on sustainable agricultural production. Further, identifying agrodealer's knowledge and perception towards the fungal based biopesticides would also provide critical feedback in designing policies for disseminating the sustainable alternative approach to managing the invasive *Tuta absoluta* that poses a significant threat to the country's horticultural sub-sector.

1.6 Scope and Limitation

This study was carried out in Kirinyaga County in the central part of Kenya, and only agrovets in Mwea East and Mwea West were considered. In this study, agrovets were considered as the marketing outlets of agricultural inputs, and therefore, Agrodealers dealing in pesticides was the sampling unit. The study focused only on the feasibility of a new biopesticide ICIPE 20 used to control the tomato leaf miner *Tuta absoluta.* The fungal based biopesticide was only compared to the competing pesticides that were on high demand by tomato farmers hence narrowed down to Coragen, as the most used pesticide.

1.7 Operational Definition of Terms

i. **Agrodealers** - The marketers of farm input required by farmers in production of farm products.
ii. **Biological control –** This is a method of controlling pest such as insects, mites and weeds using other organisms.
iii. **Biopesticides** – Are certain types of pesticides derived from natural materials as animals, plants, bacteria and certain minerals.
iv. **Capacity to stock** – The ability to do something based on your resources
v. **Feasibility** -The assessment of practicality or viability of a proposed plan.
vi. **Fungal based biopesticides** -A form of pesticides based on microorganisms or natural products

vii. **Integrated pest management** -An eco-system-based strategy that focuses on long term prevention of pests or their damage through mass trapping, Orchard sanitation and biological control.

viii. **Pest resistance –** The decreased susceptibility of a pest population to a pesticide.

ix. **Sustainability** – The ability to exist constantly by focusing on meeting the needs of the present without compromising the ability of the future generations to meet their needs.

x. **Synthetic chemical pesticides –** An in organic substance that is not found naturally and does not contain the element 'carbon', used in the garden to control pests.

xi. ***Tuta absoluta*-** A species of moth in the family Gelechiidae known by the common names leaf miner, tomato pinworm and South American tomato moth.

xii. **Vendors** – A party in the supply chain that makes goods and services available to consumers.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of the Biopesticides Industry

Biopesticides are significant components of integrated pest management and a potential alternative to synthetic chemical pesticides. Microbial pesticides, entomopathogenic nematodes, baculoviruses, plant-derived pesticides, and insect pheromones are examples of biopesticides that can be employed as alternatives to chemical pesticides and are critical components of an integrated pest management (IPM) strategy (Kumar *et al*., 2021). Biological pesticides, in reality, account for a minor portion of the global pesticide business at the current time. In 1995, it was expected that the biopesticide market share would be around $380 million. They are essential despite accounting for only 1.3 percent of total biopesticides, and the great majority of biopesticides are now offered for insect control.

The market for biopesticides is expected to grow at a rate of 10 to 15 percent per year over the next decade, compared to 2% for chemical pesticides. Biopesticide research is not a new concept; it dates back to the primordial age (Dar *et al*., 2019). Even though biopesticides account for fewer than 1% of all plant protection agents on the planet, their quantity and rate of growth have both surged over the previous two decades (Ivase *et al*., 2017). The most commonly made and used biopesticides are neem, Bacillus thuringiensis, NPV, and Trichoderma-derived insecticides, accounting for more than half of all production and use.

Biopesticides differ from chemical pesticides in that they are environmentally friendly and quickly biodegradable. As a result, they produce fewer hazardous residues and, in most circumstances, do not cause the pollution issues that chemical pesticides do. Furthermore, using biopesticides as part of an integrated pest management program can significantly reduce the use of conventional pesticides while maintaining or boosting crop yields to similar levels (Deguine *et al*., 2021).

According to industry observers, the biopesticide industry is growing at a breakneck speed. Biopesticides have expanded dramatically from less than 0.2 percent of the whole pesticide market in 2000 to roughly 2.5 percent of the total pesticide market in 2005. With a market capitalization of greater than $1 billion, this ratio is predicted to climb to over 4.2 percent by 2010 (BCC Research). On the other hand, biopesticides are predicted to grow at a pace of roughly 10% per year for the next five years, according to forecasts. When it comes to application, orchards account

for most biopesticides used in the United States (55 percent). North America consumes the majority of global biopesticide output (40 percent), with Europe and Oceania (each 20 percent) following closely after. The research and development status of the biopesticides listed here is assessed using a combination of two measures: publications and patents. In biopesticides, Indian researchers have produced 443 papers, accounting for between 13 and 23 percent of the total 3,348 papers published worldwide. India owns about 3.55 percent of all biopesticide patents globally, which is a modest percentage of the total (Rohatgi *et al*., 2017).

Global publications expanded at an average yearly rate of 51.1 percent over the study period, but India's publications grew at 37.4 percent on average. India appears to be in bad shape in terms of patents, even though the total number of patents issued worldwide has only slightly increased in recent years. India has only received 19 patents in biopesticides so far (Rohatgi *et al*., 2017).

The adverse effects of synthetic chemical pesticides on the environment and biodiversity and corresponding consumer demand for safe food have greatly stimulated biopesticides research, which seems to be a good measure and an excellent alternative for crop protection. Biopesticide development is therefore taking a new shape due to the realization that chemicals are hazardous, and not sustainable. Many people are also becoming aware and knowledgeable about the safe products which are absolutely organic. The synthetic chemical pesticides market therefore has also declined due to demand for organic products worldwide (Moshi *et al*., 2017). This decline is approximated to continue in the future years. At the same time, the alternative and sustainable biopesticides and their market are growing and expected to keep increasing over the coming years. Much research has been done to develop biopesticides, hence increased planting of genetically modified crops (Loughlin, 2017a). The wide application of integrated pest management methods, which entails mass trapping, orchard sanitation and biological control for crop protection and increased areas under organic farming, is the crucial development that will contribute significantly towards the growth of biopesticide markets in future (Loughlin, 2017b).

The orchards, including floriculture, vegetables, and fruits, have a more significant share of biopesticides use, adding up to about 55% of biopesticides applied in crop protection (Niggli *et al*., 2016). Organic farming is also considered an integrated pest management method since it is a driver for the heavily increasing biopesticide market and aims for sustainability. Therefore,

integrated pest management takes a holistic approach that combines both conventional and biopesticide use in crop protection for sustainability.

2.2 Feasibility of Stocking Pesticides

Biopesticides are potentially essential tools in integrated pest management programs, and they are target specific, therefore beneficial when aiming to reduce environmental damage (Samada *et al.,* 2020). Besides, they have a competitive advantage over chemicals since they are safe for humans and the environment. They are also cost-effective since they are made from naturally occurring materials and organisms. Thus, products from biopesticides have low chemical residues hence safe for consumption (Damalas & Koutroubas, 2018). Looking at the future of agriculture and food system, incorporating sustainable plans and systems that doesn't compromise the environment seems to be the solution that each and every economy requires. Based on the availability and demand of the pesticides, biopesticides are readily available, and most of them are registered, yet the agrodealers stock not all registered products in their outlets. Studies indicate that if there is little market for a product, agrodealers are less likely to stock the products (Constantine *et al*., 2020). Thus, there is a pressing need to venture into the advertisements and product promotion to upscale their use. Further, certifications also form the basic root of making biopesticides available and known for effective use.

Previous studies also show that agrodealers don't stock biopesticides since they perceive them to have low demand (Constantine *et al*., 2020). These biopesticides are therefore scarce in the agrovets. Thus, availability and access are factors perceived to be significant constraints to the greater adoption of these biopesticides. Hence, influencing agrodealers to stock these products might have a tremendous impact on profitability. Some of the factors that statistically show significant effects on the feasibility of stocking biopesticides by the agrodealers include; County location, health perception, farm specialization and education level. For instance, agrodealers with tertiary education might be willing to stock the biopesticides than those with no education (Rwomushana *et al*., 2019). The cost of biopesticide is also of high importance since the agrodealers aim at maximizing profits. Reduced cost or availability of subsidies for biopesticides, could be a strategy towards enhancing higher stocking decisions. Therefore, biopesticide companies will obtain a more significant market share, thus improving their ability to compete with already existing and established chemical pesticides (Constantine *et al*., 2020).

These biopesticides have the characteristic of being efficient and sustainable; therefore, they seem to replace synthetic chemical pesticides (Essiedu *et al*., 2020). This is because they are safe for the environment and does not cause depletion. They are also safe for humans due to low chemical residues in food substances. Biopesticides are specific to their target and suppress pests with a critical timing since they have a narrow target range that makes them effective. Since the agricultural commodity markets fail to incorporate the environmental costs of agricultural production, there is a huge gap that needs to be filled. Besides, given the expressed social goals of reducing environmental damages and depletion, a holistic approach needs to be taken into account in developing a truly sustainable agriculture (Essiedu *et al*., 2020). The debate therefore needs to focus on how alternative public policy instruments can be effectively utilized to provide better solutions and resolve conflicts, or rather the most efficient alternative that can actually bridge this gap. A lot has to be put in place with a view to focusing on the better safe ways of exploiting the resources, and at the same time taking care of the environment, which is heavily getting depleted.

In different countries, regions, regulatory organizations, and even among scientific community members, biopesticides are described and classified in several ways. PIPs, for example, are categorized as biopesticides by the United States Environmental Protection Body (US-EPA), a Washington, D.C.-based government agency. Pesticidal compounds produced by plants due to genetic material inserted into the plant, such as the Bt gene, are known as Phyto insecticidal compounds (PIPs). Under the European Union, the word "biopesticides" has been replaced by "biological control agents," and PIPs are not considered biopesticides in that jurisdiction (Ndolo *et al*., 2019).

Several review papers, including the one described above, have looked into these divergences, making it difficult for businesses to navigate regulatory systems easily. Even though many biopesticide-active compounds have been discovered and synthesized, only a limited number of these compounds have been registered due to lengthy and bureaucratic regulatory processes in many countries (Leather & Pope, 2019). However, there are a few notable outliers, such as the United States. These methods are generally similar to those used to register conventional pesticides and have not progressed far enough to allow for effective biopesticides control. The risk assessment stage of the biopesticide registration procedure is crucial. Even though this evaluation should be based on scientific data, several countries' submission procedures are excessively lengthy. As a result, registration procedures must be changed to assess biopesticide

active chemicals effectively. Another barrier to biopesticide registration is the difficulty in obtaining registration for new chemicals (Damalas & Koutrobas, 2018)

Regulatory organizations should speed up the registration procedure for biopesticide products based on reasonable and acceptable regulations, allowing innovative products to access the market and earn revenue faster than previously feasible. The majority of biopesticide research is conducted in the early stages of development, resulting in many scholarly publications on "possible" biopesticides. Such compounds should be referred to as biocontrol agents rather than biopesticides, and they should not be labelled as such until commercial approval has been given (Ghosh *et al*., 2021).

Transferring knowledge from a research project to the product development process necessitates knowledge from a variety of domains. Biopesticide innovation chains are required for biopesticide research to be coordinated, resulting in "biopesticide innovation chains" and for biopesticide research, development, and delivery to be centralized. Biopesticide development, like all other types of R&D, requires the use of skilled human resources, adequate physical infrastructure, and collaboration with one or more small and medium-sized enterprises (SMEs) to provide input during the early stages of R&D to ensure that developed products have market potential (Ghosh *et al*., 2021).

To succeed, it is also necessary to increase cooperation with complementary sectors outside of the pesticide industries. Patenting ideas is critical, especially for small businesses, if they want to reap larger organizations' rewards (Glare *et al*., 2016). This is particularly true for new businesses. Even though it is currently illegal to patent naturally occurring organisms, patent laws can distinguish between discovery and invention, the latter of which can be patented if it meets the patentability criteria (novelty, inventive step, and industrial applicability) outlined in article 27 of the Trade-Related Aspects of Intellectual Property Rights (TRIPS), a treaty governing international intellectual property rights. The most significant drawbacks for consumers are the additional maintenance requirements and acceptance of efficacy generally lower or slower than chemical options. In a nutshell, in the future of biopesticide development, increased collaboration across disciplines and industry participation will be required, beginning with the selection of the agent to be taken through the research and development process and ending with the determination of the most appropriate business and funding models (Glare *et al*., 2016)

2.3 Importance of Biopesticides

Fungal biopesticides are natural alternatives to chemical pesticides that utilize specific strains of fungi to control pests and diseases in agriculture (Myresiotis *et al*., 2017). These biopesticides offer several advantages, including their effectiveness, environmental safety, and potential for sustainable pest management practices. Fungal biopesticides are derived from naturally occurring fungi that have the ability to infect and kill target pests or pathogens. One example is the use of the fungus *Beauveria bassiana* as a biopesticide against a wide range of insect pests, including aphids, whiteflies, and beetles. This fungus infects the pests by attaching to their cuticles and invading their bodies, eventually causing mortality. Other fungi, such as *Metarhizium anisopliae* and *Trichoderma* species, are also commonly used as biopesticides due to their ability to control pests like termites, nematodes, and fungal pathogens.

The effectiveness of fungal biopesticides lies in their unique modes of action. Fungal spores or hyphae can penetrate the pest's exoskeleton or directly attack the pathogen, leading to their demise. Moreover, some fungi produce toxins or enzymes that further contribute to the pest-killing process. These biocontrol agents have shown promising results in field trials and are increasingly being integrated into integrated pest management (IPM) programs as part of sustainable pest control strategies (Mouden *et al*., 2017). One of the key advantages of fungal biopesticides is their environmental safety. Unlike chemical pesticides, fungal biopesticides are biodegradable and pose minimal risks to non-target organisms, including beneficial insects, mammals, and humans. They offer a targeted approach, reducing the chances of disrupting the ecological balance or causing resistance in pests. Additionally, their short persistence in the environment reduces the risk of pesticide accumulation and contamination.

Research and development in fungal biopesticides have gained significant attention, leading to the availability of commercial formulations in various regions. However, their adoption and implementation in agricultural systems still require further studies, including formulation optimization, application techniques, and integration with other pest management strategies. Continued research and investment in this area are crucial to harness the full potential of fungal biopesticides in sustainable agriculture.

Agriculture's ability to produce and deliver sufficient food has been severely hampered by the world's uncontrolled and ever-increasing population. Pests have long been a source of concern for many in the food manufacturing business (Kumar *et al*., 2021). Nematodes, one of the most prevalent pests, have gained popularity in recent years due to their ability to affect a wide range of hosts. Lentils, cereals, citrus family members, grasses, and horticulture crops are particularly susceptible to nematodes, which can cause total crop losses or crop losses of 100% or more. Meloidogyne, *Heterodera*, *Pratylenchus*, and *Globodera* are the genera with the most plant-parasitic nematode species, and they cause an estimated $100 billion in annual economic losses to plants (Roopa & Gadag, 2020). These losses, which account for 90% of overall yields, affect cotton, wheat, tomato, beans, soybeans, and a range of horticulture crop outputs. Neptune management can be performed in many ways, including cultural strategies such as cleanliness and crop rotation, as well as chemical means; however, the most common, cost-effective, and ecologically friendly option is the judicious use of nematodes. The most significant difficulties of chemical management, which is the primary disadvantage, are health and environmental issues. Alternative modes of transportation that are less harmful to the environment and have fewer health risks have become increasingly popular in recent years. In this context, biopesticides are critical (Roopa & Gadag, 2020).

Biopesticides are formulations made from naturally occurring substances that control pests in a way that is not harmful to humans and the environment. This is because they are derived from plants, animals and microorganisms (Kumar *et al.*, 2021). Living organisms compete with other organisms and, at the same time, are subject to parasitism and predation. This scenario has significantly contributed to their use as biopesticides to control pests, thus leading to improved crop yields. Biopesticides prove to be effective and efficient in various ways that include, Absence of residues in crops after harvesting as compared to synthetic chemical pesticides hence the safety of consumers. They also perform well with minimum applications and superior resistance management potential. Therefore, these products are environmentally friendly, less harmful to humans, specific to the target, efficient in small quantities during application, and decomposes quickly and effectively as a component of integrated pest management (IPM) projects. They include *Bacillus thuringiensis*, *beauveria bassiana* and *Metarhizium spp* (Kumar *et al.*, 2021).

2.4 Traders Knowledge and Perception Towards Biopesticides Use

Biopesticides being critical inputs for the integrated pest management (IPM) approach, holds promises as beneficial alternatives to synthetic chemical pesticides to reduce their externalities to the environment and human health (Berini *et al*., 2018). Biopesticides are crop protection agents that effectively utilize microorganisms or plant extracts as their active ingredients. While there have been significant programs in Africa on research to identify, develop and promote their use in crop protection, there has been little use apart from the *Bacillus thuringiensis* (Kumar *et al*., 2021).

A perception thus prevails that the biopesticides cannot simply replace the synthetic chemical pesticides unless they are used as part of the integrated pest management approach (IPM) (Deguine *et al*., 2021). Exposure in terms of the number of years spent in the pesticides business positively influences the health risks. This is due to frequent interaction and handling the pesticides in their respective stores. The trader's age, experience and the training received in pesticide use and handling are also critical determinants of the adverse effects on health.

2.4.1 Empirical Studies on Knowledge and Perception

According to Abudulai *et al.* (2006) key factors that influence knowledge and perception include; illiteracy, which influences perception. This was based on a sample of 337 cotton farmers in the northern parts of Ghana. A multi-stage random sampling technique was employed and data collected through pre-tested questionnaires and interviews

Results from descriptive statistics showed that a lower percentage of only 28% of farmers have an idea of alternative ways of pest management, which is the integrated pest management approach. Therefore, there is a need for workshops and training through farmer field schools on the IPM approaches in pest management to improve the farmers' perceptions of the biological methods of crop protection. This study differs from the previous one as it targets the agrodealers' knowledge and perception of biopesticides to understand their decision-making in stocking new products. The current study uses principal component analysis to get the perception scores on health, environmental and cost issues.

Issa (2014) also conducted a study in Kaduna and Ondo states in Nigeria where 260 farmers were selected using a multi-stage sampling procedure and interviewed on factors influencing knowledge and perception. The author used descriptive statistics and multiple regression models. The study results showed that socio economic characteristics have a strong positive effect on how

farmers perceive Agrochemicals. Perception is strongly influenced by the level of education and experience in farming activities. The perception on the accessibility of the Agrochemicals, on the other hand, is influenced by the education and income level of the individual farmer. The author further states that age and social participation have a strong positive influence on the perception of accessibility and quality of the Agrochemicals use in farming techniques. This study explains the perception of Agrochemicals among farmers. It is thus different since the current study looks at knowledge and perception on a newly produced biopesticide that is safe to humans and to the environment.

Schreinemachers *et al.* (2017) also analyzed households' knowledge attitude and practices towards pesticides used in South East Asia regarding agricultural pest management and synthetic pesticide use. Data was collected from 900 households producing leaf mustard, who employed synthetic chemical pesticides to spray their crops as they considered them highly effective. They used a regression model and descriptive statistics to show the means and standard deviation. They found that greater use of pesticides is associated with a more significant number of self-perceived pesticide poisoning symptoms. Thus, pesticide dependence can be reduced by increasing the households' knowledge, attitudes, and perceptions towards using alternative ways of pest control such as biopesticides that are safe for both humans and the environment. The current study differs from the previous one since it aims to look into the knowledge and perception of agrodealers towards newly produced biopesticides based on fungus. It also targets agrodealers, unlike the previous that targeted the households.

2.5 Traders' Capacity to Stock New Products

Most manufacturing firms tend to get involved in closer relationship with wholesalers and retailers to utilize their capabilities, resources, and skills to develop and promote new products at a convenient cost. The rationale behind new product stocking decisions among wholesalers and retailers are perceived to be based on various factors which are considered to enhance the efficiency of the business and contribute towards profitability and survival. These factors include the contribution margin of the new product, price of the commodity compared to competitors, the quality and quantity of the commodity, the marketing reputation of the manufacturer of that particular product, and the potential opportunities that are likely to be provided new venture. Scholars also recognize the relationship, commitment and trust as ingredients in involvement in new product development (Tabrani *et al*., 2018). When the buying process is investigated, some

other factors, which include profitability, the newness of the product and the role of the new commodity in the total mix that the retailer carries, becomes significant in determining patronage decisions.

2.5.1 Empirical Studies on Traders Capacity to Stock New Products

In a case study in Zimbabwe, 659 rural agrodealers were linked to wholesalers to receive inputs, and 500 agrodealers trained in retail business management focused on restocking programmes. The pilot project results indicated that rural agrodealers lack the financial capacity to stock their stores with new products. On the other hand, the suppliers of agricultural inputs also have a low financial capacity to support agrodealers. The findings also illustrate that both agrodealers and farmers cannot receive the agricultural extension support necessary for acquiring and dealing in agricultural input products. Training and mentorship of employees become a critical issue when it comes to the handling of new products that retailers stock; therefore, the agrodealers need to train and mentor their employees on new products restocked and establish active retailers networks that will ease transactions in newly stocked products among the retailers since the information that is vital based on new products, market niches and manufacturers will be available for exploitation (Mwema *et al.*, 2022). The current study focused on rural agrodealers restocking agricultural inputs and analysing the incentives based on credit facilities and training programmes. The current study differs from the existing one since it examines the agrodealers capacity to stock a fungal based biopesticide. It aims to look into the agrodealers access to finances, specialised storage facilities, knowledge and skills of handling the biopesticides, the employees available and the agrodealer networks that effectively promote sales.

In a baseline survey done in various counties in Kenya, interviews and focus group discussion was used on 438 agrodealers in Muranga, Taita taveta, Trans nzoia, Kericho, Nakuru, Kisii, Meru and Bungoma. This study assessed the relationship dynamics between agrodealers, seed companies and farmers based on a new seed variety. Descriptive statistics illustrated that agrodealers use ICT to access information related to new products from manufacturers. It also showed that agrodealers train their employees on handling the new products and educate them about the new varieties. The results from the survey further indicate that the agrodealers incur costs such as storage costs, transport, loading and offloading, labour, licensing, wages and salaries and sales promotion (Bayesian, 2016). The current study has mainly focused on the relationship between agrodealers, manufacturers and farmers based on trends in the sale and adoption of new

seed varieties. Therefore, this study aims to add to the body of knowledge, the capacity of agrodealers to stock a fungal-based biopesticide (ICIPE 20) that is efficient in crop protection.

2.6 Factors Influencing Traders' Willingness to Stock a New Product

The permission and assistance of merchants are frequently required for a new product's success. Retail shelf space, despite its scarcity, may be a precious resource, and how well a retailer uses it can make or break a business's profitability (Avlijas *et al*., 2018). As a result, when selecting products from the vast diversity of possibilities accessible, the retailer must approach with considerable caution. Aside from the product's specifications and market conditions, other factors frequently impact the evaluation of a new product. On the other hand, prior research has focused solely on product and market characteristics, overlooking the significance of buyer-supplier relationships in channel operations. Even though institutional theory and connection marketing literature implies that relationships influence retail buyers' appraisal and adoption of new products, little research has been done on how relationship qualities influence marketing researchers.

A trader examines the competitive nature of the market environment in which it works when selecting whether or not to carry a new product. Researchers examine future market rivalry while assessing environmental competitiveness, which has been disregarded in prior studies. The competitive intensity of new products is a crucial determinant in their success. The degree to which a corporation is exposed to competition in a specific market is referred to as this. Furthermore, increased competition raises market uncertainty and unpredictability because clients now have a more comprehensive range of options. As a result, the marketplace's competitive intensity has an impact on new product sales. If a competitor has a product, the retailer is more likely to carry it if it aligns with the store's broader strategy and objective (Nastasoiu & Vandenbosch, 2019).

When calculating market competitiveness, the predicted size and expansion of the market is taken into account. An expanding market for new products not only attracts more rivals but also suggests increasing sales and profits, which raises the chances of securing shelf space for a new item. The availability of such market potential may lessen the perceived risk associated with the launch of new items. According to studies, more prominent and increasing markets are related to a higher likelihood of new items being accepted and succeeding. Finally, market dynamism, or how quickly markets change, is a crucial factor to examine. The market is also a major factor in retailers' decision-making when it comes to new product development. Market dynamism refers

to both the rate of technology innovation and changes in consumer preferences and corporate operations in the marketplace. Because the marketplace is constantly changing, product or service adaptation is necessary to maintain a firm's competitive advantage. Merchants are more likely to accept new things into their inventory as a result of this (Caro & Sadr, 2019).

New product introductions in the market are made through retailers, and therefore the retailers' decisions on these newly introduced products become indispensable. Retailers, therefore, plays a crucial role in the success of new products from manufacturers. There exist several factors influencing a retailers new product acceptance that includes; Judgement about the quality and uniqueness of the product, the expected margin that the product will provide, the consumer demand of that particular product, competition in the market, marketing mix variables and the shelf space availability (Arunachalam *et al*., 2020). These retail adoption variables can further be categorized into; profit-related variables such as gross margin, the new product price, the consumer support and trade support, Category variables which include category role, expected cannibalization on store brand and expected category growth due to new product introduction, and finally the relationship variables of perceived relationship quality, the perceived dependence on supplier and the relationship length (Arunachalam *et al*., 2020).

Both suppliers and retailers seek to optimize value in new products. New products, therefore, seem to be instrumental for the firm's long-term success since they aim to rejuvenate the old products portfolio and enhance customer loyalty. Manufacturers, therefore, sell their products to consumers via the retailers, which makes their success depending on the retailers' new product acceptance (Lofti *et al*., 2021).

2.6.1 Empirical Studies on Traders' Willingness to Accept Stocking New Products

Van *et al.* (2011b) conducted a study to determine new products adoption decisions. They collected data with the aid of a pre-tested questionnaire from a sample of 392 retailers. They analyzed using descriptive statistics and a binomial probit model to assess the effect of the independent variables of interest. The authors used a multi-item scale to measure these variables that seemed robust among the Dutch food retailers. Their results found out that both relationship and category variables are essential in retailers' adoption decisions. These key variables included relationship intensity, promotion, channel motivation, pricing, shelf space, trading area and competition. The higher levels of expected category growth resulting from new product introduction are also associated with the high probability of adoption by the retailers. The study

also shows an increase in gross margin with a correspondingly high probability of retailers adopting new products for stocking. The previous study assessed willingness to stock new food products among retailers; hence the current study differs from the previous as it targets a fungal based biopesticide, its costs and profitability to the agrodealers as an alternative to the hazardous and costly chemical pesticides.

Beck *et al.* (2015) also used means, percentages and multiple regression models to determine factors that influence new product stocking decisions. Data was collected through an online survey of 163 participants with questionnaires in Dusseldorf, Germany. They found out that; a strongly perceived firm image has a more significant positive effect on trustworthiness hence new product acceptance, thus decreasing the manufacturer's failure rate. A retailer's brand would also have a positive influence on customers' belief in new products. Therefore, the current study differs from the previous studies since it will focus on agrodealers in Kirinyga County in Kenya with a totally different socio economic and Agro ecological characteristics compared to other countries. The study will also focus on all factors influencing agrodealers willingness to stock a fungal based biopesticide that is different from previous studies, which focused on foodstuff, cellular phones and family firm image.

2.7 The Cost-Benefit Analysis of Pesticides and Non-chemical Methods of Pest Control

The Cost-Benefit Analysis (CBA) is a tool for analyzing the efficiency effects of policies and other actions in a systematic way. As a result, it's a social cost-benefit analysis because it considers all of a society's benefits and costs, also known as social costs and benefits. The process of finding, estimating, and comparing the social benefits and costs of a project or program is referred to as social cost-benefit analysis. CBA's overarching purpose is to aid in social decision-making in general and facilitate the efficient allocation of a society's resources in particular. There are two types of CBAs: monetary and nonmonetary CBAs. Conducting an ex-ante CBA occurs when a project or policy is being evaluated before it is initiated or implemented. This strategy is used to determine whether or not to assign specific resources to a project (Mishan & Quah, 2020).

Ex-post CBA is used to establish whether or not a project was helpful after it has been completed. In this scenario, the ex-ante aspects of these investigations are equal to the ex-post aspects; however, the ex-post sections of these investigations are analogous to the ex-post aspects. Ex-ante analysis has the potential to influence a project's choice to proceed, whereas media res analysis has the potential to influence a project's decision not to proceed. They can be based on

observed costs and benefits rather than projected costs and benefits for specific costs and benefits, comparable to ex-post-analysis. Ex-ante analysis can benefit from media res analysis since it gives data for estimating future costs and benefits (Pearce, 2016)

According to the authors, when it comes to learning about the efficacy of CBA as a decision-making and evaluation tool, a CBA that compares the results of two different CBAs on the same project is the most helpful for policymakers. The terms "net benefits" and "Pareto efficiency" are inextricably linked. The CBA uses a less conceptual decision rule but is more pragmatic than the Pareto efficiency rule, which many other companies employ. It is based on the Kaldor-Hicks significance criterion (Sharma *et al*., 2019). A policy should only be implemented if and only if those who profit from it can pay those who lose everything due to it. The net benefit criterion is a hypothetical Pareto efficiency criterion based on the Kaldor-Hicks criterion that only policies with positive net benefits should be implemented. Compensation for losers is permissible as long as the net benefits are positive to boost the program's Pareto potential. This is not an option in this circumstance because of the opposing net benefits. On the other hand, a cost-benefit analysis compares overall costs and benefits to help inform, but not always determine the final decision (Brent, 2006).

The cost of pesticides and the non-chemical methods of pest control are relatively low compared to the farm crop prices and the total production cost. It is estimated that pesticides account for 7 to 8% of the total farm production costs, therefore, effective in crop protection with sufficient returns to the farmers. Farmers, therefore, have sound reasons for putting into use the pesticides in crop protection (Mishra *et al*., 2021). This is because pests cause much losses which approximate to about 35% on the real value of crops, thus contributing to low yields and returns to the investing farmer. Farmers expect a return of approximately 4USD on every dollar they invest in pesticides use for agricultural crop production. Later in the second half of the twentieth century, the national pesticide benefit studies documented a massive net return of costs associated with herbicides, insecticides, and fungicides on their application during crop protection (Popp, 2011; Zhang, 2018).

Farmers spray herbicides close to approximately 90% of the land acreage for the past 30 years for weed control. The value of the herbicide they used in 2005 is estimated to have been 16 billion USD in crop yield increase and 10 billion USD in reduced costs of weed control. The increased fuel and labour costs make the alternatives to the use of herbicides higher; therefore, the

aggregate cost of hand weeding and cultivation as a replacement increased to about 16.8 billion USD. This resulted in a net increase in the costs of controlling weeds to 10 billion USD in 2005. Therefore including the value of crops, there is a tremendous loss of crop production of approximately 16 billion USD, consisting of three components; cost of the product, application, and premiums for herbicides tolerant crops (Zhang, 2018). Insecticides are the primary means of controlling insect pests and accounts for about 90% of insect pests attacking crops. While spraying, farmers incur a cost of 1.2 billion USD and gain 22.9 billion USD in increased production value from the control of insects feeding on crops by insecticides (Amanuel, 2019). Despite the benefits associated with the use of pesticides arising from the cost-benefit analysis perspective, the human health threat and environmental destruction nature of pesticides necessitates alternative ways of crop protection that are environmentally friendly and safe for human health (Zhang, 2018).

2.7.1 Empirical Studies on Cost-Benefit Analysis of Pesticides

Pimentel (2014) studied pesticides' environmental and economic costs in national pesticide benefit studies from the United States. The gross margin analysis was used for effective results and the research covered 50 crops in the US. The author found out that Pesticides indirectly cost the US 8.1 billion per year. This includes losses from a wide range of sources such as loss of natural plant pollinators, increased resistance of pests, thus continuous destruction, contamination of the ground water sources and harm to human and livestock health. The total indirect costs associated with pesticide use was approximated to be around 9.6 billion USD in 2005. This figure incorporates the inclusion of social, environmental, and human health costs that emanate from pesticides. Therefore, the current study differs from the previous one as it aims to analyze the profitability of biopesticides to an agrodealer as an alternative pesticide to the chemicals used in crop protection.

Amoabeng *et al.* (2014) also compared biopesticides extracts with synthetic chemical pesticides in Ghana. They found that the highest cost-benefit ratio of 1:29 is observed for fields sprayed with biopesticides while those plots sprayed with synthetic chemicals resulted in a cost-benefit ratio of 1:15. The biopesticides differed in levels of pest control to the synthetics and indicated a positive margin in the markets. His randomized replicated fieldwork included costs of each material and labour, then the revenue calculated based on each treatment. The cost-benefit ratio of the sprayed treatments was then derived by comparing the cost of each against the market value. These biopesticides are also safe for the environment hence sustainable for use by

smallholder farmers. The previous study compared both chemical and biopesticides extracts in actual farming. In contrast, the current study looks at the costs and benefits of stocking a newly produced biopesticide (ICIPE 20) by agrodealers towards profitability.

A field trial was conducted by Korejo *et al.* (2000) in Pakistan to determine the cost-benefit ratio of pesticides used to control the insect pest complex, based on the number of sprays through the spray of five different insecticides in cotton production. They found out that maximum yields were obtained through spraying the crops thrice, and the yield registered a significant decrease when the number of insecticide sprays was increased hence increasing the number of pests in the fields. According to cost-benefit analysis, the study concluded that two to three sprays are considered sufficient for maximum yield with a corresponding decrease in production costs, thus resulting in improved profits. The current study differs from the previous, which analyzed the cost-benefit ratio of pesticides based on the number of sprays. It looks into the costs and benefits of biopesticides based on agrodealer sales for profitability.

The results of Korejo *et al.* (2000) corroborates that of Engindeniz (2006), who collected data from 51 farmers who used pesticides and analyzed using gross margin analysis and net profit. The results show a positive outcome based on the profitability of pesticide use in crop protection. Engindeniz analyzed the economics of pesticide use on processing tomatoes grown in Torbali-izmir in Turkey to determine the problems of pesticides use. The current study analyzes stocking decision of biopesticides in the Agrovets and sales for profitability, thus different from the previous that looked at the effect of pesticides in crop protection.

Emanuele *et al.* (2014) also found out that insecticide-based management of pests proved less and less profitable since rising pest levels lead to the insecticide application's intensification. On the other hand, despite the exclusion netting being more expensive, it is much more profitable in reducing pest population and low societal impacts. This is after estimating cost and benefit to evaluate the most profitable method of crop protection using partial budgets. The study took place in Trentino, Northern Italy where the effect of invasive pest *Drosophila suzukii* on soft fruits such as strawberry, blackberry and blueberry was severe. Using the cost-benefit analysis, a conventional integrated pest management based on insecticides, mass trapping and cultural measures was compared to an upgraded IPM strategy based on exclusion netting.

The economic and social implications of pesticide research and development especially to the traders, in addition to the broad aspect of analyzing the feasibility factors, are very beneficial

and effective when sustainability and upscaling profit margins is of priority. Highly variable market conditions strongly affect both traders and farmers' management decisions. But, to the extent that farm and environmental plans modify those decisions, and research provides new options for consideration in the decision-making process, economic and policy factors, instituted by the policy makers through the government, will be the principal guides for the direction of both private and public pest control research, and the broad use of biopesticides as safe and sustainable pest management method. Previous studies have focused on the cost-benefit analysis of the synthetic chemical pesticides and biopesticides on yield, health and environment by only targeting the farmers' side. Therefore, this study seeks to add to the body of knowledge the cost-benefit analysis of biopesticides by focusing on agrodealers and willingness to stock towards profitability. Thus, promoting their commercialization by the agrodealers for sustainability.

2.8 Theoretical Framework

The study employed three theories namely; the innovation theory of profitability, the profit maximization theory and the theory of planned behavior.

2.8.1 The Innovation Theory of Profitability

This study took into account the innovation theory of profitability. This theory assumes that any research and development capable of yielding a normal return on investment will lead to an increase in the level of output or a corresponding decrease in inputs. For example, when the level of productivity is represented by A_t and the cost of production is $C_t = KA_t$ Where K is a constant. In period 0, the dominant technology is widely available and determines the market price.

The dominant technology has cost C_0 and the good has a market price of $P_0 = C_0$. When a new innovation arrives in period 1 and lowers production cost to$C_1 < C_0$, Assume that the inventor can appropriate the fraction *a* of the cost-saving from the innovation. The inventor thus maximizes profit by setting the price at $P_1 = C_1 + a(C_0 - C_1)$ (Nordhaus, 2004).

2.8.2 Profit Maximization Theory

In agribusiness enterprises, optimization is done at the average levels with either average revenues, average costs or average production. This is usually the first-order condition for enterprise optimization. However, to maximize returns, the marginal optimization is vital. This is done through marginal cost, marginal revenue and marginal productivity. In the normal profitability functions, an entrepreneur relates total revenue with total costs. Therefore, the total

profit of the firm and all the production processes can be worked out between total revenue and total costs.

$$\Pi = TR - TC \quad \text{(2.1)}$$

The profitability at the total level would be maximized where the total revenue and the total costs have the greatest divergence, and total revenues are greater than total costs. At this stage, it is expected that the marginal profit has been differentiated to zero hence no more differentiation that can be done, however, total profits at this stage should be maximized. It is also important to note that at this point of divergence, the marginal cost and the marginal revenues are equal (Baye, 2010)

$$MR = MC \quad \text{(2.2)}$$

2.8.3 The Theory of Planned Behavior

Planned behavior refers to the process of engaging in the behavior of interest and prompting another to follow a different course of action. This study also factors in the theory of planned behavior. This theory provides a vital framework for understanding diverse, complex human behavior. It aids in the prediction of human behaviors in a specified context. An individual's knowledge, attitudes, and perceptions model the intentions to perform behaviors of different kinds. They are therefore perceived to predict behavioral intentions with a tremendously high level of accuracy. An agrodealers knowledge attitude and perception towards biopesticides thus can be used to illustrate and predict their stocking decisions of respective products to maximize profits and be in business, and willingness to accept a new product (Ajzen, 1991)

2.9 Conceptual Framework

High returns on pesticides depend on the traders themselves, biopesticide and buyer-supplier characteristics in the process of commercializing the fungal based biopesticide. The whole concept takes into account the socioeconomic factors, institutional factors, technical aspects of the product, and feasibility factors which entails the infrastructure available and human capital required to venture into the business. Factors such as Age, gender, education level, years in agrovet operation, membership to agrodealers' networks, contracts with farmers, access to credit facilities, and access to information determine a trader's knowledge and perception towards stocking biopesticides. Feasibility factors such as availability of finances, access to physical distribution facilities, access to specialised storage facilities, existence of effective communication,

promotional support, managerial support, favourable price, age, education level and knowledge of handling biopesticides influences agrodealers willingness to stock the biopesticide. The whole framework also incorporates the technical aspects of biopesticides such as, the shelf life of the product offered, the nature of the product based on toxicity, whether the product is specific to its target, and if its effective when used in smaller quantities. These factors influence the knowledge, perception and the agrodealers willingness to stock that particular product offered in the market.

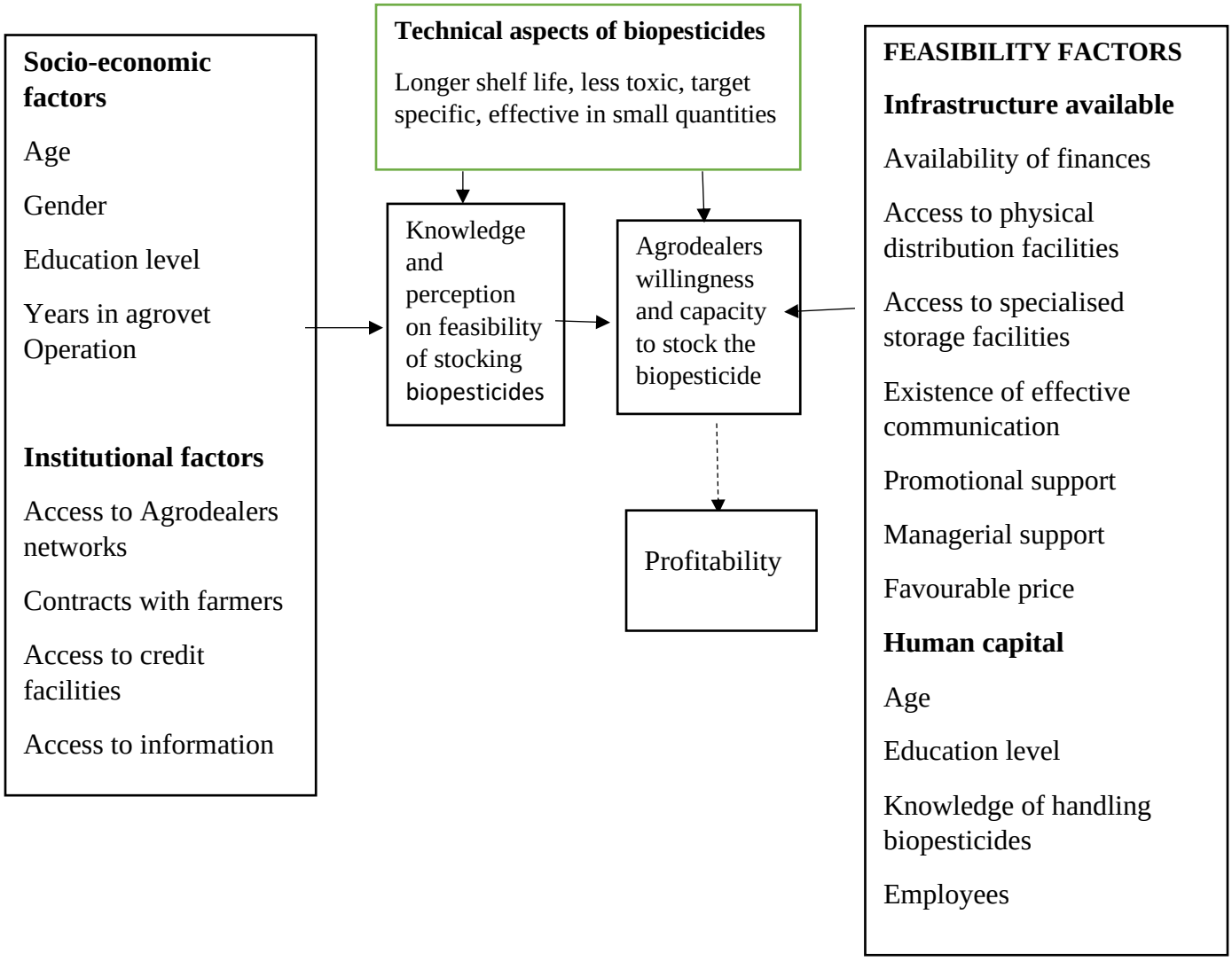

Figure 2.1: The conceptual framework of factors influencing agrodealers willingness to stock.

CHAPTER THREE
METHODOLOGY

3.1 The Study Area

The study was conducted in Kirinyaga County, located in the central parts of Kenya. Kirinyaga County covers an area of approximately 1,478.1Km^2 at the foothills of Mount Kenya and 112Km from Nairobi. It borders Embu to the East, Machakos to the South, Murang'a to the South West and Nyeri to the West. It lies between 1,158 meters and 5,380 meters above sea level in the South and at the Peak of Mt. Kenya, respectively.

The county has three ecological zones; the lowland areas that fall between 1,158 meters to 2,000 meters above sea level, the midland areas that lie between 2,000 meters to 3,400 meters above sea level and the highland comprising areas falling between 3,400 meters to 5,380 meters above sea level. The lowland area is characterized by gentle rolling plains that cover most of Mwea constituency. The midland area includes Ndia, Gichugu and Kirinyaga Central constituencies. The highland area covers the upper areas of Ndia, Gichugu and Central constituencies and the whole of the mountain area (County Integrated Plan, 2017) Kirinyaga County comprises of five sub counties namely Kirinyaga East, Kirinyaga West, Kirinyaga Central, Mwea East and Mwea West. 605,630 people reside in Kirinyaga with a higher population of females compared to males (51% and 49% respectively) (Census, 2019).

Kirinyaga is one of the wettest counties, with annual temperatures averaging 19℃ and annual precipitation of about 1250mm. There are two rainy seasons: long rains of March- May and the short rains of October –December. Agriculture is the main economic activity in Kirinyaga County, with over 70% of the residents practicing small scale farming activities. The most common crops grown include coffee, tea, rice, maize, beans, bananas, and various fruits and vegetables (County Integrated Plan, 2017).

Kirinyaga County was purposively selected since it is one of the leading tomato producing counties in Kenya. Tomato production in Kirinyaga is approximated to about 17% followed by Kajiado with 11.8% and Taita taveta with 8.5% (HCDA, 2018). According to Nderitu et al. (2018), Tuta absoluta threat is estimated to cause destruction to tomato vegetable between 80 to 100 percent if not controlled, hence highly prevalent in Mwea Kirinyaga County. This study targeted the agrodealers in Kirinyaga County to aid in assessing the feasibility of stocking a fungal-based biopesticide to manage the tomato leaf miner *T. absoluta*. Additionally, According to Fulano *et al*.

(2021), factors such as favorable climatic conditions in Kirinyaga County for tomato production, with warm temperatures and well-distributed rainfall, are ideal conditions for tomato growth and can lead to high yields. Kirinyaga County has a significant amount of arable land suitable for tomato farming, which makes it an attractive location for tomato production, as there is enough land to support large-scale production, Proximity to markets since it is located in a strategic location, close to major markets such as Nairobi and Thika. This makes it easy for farmers to transport their tomatoes to these markets and access a wider customer base. Access to water: Kirinyaga County has several rivers and streams that provide water for irrigation. This ensures a constant supply of water, which is essential for tomato growth. Supportive government policies: The government of Kenya has implemented policies to support agricultural development, including tomato production. Kirinyaga County has also implemented policies to support tomato farming, including providing farmers with extension services and access to credit facilities. Established tomato value chain: Kirinyaga County has also an established tomato value chain, with processors, traders, and exporters. This provides a ready market for farmers and ensures that they can sell their tomatoes at competitive prices.

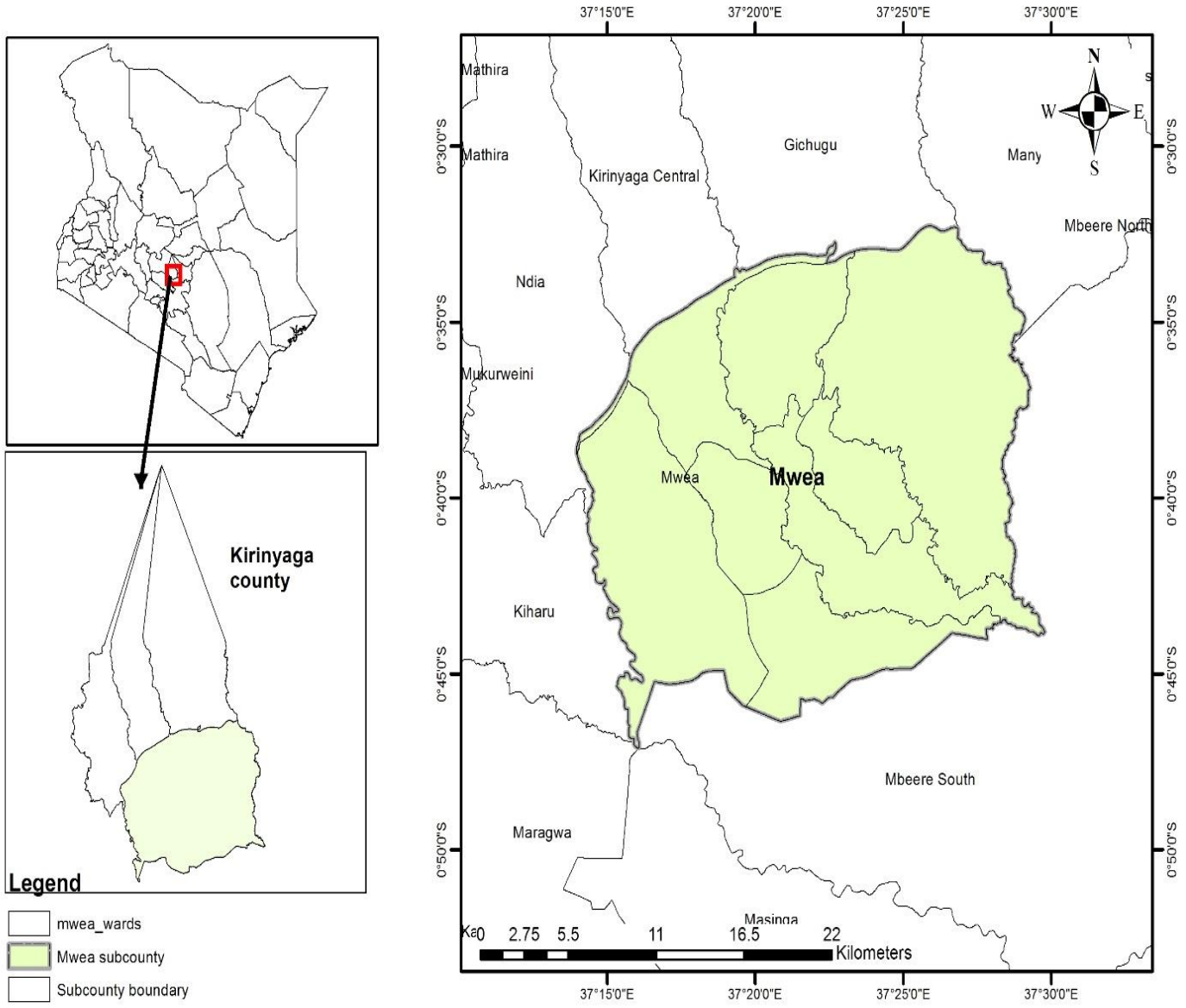

Figure 3.1: Mwea East and Mwea West sub counties map.

Source: www.ngcdf.go.ke

3.2 Research design

The study employed a cross-sectional research design, a type of observational study design used for population-based surveys. It analyzed variables collected at one given point across a sample population or a pre-defined subset. The population of study comprised the agrodealers in mwea Kirinyaga county. The respondents therefore comprised agrodealers dealing in pesticides in various agrovets.

3.3 Sampling Design

The study population constituted the agrodealers in Kirinyaga County, and the sample unit was the agrodealers trading in pesticides. Mwea East and Mwea West have been purposively selected based on their predominance in tomato production. A census was carried out by enumerating all the 141 agrodealers using a list obtained from a pre-visit with the help of sub-county agricultural officers.

3.4 Data Collection and Analysis

Primary data was obtained from the census conducted of agrodealers, and it was done using various methods, including observations, interviews, and semi-structured questionnaires. Questionnaires were administered to the respondents (see appendix A) by a team of trained enumerators and supervised by myself. Data collected from the field were captured using a data collection program (Cspro) installed on tablets and then transferred into statistical software for analysis. Percentages, graphs and charts, Principal component analysis, cost-benefit analysis and binary probit model were used to analyze the data. Two computer packages, Statistical package for social sciences (SPSS) and STATA were also used for data management and analysis.

3.5 Analytical Framework

The data regarding objectives outlined were analyzed as follows:

Objective 1: To analyze biopesticides knowledge and perception among agrodealers in Kirinyaga County

Percentages, graphs and charts were used as modes of presentation. Principal Component Analysis (PCA) was also used to analyze data obtained by the Likert scale. The Principal Component Analysis is a data reduction technique that provides a roadmap for reducing a complex data set to a lower dimension that is simplified (Shlens, 2014).

The first principal Component can be computed as,

$$PC_n = f(a_{ni}\, x_{i,\dots} a_{1k} x_k) \dots \dots \dots \text{(3.1)}$$

if the number of principal components is of n numbers, then each principal component is a continuous factor related to the products of the values of the constituent factors and their respective weightings. Thus, the value of the principal component can be obtained by the addition of the products as shown below:

$$PC_n = f(a_{11}\, x_1 + a_{12} x_2 + \dots a_{1k} x_k) \dots \dots \dots \text{(3.2)}$$

Where;

a_{1k} Is the eigenvector of the covariance matrix between the variables also known as the regression coefficient and x_k is the value of the *k*th variable thus resulting to the equation below

where, $PC_{ij} = B_0 + B_1X_1 \ldots B_nX_n + e$ …… (3.3)

where; PC_{ij} (Dependent variable) = generated regression principal component scores

PC=Principal component

i= The i^{th} trader

j= Unobserved latent variable of knowledge and perception

B_0= The intercept

B_n= Regression coefficient

X_n= Parameters to be estimated

e= The error term

Hence a system of equation as shown;

$PC_{ij} = B_0 + B_1Age + B_2Gend + B_3Educ + B_4YrsOper + B_5NetAccess + B_6Contracts + B_7CredAcc + B_8InfoAcc + e$……. (3.4)

Table 3.1: Variables used in the principal component analysis

Variable Code	Variable	Measurement of the Variables	Expected Sign
Dependent Variable			
Know&Perc	Knowledge and perception	Dependent variable for outcome equation (Dummy variable 1=yes, 0=No) (Ordered variables 0=strongly agree, 1=Agree, 2=Neutral 3=Disagree, 4=Strongly disagree)	
Independent Variables			
Age	Age in years	Continuous variable	+
Gnd	Gender	Gender (Dummy 1 =Male, 0= Female)	+/-
Educ	Education (Years of schooling)	Continuous	+
Yrsoper	Years in Agrovet operation	Continuous variable	+
Netacces	Access to Agrodealers networks	Dummy variable (1=Membership, 0=Otherwise)	+/-
Contracts	Contracts with farmers	Dummy variable (1= Contracts, 0= Otherwise)	+/-
Credacc	Access to credit facilities	Dummy variable (1=Access, 0=Otherwise)	+/-
Infoacces	Access to information	Dummy variable (1=Access, 0= Otherwise)	+/-

Objective 2: To determine the factors influencing the agrodealers willingness to stock the fungal based biopesticide for management of *T. absoluta* in Kirinyaga County.

The binary regression model was employed to identify covariates that influence agrodealer's willingness to stock a fungal-based biopesticide. The model gives the probability that

y (dependent variable) is equal to one, is chosen conditional on a set of independent variables. The most used approaches are the logit and probit models which assumes that the functional form of dependence on the independent variables is known. Both the probit and logit models yields similar inferences though not identical since the logit regression has a standard logistic distribution of errors while the probit has normal distribution of errors (Van *et al*., 2011). Therefore, the probit model is appropriate since it assumes normality that is; a mean of 0 and a standard deviation of 1.

The probit model is a statistical probability model with two categories in the dependent variable. Probit analysis is based on the cumulative normal probability distribution. The binary dependent variable, y, takes on the values of zero and one. The probit analysis provides statistically significant findings of which demographics increase or decrease the probability of stocking. In the binary probit model, willingness to stock was taken as 1, while not willing to stock taken as 0. The probability pi of choosing any alternative over not choosing it can be expressed as in the figure below, where φ represents the cumulative distribution of a standard normal random variable:

$$pi = prob\left(Yi = \frac{1}{X}\right) = \int_{-\infty}^{Xi\beta}(2\pi)\ -\frac{1}{2}\exp\left(-\frac{t2}{2}\right)\mathrm{dt}\ = \Phi\ (\mathrm{xi}\ \beta)\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (3.5)$$

hence, the factors influencing agrodealers willingness to stock a fungal based biopesticide was estimated using the probit model of the form;

$$Y_i = B_0 + B_1X_1 + e_i \text{ ---------- (3.6)}$$

The decision to use the independent variables in this study were guided by the review of previous literature on willingness to pay for new products (Beck, 2015; Lin, 2012; Van *et al*., 2011), and knowledge, attitudes and practices towards pesticides use (Abudulai *et al.,* 2006; Schreinemachers *et al*., 2017; Trevor, 2014)

Table 3.2: Variables used in the binary probit model

Variables	Description of Variables	Measurement of Variables	Expected Sign
Dependent Variable			
WTS	Willingness to stock	Dependent variable for outcome equation (Dummy 1=willingness to stock, 0= Otherwise)	+/-
Independent Variables			
Age	Age in years	Continuous variable	+
Edu	Education level	Continuous variable	+
Know	Knowledge of handling biopesticides	Dummy variable (1= Knowledge, 0= Otherwise)	+/-
Favprice	Favourable price	Discreet variable	+
Avafinance	Availability of finances	Ordered variable (1=non-financial constrained, 2=Partially financial constrained 3= Fully financial constrained)	+/-
Accdistrib	Access to physical distribution facilities	Dummy variable (1=Access, 0= Otherwise)	+/-
Storage	Access to specialized storage facilities	Dummy variable (1=Access, 0=Otherwise)	+/-
Effecomm	Existence of effective communication	Ordered variable (0=Non effective, 1= effective 2= Highly effective)	+/-
Promsupp	Promotional support	Dummy variable (1=promotional support, 0= Otherwise)	+/-
Employees	Employees	Dummy(1=employees,0=Otherwise)	+/-
Mansupp	Managerial support	Dummy variable (1= Managerial support,0= Otherwise)	+/-

Objective 3: To assess the Agrodealers' capacity to stock a fungal based biopesticide in Kirinyaga County.

Descriptive statistics were used. Both central tendency and variability measures were employed to describe the agrodealers capacity to stock a new product (Bayesian, 2016). The modes of presentation, such as percentages, graphs, charts and tables, illustrated various aspects of agrodealer capacities towards stocking decisions which include; Availability of employees, the presence of agrodealer networks through information and communication technology, knowledge and skills of handling biopesticides, access to credit facilities, availability of finances, availability of specialized storage facilities and the ability to carry out sales promotion.

Objective 4: To determine the costs and benefits associated with stocking ICIPE 20

The gross margin analysis, benefit-cost ratio and net present value accounting techniques were used. The Gross margin is a trader's total revenue of a product less its total variable costs. It is the sales revenue retained after incurring the variable costs associated with producing a good. A variety of management techniques have been developed to assess the technical and economic viability of conventional farm businesses. Such services include gross and net margin analysis, as well as detailed cost accounting. Traditional farm business analysis methods include two stages: a broad evaluation of financial statements and other pertinent data, followed by a more detailed examination of the farm's multiple operations, reported as gross margins for each enterprise.

A company's gross margin is the difference between its financial output and its variable costs. Gross margins became prominent in the United Kingdom as farm management experts popularized them for research and planning purposes. Farms with similar qualities and production procedures should be compared to one another when it comes to net earnings. With this constraint in mind, comparisons can provide valuable insight into a company's multiple operations' productivity and economic efficiency. Gross margins are particularly valuable in both inorganic and organic systems when it comes to farm planning and comparisons between companies within the same company, across organic holdings, or between conventional and organic operations in both inorganic and organic systems (Lampkin *et al*., 2001). According to Farris *et al*. (2010) on their definitive guide to measuring marketing performance, gross margin can be estimated as illustrated below.

Gross margin =Total Revenue – Total Variable Costs

$GM = TR - TVC$ ..... (3.7)

Unit margin (Ksh) = Selling price (Ksh) – Cost per unit (Ksh)

Gross margin per unit (%) = Unit Margin (Ksh)/ Selling price per unit (Ksh) (100)

$$GM_{Ksh} = \frac{UM}{SP} \times 100 \quad \text{..... (3.8)}$$

GM = Gross margin

TR = Total revenue

TVC = Total variable costs

The total revenue was obtained by summing up total receipts of selling pesticides less total variable costs, which include; Transport costs, loading and offloading costs, cost of protective gears, advertisement costs and value-added costs such as packaging activities.

Benefit-cost ratio (BCR)

By comparing the economic advantages and costs of an activity, benefit-cost ratio analysis (BCR) is a technique for determining the economic benefits and costs of a project or investment. It's used to calculate a project's or investment's economic benefits and costs. The benefit measure is usually denoted by the letter B, whereas the cost measure is denoted by the letter C. For a variety of reasons, a benefit-cost analysis is beneficial. To begin, a business case analysis (BCA) can be used to determine a project's economic viability. The capacity to evaluate and contrast the relative merits of several competing efforts is a second use of the outcomes of a series of benefit-cost analyses. Business case analysis is used to assess incorporated decisions, the worth of public investments, the wisdom of resource usage, and environmental change (BCA). Finally, BCA strives to investigate various courses of action with the goal of increasing long-term societal wellbeing. Regardless of the objective, all benefit-cost studies share basic characteristics. A BCA can begin by identifying an issue that needs to be solved. The project's costs and benefits would be determined, quantified, and compared and contrasted. While decisions are rarely made purely on the basis of BCA, it is beneficial and, in some situations, legally necessary. The results of a BCA may surely be used to increase public awareness of a project, which is an important consideration.

The benefit-cost ratio measures the relative value of benefits generated per investment unit. It is expressed as a ratio of the sum of the biopesticides discounted benefits to the sum of the discounted costs. A ratio greater than 1 justifies the relevance and profitability potential of

investing in the fungal based biopesticide. The benefit-cost ratio is thus expressed as shown below (Soul-kifouly *et al*., 2016)

$$BCR = [\sum_{t=0}^{T} B_t \ (1+r)^{-t}] \ / \ [\sum_{t=0}^{T} C_t \ (1+r)^{-t}] \quad \text{..... (3.9)}$$

Net present value

The present value of all net benefits accrued during the project's lifetime is the net present value (NPV). The value of net benefits is equal to the total of the benefit (B) and the cost (C) at any given time. The time period being discussed is denoted by the subscript t. We use the discount rate r to discount future values whenever we calculate the cumulative sum of net benefits across time, as indicated in the following equation. It means that if the project's net present value (NPV) is more than zero, it's a good choice for this method of implementation. The Net Present Value measures the surplus earned against costs with the aid of the given interest rate. This, therefore, reflects the opportunity cost of funds invested, which is the profitability rate of funds invested in the new product (Soul-kifouly *et al*., 2016). The Net Present Value is thus expressed as;

$$NPV = [\sum_{t=0}^{T} (B_t - C_t)(1+r)^{-t}] \quad \text{..... (3.10)}$$

BCA is a decision-making tool that has a lot of potential. It is especially useful because it establishes a benchmark against which a project can be measured and evaluated. Both supporters and opponents of projects are required by BCA to produce quantitative evidence to support their qualitative arguments in favour of their ideas. In order for the BCA analysis to be valid, actual data must be used to support it. When deciding on initiatives or investments, subjective reasoning or value judgments are routinely utilized in the decision-making process. While BCA may not be able to cover all of the evaluation criteria, it does give interested parties the opportunity to properly articulate the issues at hand. Furthermore, BCA has the advantage of allowing for comparisons between investments or projects. This comparison is made easy because all investments are evaluated in the same way. If a proposal is manifestly bad, it becomes much easy to eliminate it from consideration.

CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter is divided into two sections. The first section discusses descriptive statistics of the agrodealers, institutional factors, and their socioeconomic characteristics. The second section of the chapter discusses the principal component analysis, binary probit model, and gross margin analysis. Specifically, the knowledge and perception components towards biopesticides, the factors influencing agrodealers willingness to stock biopesticides, the factors influencing their capacity to stock, and the gross margin techniques for costs and benefits associated with stocking biopesticides among agrodealers.

4.2 Descriptive Results

4.2.1 Agrodealer Characteristics

The description and summary of selected socioeconomic characteristics of the sampled agrodealers are presented in Table 4.1. On average, the age of the agrodealers was 35 years. Most of the agrodealers had 13 years of schooling, implying that the majority of the traders were youth and had attained secondary level education. Education is considered a human capital that facilitates the use of available information to reduce the existing constraints (Constantine *et al*., 2020). For example, agrodealers who are better educated may have better business skills that enable them to operate their businesses more efficiently. Based on the period of business operation within the pesticide business, the average years were four. About 46% of the agrodealers stated that they had access to credit facilities whenever they required them. However, only 7% of them reported that they needed credit for the agrovet business operations. Chia *et al*. (2020) observed that access to credit enhances willingness to stock new products, with a corresponding positive perception towards them.

On employment status of sampled agrodealers, the results indicated that 33% had employees. Further, the survey results showed that 2% were part-timers, 29% had full-time employees, and only 1% had employees working both full-time and overtime. The rest 68% of the agrodealers employed family labour. Access to market information by agrodealers on prices, new products, competition, and market trends are seen to influence willingness to stock. Previous studies indicate that the availability of workforce in businesses triggers expansion of the ventures sales volume (Maunze, 2012). This is justified by Nicod *et al*. (2020) on customer proactiveness,

satisfaction and sales volume. In this survey, the agrodealers who had access to social networks were 44%. Empathy for brands is elicited by social network platforms, which also help customers get more familiar with brands. It is an interdisciplinary and cross-functional concept that uses social media, generally in conjunction with other channels of communication, to fulfil organizational goals while also providing value to stakeholders, according to the definition. Manufacturers, wholesalers, and retailers must have a better knowledge of how social networks plays a part in the marketing process (Torres *et al*., 2018).

Agrodealers who had access to market information especially information on prices, new products, competition, and market trends, were found to be 92%. This indicates that they have good knowledge and perception on the new products especially the biopesticides. Having better knowledge on specific products before stocking provides an entrepreneur with the confidence of stocking or just investing in the products in large scale, hence operate at positive margins.

Managerial support can take the form of a strong brand, generating photos and films of items for promotional purposes, delivering marketing materials, providing product samples, and providing wonderful customer service through an excellent communication line and appealing packaging. Managerial support by manufacturers and suppliers, as one of the key variables in supply chain management, is positively related to performance at both retail and supply level (Hamister, 2012). The survey results indicate that 81% of the agrodealers received support such as transport and delivery at doorstep, advertisement of the products and even personalised attention from the manufacturers and suppliers on their respective products.

Table 4.1: Socio-economic characteristics of Agrodealers in Kirinyaga County (n=141)

Variables	Definition	Statistics
Age	Age of the agrodealers in years	35.73 (10.65)
Education level	Years of schooling of agrodealers	13.00 (2.13)
Experience	Years in Agrovet operation	4.97 (5.19)
Credit access	Agrodealer access to credit (%yes)	46.1
Labour	Hired labour in the agrovets (%yes)	32.62
Information access	Agrodealer access to information (%yes)	92.20
Social networks	Agrodealer access to social networks (%yes)	43.97
Managerial support	Support by manufacturers and suppliers (%yes)	81.56

Note: Standard deviation in parenthesis

4.3 Agrodealers Knowledge on Biopesticides

Most of the agrodealers were aware of non-chemical practices for the management of leaf miner. As illustrated in Table 4, about 43% of the respondents were aware of the specific non-pesticide practices that could be used to control the pest, and 79% of the respondents stated that crop rotation with the non-host crop is the main control measure put into practice by most tomato farmers in control of *Tuta absoluta.* The agrodealers also have knowledge on the importance of using biopesticides over the chemicals based on their level of safety both to the environment and human beings. They also identified some of the risks and diseases that are caused by consuming products obtained from sprayed fields and how they pose health hazards.

Table 4.2: Agrodealers knowledge of biopesticides

Characteristics	**Percent** **n =141**
Knowledge on non-chemical pesticides for control of Leaf miner (%yes)	70.92
Knowledge on non-pesticide practices for control of Leaf miner (%yes)	43.36

4.4 Agrodealer Perception Towards Biopesticides in Kirinyaga County

The concept of low perception versus high perception plays a crucial role in this study. Low perception refers to a limited understanding or awareness of biopesticides among agrodealers. These individuals may have limited knowledge about the benefits, efficacy, and proper usage of biopesticides. On the other hand, high perception signifies a comprehensive understanding and awareness of biopesticides among agrodealers (Constantine, 2020). They possess in-depth knowledge regarding the advantages, application techniques, and safety measures associated with biopesticides. High perception enables agrodealers to effectively disseminate accurate information, provide appropriate recommendations, and address concerns related to biopesticide usage. Understanding the variations in perception levels is essential for designing targeted training programs and interventions to enhance agrodealer knowledge and perception, thereby promoting the sustainable use of biopesticides in Kirinyaga County.

The principal component analysis (PCA) method was used to extract perception indicators from agrodealers. The robustness of the analysis was tested using Kaiser-Meyer-Olkin (KMO) test, Bartlett's test, and Cronbach's alpha tests, as shown in Table 5. The KMO value of 0.8099 is

higher than the accepted value of 0.5, indicating that the sample was adequate and principal component analysis could be used for the given data set. The p value of 0.0000 acquired for Bartlett's test also indicates a sufficient measure of sampling adequacy. Further, a Cronbach's alpha value of 0.7747 indicates a high level of internal consistency. Thus, the indicators measured the same latent perception variables.

From the survey, agrodealers were asked to rank their preference based on the use of biopesticides in crop protection, that is from 0 to 4 (0 for Most preferred, 1for preferred, 2 for Less preferred, 3 for Least preferred, and 4 for others). They were also asked if they consider pesticides characteristics such as price, the type of pesticide, the effect of pesticide on human health, and the pesticides demand when making stocking decisions. Further, they were also asked to rank their level of agreement concerning biopesticides which included; Biopesticides are effective in controlling *Tuta absoluta*, biopesticides are safe to both human and the environment, willingness to trade biopesticides, biopesticides contributes to high yield as compared to synthetic pesticides, and if they believe that biopesticides can replace synthetic pesticides. After running the principal component analysis, Table 5 illustrates three principal components that were extracted from the agrodealers. The first one contributed the highest percentage (35%) to the variance, while the second and third components contributed 15% and 13%, respectively.

The first principal component (PC 1) captured the following dominant factors; 'Preference of biopesticide use in crop protection', 'Biopesticides are effective in controlling *Tuta. absoluta',* 'Biopesticides contributes to high yield as compared to synthetic pesticides, and 'Biopesticides can replace synthetic pesticides. These results show that the PC 1's dominant factors represented the effectiveness of Biopesticides in crop protection over synthetic chemical pesticides. The perception indicators captured in PC 2 were; 'Biopesticides are safe to both humans and the environment and 'I am willing to trade in biopesticides' PC 2's dominant factors represented the general effect Biopesticides on human health and the environment. PC 3, therefore, captured the aspect of commercialization and factors considered in decision making when trading in pesticides which included; 'Price when trading', 'the type of pesticide' and 'the demand' as given in Table 4.3 below.

According to the findings of the study done by Achiri *et al*. (2017), small-scale farmers and agrodealers in rural areas are more cautious about pesticide safety standards than their counterparts in metropolitan areas. As previously noted, this runs counter to the idea that agrodealers in

metropolitan regions with easy access to information are well informed and recognize the aspect of safety of the biopesticides over the synthetic pesticides as depicted in the study findings. This therefore calls for a need for training of all farmers and agrodealers in order to improve their pesticide management methods in the coming years. The results of the study are also consistent with the findings of Migwi (2016) who found that Boosting and growing information about bio-products among farmers and agrodealers, may be critical for their long-term acceptance. The fact that component efficacy accounted for 20% of the variance in their analyses demonstrates this. As a result of their findings, respondents were satisfied that the bio-pesticide would help to reduce pollution and provide a solution to an ongoing problem in crop protection. As a result of this perspective, the adoption of biopesticides will rise, as agrodealers will be more likely to stock biopesticides in large quantities in order to profit from their favourable assessment of the biopesticide's effectiveness.

Table 4.3: Agrodealers' perception towards biopesticides

Variable	PC 1 **Effectiveness in crop protection**	PC 2 **Effect on health and environment**	PC 3 **Commercialization aspect**	**Unexplained**
Use of Biopesticides in crop protection	0.4676			0.2037
Effectiveness	0.4916			0.1683
Safe to human and environment		0.6635		0.3463
Willingness to trade		0.6139		0.4176
Contributes to high yield	0.4807			0.1646
Can replace synthetics	0.4671			0.225
Price when trading			0.6046	0.4575
Type of pesticides			0.6426	0.4002
Effect on health				0.6061
Demand			0.4319	0.6782
Test for robustness				
Kaiser-Meyer-Olkin	0.8099			

Bartlett’s test	0.0000
Cronbach’s alpha	0.7747

4.5 The Agrodealers’ Capacity to Stock the Fungal Biopesticide

This study took into account the availability of employees, the presence of agrodealer networks through information and communication technology, knowledge and skills of handling biopesticides, access to credit facilities, availability of finances, availability of specialized storage facilities and the ability to carry out sales promotion as the capacity variables, to assess the agrodealers capacity to stock the biopesticides. Based on market analysis by various studies, increased stocking capacity results in more than just lower per-item sales pricing. In tandem with the increase of economies of scale, there is also the possibility to develop strategic advantages that will aid in maintaining market share and fighting off competition (Baumers *et al.,* 2016). Examining the financial, labour planning, and customer service components of production requirements will make determining whether or not expanding production capacity is beneficial and easier. It is also possible to reduce the price of restocking each individual product.

Labour economies of scale can be achieved because inventory holding expenses remain constant regardless of whether 200 or 400 units are stocked per day, potentially resulting in higher profit margins. Moreover, if energy costs do not rise in lockstep with increased production, the same is true. Gross earnings will rise as a result of greater inventory capacity. It's possible that expanded inventory capacity may allow for larger material and supply orders, resulting in lower prices and greater economies of scale. By examining profit margins and sales volume, it is critical to establish whether or not updating machinery with more efficient machines pays for itself.

Increased stocking capacity enables for more efficient filling of customer orders, resulting in increased profitability, for seasonal enterprises or huge orders that cannot be accommodated. Customers who are compelled to turn to one of the company competitors to meet all or part of their needs risk being permanently lost to the competitor who did not meet their wants in the first place. Even if increasing stocking capacity does not boost sales or profits, it is critical to invest in the ability to make more product in order to maintain present levels of sales and profitability. If increasing stocking capacity allows for the elimination of a shift or more hours, the most cost-effective option will be to reduce salaries, which will also have the added benefit of potentially lowering workers' compensation premiums and claims. The company would not only save money

on direct labour expenditures, but it might also save money on administrative costs. Whether raising productivity without increasing labour expenses pays off or requires revisions will be determined by the number of returns and customer service feedback received. The flexibility to extend inventories during sluggish periods enables the stocking of additional product to respond to last-minute demands or the stockpiling of inventory to meet large orders that arise while the business is at capacity. Order fulfilment wait times will very certainly be reduced even further if a just-in-time strategy is used. A corporation may be able to outsource production in order to meet inventory requirements while still making a profit if demand forecasting is accurate.

This study therefore shows that, assistance from the manufacturers to agrodealers through well-operating hotline numbers and training on sales and service aims at lowering costs and risks to agrodealers. Agrodealers have a massive opportunity to upscale their businesses since costs are cut and knowledge made available at their disposal by the manufacturers. Thus, they become more willing to accept new products from manufacturers. In the survey, 96% of the agrodealers received managerial support which constituted product advertisement for sales promotion, transport facilities hence premise delivery, personal attention from the manufacturers through sales agents, credit sales, discounts on bulk sales, and market information on pesticides trends. On the other hand, only 4% lacked support from the manufacturers, as shown in Figure 3.1 below. The higher percentage depicts that when the agrodealers are offered managerial support, they are more willing to stock new products from their manufacturers. These results align with a study done by Lin *et al*. (2012), who found out that suppliers always furnish managerial assistance to stimulate retailers' interests in their new products. It may be argued that Managerial support plays a critical role in promoting sales of both existing and new products at agrodealer level. These findings also justify the results of Maina (2020) that emphasize how crucial success factors influence the growth and development of a venture, for instance education of the business owner and finance access. Capacity building also forms part and parcel of critical factors of managerial support for improved sales of new products.

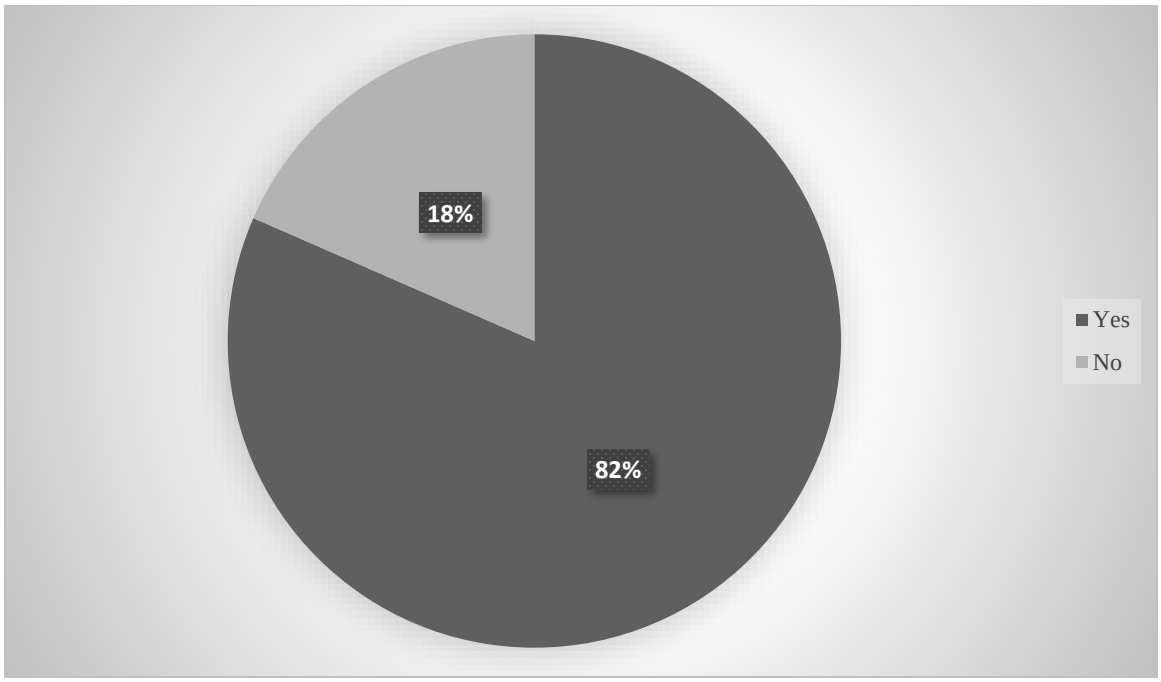

Figure 4.1: Managerial support to agrodealers by manufacturers

Physical distribution facilities such as trucks, motorcycles, and vans are key in the agrodealer business. A strong brand created by the manufacturer, generating photos and films of items for promotional purposes, delivering marketing materials, providing product samples, and providing wonderful customer service through an excellent communication line and appealing packaging, enhances retailer incentive to adopt and stock their new products. As indicated by the results, manufacturers are always present and play a very critical role in providing transport and distribution facilities, thus giving the agrodealers an incentive towards the high transport costs that usually make ventures operate at abnormal profits. Van *et al*. (2011) justifies retailers new product adoption by indicating that the probability of a retailer adopting a new product is positively related to the level of support such as the physical distribution facilities in the business (Van *et al*., 2011). To illustrate this further, Obiero (2019) justifies the essence of physical distribution facilities as highly effective in order processing and stock management in ventures. It can be concluded that agrodealers need to improve transportation of products, and the usual planning for distribution purposes. This inventory management is part and parcel of good management of the business and customer service.

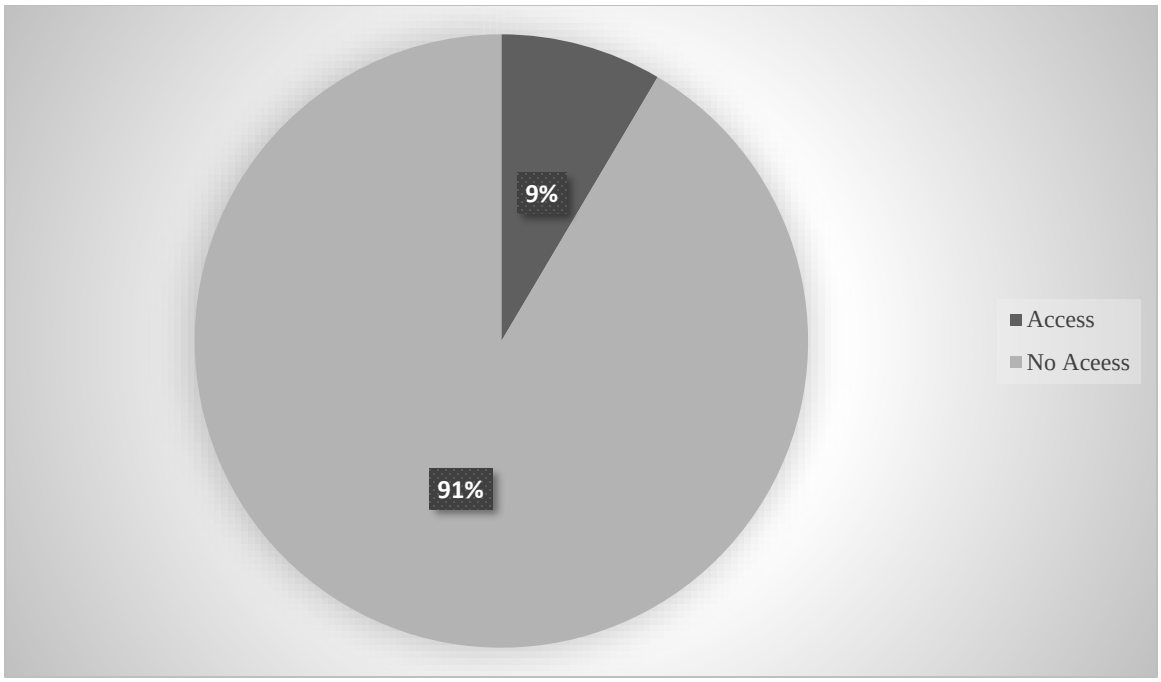

Figure 4.2: Agrodealer access to physical distribution facilities

Most Agrovets, approximately 67%, did not have employees and used family labour in all their operations. Only 33% of the agrodealers had employees who either worked part-time, full time, or part-time and full time. It can be argued that most small and medium-sized agrovets mainly employ family labour in their businesses since most of the operations do not require much expertise but rather experience in handling most of the agrovet products. This is illustrated by Maina (2020) on the critical success factors that are highly effective in the growth and development of the venture towards improved profits. Maina (2020) therefore indicated that family labour is usually opted for mostly to reduce costs. Since investors are usually very keen on costs and would not wish for losses in any type of venture.

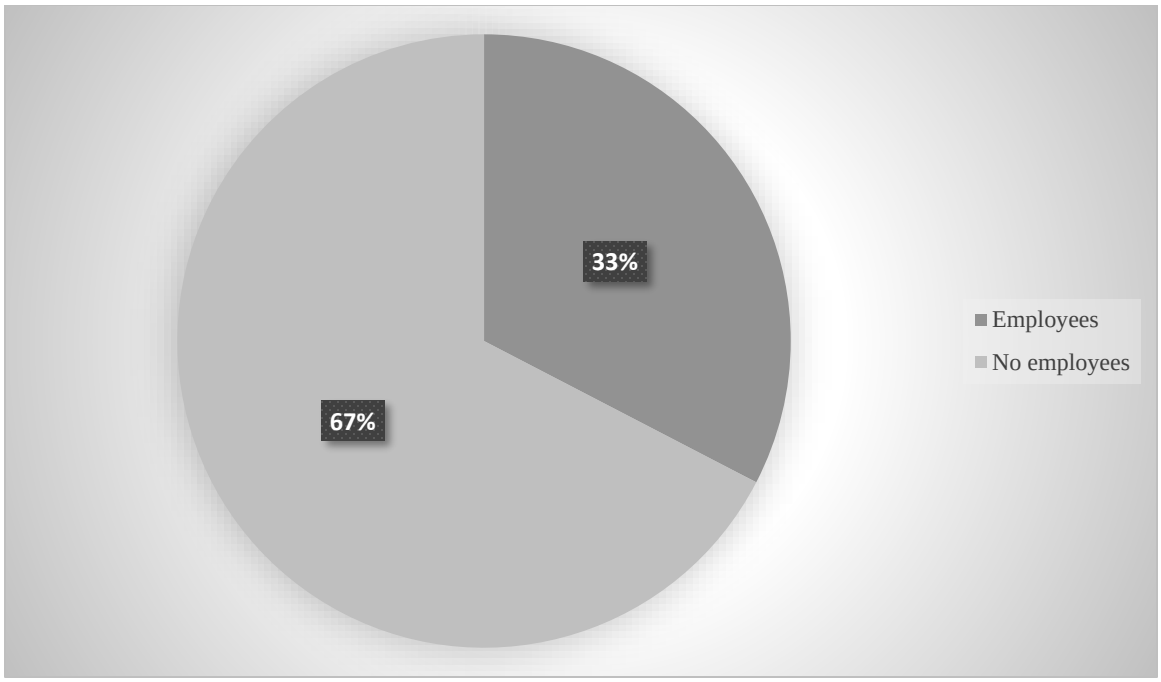

Figure 4.3: Employed labour by agrodealers in agrovets

The survey revealed a lower percentage of agrodealers who engaged employees on part-time and full-time basis. They realized that it is not economically feasible to employ workers but rather have family labour even though they are overworked during peak sales. Family labour is very instrumental in most cases when the business is just getting started or in the phase of picking and developing. This is usually a period when costs should be cut or reduced to the minimum to enable proceeds and margins. As illustrated in figure 4.4 below, access to a higher percentage of family labour is a proxy indicator for the agrodealers ability to stock new products. This is because costs are reduced and there is a likelihood of making profits in the long run. For further elaboration, it can be argued from the Bayesian report of 2016 perspective that corroborates the current study by depicting a lower proportion of full-time employees and part timers in the agrovet business. This is expected to happen in most ventures, given the lower average volume transacted by most Agrovets, especially in Mwea, Kirinyaga county. Concluding from an economic perspective, it is therefore not economically feasible to employ many employees on a full-time or rather both part-time and full-time basis. Instead, there should be casuals or part-timers who can be called upon during peak sales periods to move the inventory for increased sales volume (Bayesian, 2016).

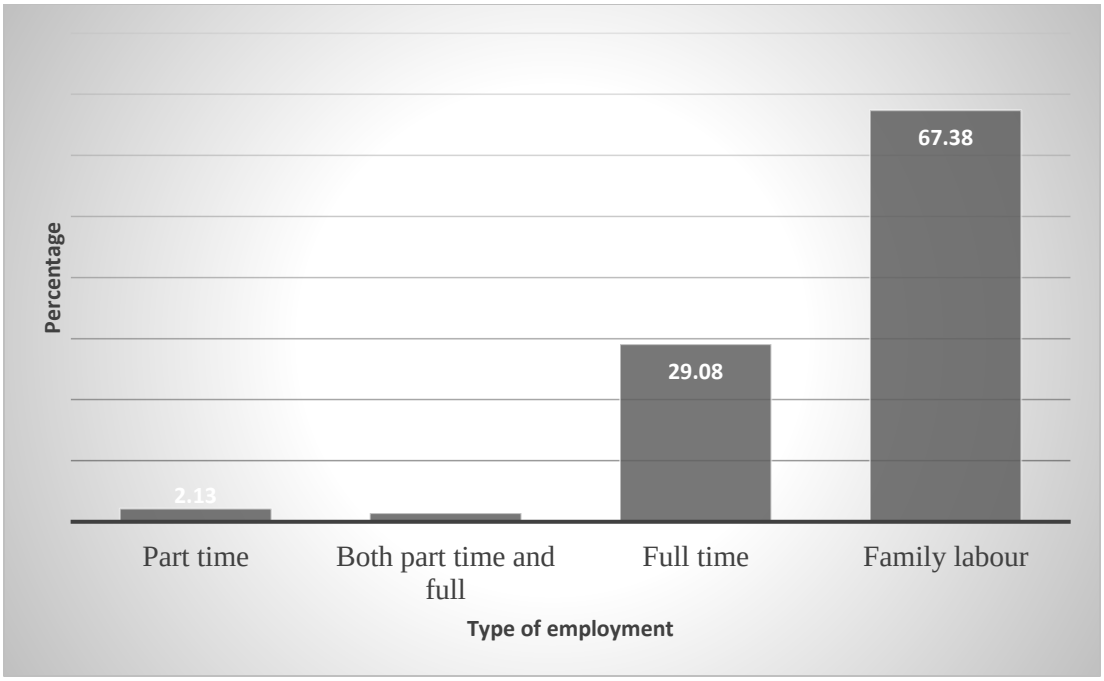

Figure 4.4: Type of employment in agrodealers agrovets

Access to credit facilities enables retailers to increase their input stocking capacity and sales. This is according to a study done by Maunze (2012). On scaling input provision as a key for successful small farmer engagement, they can increase their market base and make huge profits through a small investment in insurance of financial risks among agrodealers. About 46% of agrodealers in Mwea had access to credit facilities. This is also depicted by the percentage of the agrodealers who needed the credit facilities and those who accessed the facilities in running their ventures. Only a few agrodealers, approximately 17%, had previously accessed credit facilities for their operations in the Agrovets, yet only 7% of them needed the credit facility. These results imply a need to influence and educate them to realize the importance of credit in boosting business enterprises. The above findings are also in line with a study done by Peter *et al*. (2018) on government financial support and financial performance of small and medium enterprises. Their results also indicate that having access to credit facilities through financial assistance, has positive and significant effect on the performance of ventures (Peter *et al*., 2018). Therefore, facilitating access to adequate credit and financial support is highly effective in enhancing performance of a business. Businesses are likely to flourish if their owners take the initiative of accessing credit facilities to boost the inventory level appropriately, and in relation to the demand of that particular market segment. Also, stakeholders in partnership with the government need to upscale the rate of

credit intake by business owners and financial support intake to assist in the development and growth of both well-established ventures and small and medium sized enterprises in the economy.

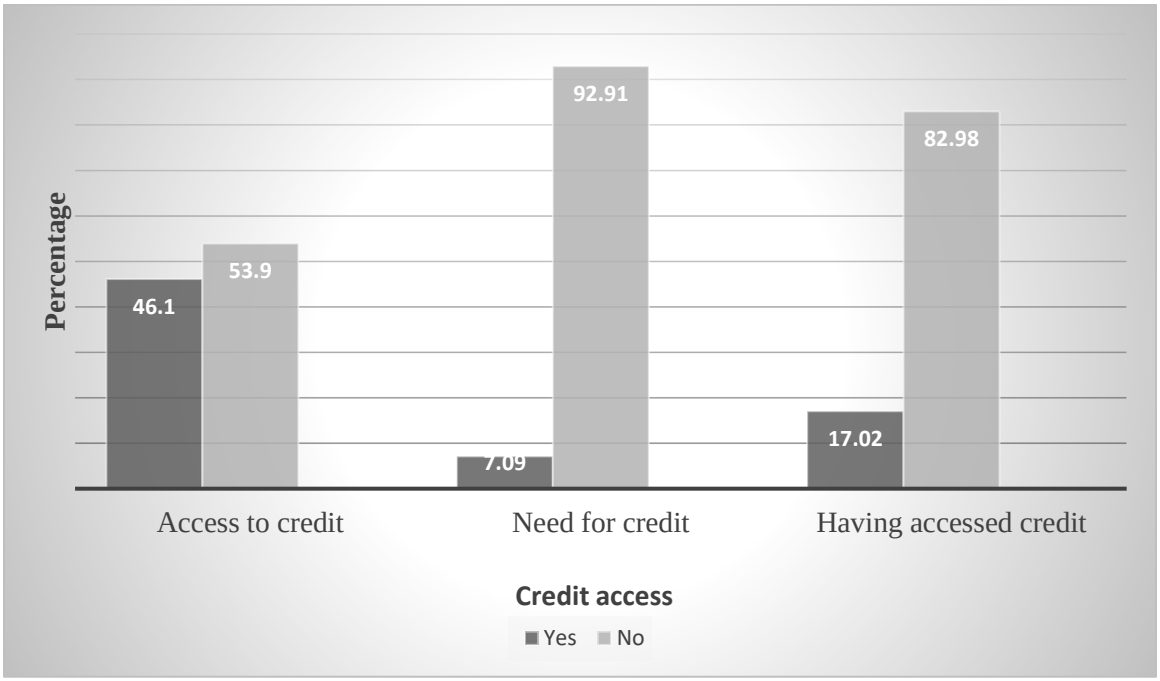

Figure 4.5: Availability of credit facilities to agrodealers

The survey results on agrodealer frequency of receiving information indicated that a higher percentage of agrodealers, approximately 55%, have access to information on prices, product characteristics, demand, and new products every week. Having information can keep agrodealers updated on the current market trends and the fluctuations that are prone to occur seasonally in most competitive business environments. 26% daily, 17% every month, while only 2% lacked frequent access. According to a study done by Jeong *et al.* (2017) on domain-specific innovativeness and new product adoption, access to information positively affects new product adoption. Therefore, with a higher number of agrodealers having access to various information based on product characteristics, as shown in figure 8 below, they are more inclined to stock new products from the manufacturers. These results are also justified by a study done by Lai (2018) in determining consumption situation and product knowledge in the event of adopting newly launched products. This study also describes the drawback of excessive information that might be misleading. By having all the information and knowledge about a certain product, there is a high possibility of adoption and stocking of that particular product by the entrepreneurs. It is also shown that

interaction of different kinds of products information have risk in diluting the entrepreneur intention to adopt it hence, more product information might be irrelevant to the suitability of the situation thus compromising the willingness to adopt that particular product (Lai, 2018).

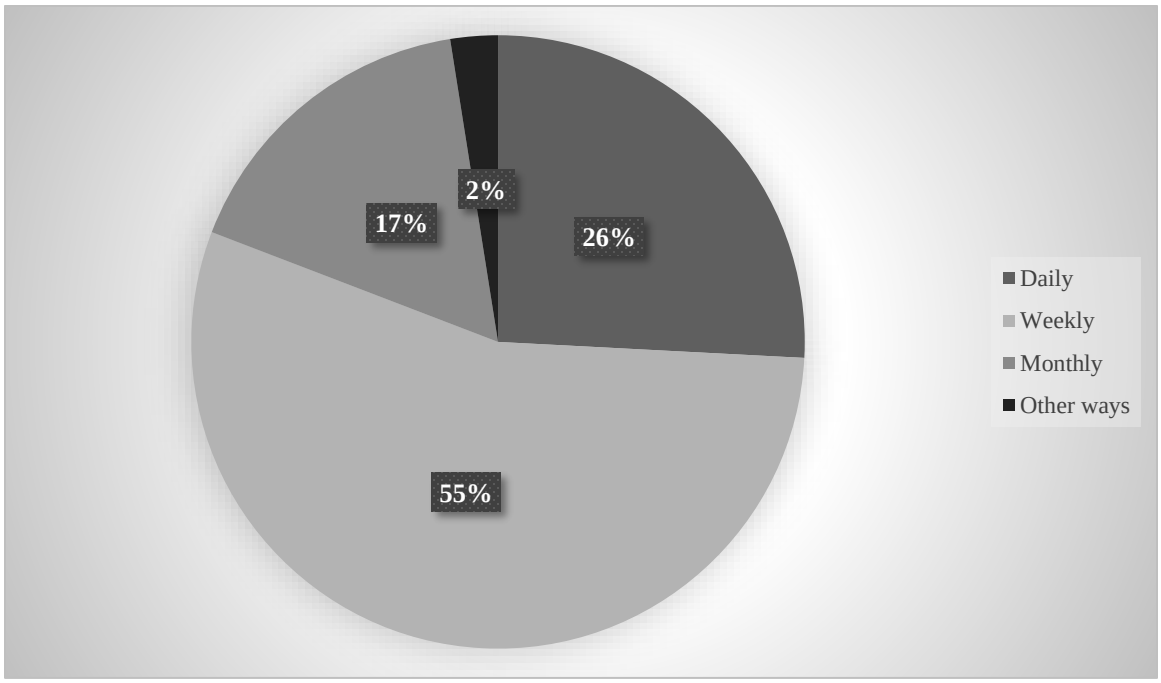

Figure 4.6: Agrodealer frequency of receiving information

The current study emphasizes various aspects such as finance and support from various institutions that influence the success of initiatives, especially those involving small and medium-sized businesses, and so verifies the great majority of Chong's previous findings. Chong *et al*. (2012) show that elements associated with venture success, such as financial help, government support, and support from family and friends, have an impact on the venture's performance. These findings corroborated those of Hayes *et al*. (2015) who also found out that financial support and support from government and other institutions are also critical in the success of a venture.

The most essential variables impacting the success of a firm, including small and medium-sized enterprises, are the entrepreneur's age, his or her talents and commercial abilities, the usage of experienced consultants, and personal financial demands. Management factors such as upper-level executive and board of director commitment and support, organizational infrastructure, human resource practices and policies, organizational culture, work environment, internal communication, corporate social responsibility, and information technology were all ranked last

in terms of their impact on the success of small and medium-sized enterprises. Chong *et al*. (2012) findings delve deeper into business characteristics like size, network structure, innovation, and ability to compete, as well as business environment factors like the economy, technology, law, sociocultural, and environmental factors that have little impact on the success of most small and medium-sized ventures.

While much research has been done on the variables that lead to the failure or success of businesses, less research has been done on the factors that contribute to the improvement of agricultural retailers' stocking capacity. Financial, logistical, management, and other essential success aspects are among the parts of the study that are particularly effective in scaling up acceptance, stocking, and restocking of new commodities among agrodealers in Kirinyaga County. There are just a few key characteristics that contribute to agrodealer performance and should be the focus of manufacturers' efforts as long as they are compatible with their nature as economic entities competing with other large enterprises in local marketplaces. The current study does not focus on the general factors that influence the success of small and medium-sized businesses, but rather on how defining decision-making areas and activities for agrodealers to engage in, makes stocking new products more feasible, while keeping in mind that these factors work in concert to ensure the success of their specific agrovets.

4.6 Willingness to Stock Biopesticides Among the Surveyed agrodealers

This study used contingent valuation to determine the agrodealers' willingness to stock biopesticides. The CVM approach employs three methods namely; single-bounded, double-bounded and, multi-bounded models. In the single-bounded model, the respondent is only offered one bid to either accept or reject. According to Hanemann *et al.* (1998), the method is not appropriate since it requires a large sample size and not statistically efficient. Studies have illustrated the effectiveness of the double-bounded model since it incorporates more information about the respondents' willingness to pay, and therefore providing efficient estimates (Nyangau *et al*., 2020; Oduniyi *et al.,* 2020; Shee *et al*., 2020). The model offers a second bid, either higher or lower depending on the respondent's first response, unlike the single-bounded model. The multiple-bounded model allows for multiple bids and choices, which offers the possibility of including alternatives for uncertainty. However, the multiple-bounded models are design bias and influenced by bid range (Vossler *et al.,* 2004)

This study employed the double-bounded model which has a good theoretical justification and provides unbiased estimates. The agrodealers were therefore asked the price for the most frequently sold pesticide for management of *Tuta absoluta.* This price was the first bid of the contingent valuation, followed either by a higher or lower amount as explained earlier in the conceptual foundation. The most commonly used pesticide for the management of *Tuta. absoluta* was Collagen at an average price of Ksh. 622 per litre (Table 4.4)**.** Eighty-two (82%) of the agrodealers were willing to stock a fungal-based biopesticide and retail at the same price as Collagen. On average, the mean willingness to pay for the ICIPE 20 was Ksh. 1,018 per litre, about 64% over and above Collagen market price. This suggests that the agrodealers consider biopesticides efficient than chemical pesticides such as Collagen, and thus would be willing to stock and sell to tomato growers.

Table 4.4: The agrodealers' mean willingness to stock and mean premium price for biopesticide and commonly used synthetic pesticide

Pesticide	**Mean**	**Z stat**	**% Change from market price**
Fungal biopesticide			
(ICIPE 20)	1018.191	17.21***	64
Corragen	621.9568		

These results indicate that agrodealers have a positive perception towards ICIPE 20, and they consider it more effective than the already existing chemical pesticides such as Coragen. Therefore, they were willing to stock and sell to consumers at a higher price.

Table 4.5: Factors influencing willingness to stock for a fungal based Biopesticide (ICIPE 20) in Kirinyaga Count

Variables	**Coefficient**	**Standard error**	**Z**
Age of agrodealers	-0.154**	0.0760	-2.03
Years of schooling of agrodealers	0.419*	0.2461	1.70
Agrodealer access to social networks	5.063**	2.3158	2.19

Agrodealer knowledge on none-pesticide practices	-1.985	1.2956	-1.53
Years of business operation	-0.073	0.0982	-0.75
Agrodealer access to credit facilities	2.408*	1.2809	1.88
Managerial support from manufacturers and suppliers	1.477	0.9956	1.48
Availability of employees in the Agrovets	-1.352	1.1243	-1.20
Agrodealer access to information	2.199*	1.2325	1.78

Note: *= significant at P< .1; **= significant at P< .05; ***= significant at P< .01 Z = z statistics

Table 4.5 presents the main factors influencing willingness to stock a fungal based Biopesticide (ICIPE 20), which included age, and years of schooling of the agrodealer, agrodealer access to social networks, to credit facilities and to information. According to the results of the study, it was found that the main factors that influence willingness to stock the fungal based biopesticide are agrodealers age, education which was represented as the years of schooling, access to social networks, access to credit facilities and information. The higher the age of the agrodealer, the lower the willingness to stock the fungal biopesticide (Pratap, 2019). When it comes to trying new products or breaking away from their usual pattern, the elderly has an innate fear of doing so. Given the importance of age as a demographic component influencing consumer behavior, it is no surprise that as people get older, their needs shift. Similar patterns emerge in their purchasing decisions. Furthermore, people are more prone to spend money on personal necessities and to be more daring in their spending while they are young. Individuals' spending on new items decreases as they become older, and they become less interested in trying new products, hence preferring to stick to their usual buying habits. Age of the agrodealer is negatively related to their willingness to stock the fungal Biopesticide as depicted in the study results. These findings thus corroborate that of Nyangau *et al.* (2020) and Bandara *et al.* (2013), who found that perception and willingness to pay for Bt 43 and ICIPE 78 in Uganda decreased with the age of the individuals.

Education or years of schooling affects how individuals view things around them. It influences the level of discretion consumers or traders employ while making purchases. Lately, years of schooling has also become the determinant of social class and the most robust way to elevate in the society. The more educated a person is, the higher the level of discretion employed in making purchases at various outlets or ventures. Agrodealers are therefore well informed and

the more a trader is educated, the more time taken in making a decision in purchases. The coefficient for years of schooling was therefore found to be significant and had a positive effect on willingness to stock, implying that well-educated agrodealers have better knowledge of Biopesticides. These results are consistent with the previous studies such as Constantine *et al*. (2020) who found that educated agrodealers are more likely to pay for Biopesticides in Kenya.

Social networks, such as group memberships and social media platforms, are critical for providing agrodealers with information on prices and market trends. In this situation, a trading platform is one that allows traders to easily operate in a range of market segments while also growing their sales volume. Being a member of a group while also having access to social media may result in a positive response in terms of awareness and being up to date on current events. Access to social networks therefore had a positive influence on willingness to stock, thus indicated a significance at 5% depicting the positive relationship of agrodealers willingness to stock. This explains that the agrodealers who had access to social networks have information on the market trends based on new products, prices and consumer demand.

The coefficient for access to credit facilities was also positive and significant, implying that agrodealers having access to the credit facilities are more likely to accept new products or increase their stocks in the stores due to availability of capital. Finance and credit availability affects an enterprise's capability in a variety of ways, most notably in terms of technological options, market access, and access to key resources, all of which have a significant impact on a company's viability and success. Obtaining the cash required for a company's start-up or operation is a crucial difficulty that every entrepreneur faces, especially those in the SME sector. Due to a lack of finance and credit resources, small and medium-sized businesses (SMEs) confront significant obstacles in developing and expanding their businesses. The findings are consistent with the previous studies such as Chia *et al*. (2020) who found that access to credit significantly and positively influenced willingness to pay for feeds among agrodealers in Kenya.

Additionally, information is very critical to both agrodealers and the farmers in the pesticide industry. Therefore, access to information significantly and positively influenced willingness to stock, implying that agrodealers who had access to reliable information on pesticides knew about them and their demand. This can be expounded a study done by Phiri *et al*. (2019) which justifies the benefits of access to information, since it increases awareness of and ability to use mobile phones and other social media platforms, which is likely to result in more

access to information for more people than ever before. Being a member of a group is designed to increase access to information, and as a result, demonstrating an interest in a range of information sources may result in a larger urge to stock information.

4.7 Cost and benefits of pesticides

The study also determined the costs and benefits of stocking a fungal biopesticide. Farms with similar qualities and production procedures can be compared to one another when it comes to net earnings. With this constraint in mind, comparisons can provide valuable insight into a company's multiple operations' productivity and economic efficiency. Gross margins are particularly valuable in both inorganic and organic systems when it comes to farm planning and comparisons between companies within the same company, across organic holdings, or between conventional and organic operations in both inorganic and organic systems (Lampkin *et al*., 2001). Therefore, the prices of the already existing pesticides were used alongside the cost of the biopesticide introduced at the willingness to pay price.

The gross margin was employed and played a crucial role in assessing the financial performance of a project hence a key factor in the cost-benefit analysis. The gross margin represents the difference between revenue generated from sales and the cost of goods sold (COGS). It provides insights into the profitability of a product or service and is typically expressed as a percentage of sales. The gross margin is an essential metric in the cost-benefit analysis as it allows decision-makers to evaluate the efficiency and viability of a project. By comparing the gross margin with the overall costs incurred, one can determine whether the benefits outweigh the expenses. A higher gross margin implies that a company is generating more revenue relative to its production costs, indicating a healthier financial position. When conducting a cost-benefit analysis, the gross margin can be used to estimate the potential return on investment. If the gross margin is sufficiently large, it suggests that the project is generating enough revenue to cover both the variable and fixed costs. This indicates a positive net benefit and signals a financially viable undertaking.

The results showed that the most used pesticide for the management of *Tuta absoluta* is Coragen at an average price of Ksh 621.96 per litre**.** Based on willingness to stock a fungal based Biopesticide, 82% of the agrodealers were willing to pay for the fungal biopesticide at the same price as Coragen. The analysis revealed that the mean willingness to pay was at a much higher

price of approximately Ksh 1018.191per litre for the ICIPE 20, implying that the agrodealers see more value in biopesticides than the chemical pesticides. Total revenues arising from the sale of the most used pesticides for control of *Tuta absoluta* were significantly higher than the total variable costs, hence a positive net margin value (Table 4.6). The benefit-cost ratio (BCR) was also greater than 1, and the net present value (NPV) positive (Table 4.6).

On average, the agrodealers sold 125 litres of the most used pesticide for control of *Tuta absoluta* (Corragen) at a cost of Ksh.725 monthly. Based on the cost of goods sold, a total of Ksh.77,745 is used in purchase of pesticides and the gross monthly income amounts to Ksh.12,880. Taking into consideration the variable costs incurred during the trading period, the agrodealers incur the costs of protective gears which average Ksh.1009.76 during pesticide handling in the agrovets. Advertisement on the other hand averages Ksh.833.33, transport costs at Ksh.4171.29, average salary to employees at approximately Ksh.2650, and loading and offloading costs at approximately Ksh.440.43 during deliveries at door step from the manufacturers. Therefore, the total variable costs amount to Ksh.9,104.81. The total gross margin less total variable costs equal the net margin at Ksh. 3,775.19, which agrodealers earn on average monthly from the sale of the most used pesticide (Coragen) to farmers. A ratio of the sum of the biopesticides discounted benefits to the sum of the discounted costs generated 1.41, which is a ratio greater than 1 hence justifies the relevance and profitability potential of investing in the fungal based biopesticide. This was calculated based on the interest rate of the central bank which was at 7 percent as at 2020. Further, The Net Present Value measured the surplus earned against costs with the aid of the given interest rate. The net present value was found to be positive (3528.22) thus reflecting the opportunity cost of funds invested, and the profitability rate of funds invested in the new product. Hence, absolute profitability potential of investing in the fungal based biopesticide by the agrodealers (Table 4.6).

Table 4.6: Revenues, costs, BCR and NPV of pesticides used in controlling Tuta absoluta (Ksh)

Revenue (725 ×125 Litres)	90,625
Cost of goods sold (621.96 ×125 Litres)	77,745
Gross margin	**12,880**
Variable costs	
Protective gears	1009.76
Average advertising costs	833.33
Transport costs	4171.29
Average salary	2650
Loading and offloading costs	440.43
Total variable costs	**9,104.81**
Net margin	**3,775.19**
Benefit cost ratio	**1.41**
Net present value	**3,528.22**

Using the common indicators that assess the economic feasibility of investing in new products, as discussed in this study, different objectives were analysed through various methods. The employed aspects looked into the knowledge and perception of agrodealers towards the use of biopesticides to manage pests, factors influencing the agrodealers willingness to stock a fungal based biopesticide (ICIPE 20) for management of *T. absoluta*, the agrodealers' capacity to stock the fungal based biopesticide, and the potential costs and benefits of stocking a fungal based biopesticide among agrodealers in Kirinyaga County, Kenya. Different robust tools and methods were employed after in-depth research and comparison with most related studies to come up with the most efficient decision. Hence, Descriptive statistics, binary probit model, cost benefit analysis, and the principal component analysis methods were used to obtain constructive results. Statistics and regressions in this study therefore show that introducing the fungal biopesticide to the agrodealers can deliver monetary benefits to them. Most of the agrodealers were aware of organic practices for the management of leaf miner, and the specific organic practices that could be used

to control the pest. Crop rotation with the non-host crop was the main control measure put into practice by most tomato farmers in control of *Tuta absoluta.*

The principal component analysis revealed a positive perception of the agrodealers, and the components expressed the extent of effective and efficient nature of the biopesticides. These were covered in the different components for example the PC 1's dominant factors represented the effectiveness of Biopesticides in crop protection over synthetic chemical pesticides. PC 2's dominant factors represented the general effect Biopesticides have on human health and the environment, and PC 3, captured the aspect of commercialization and factors considered in decision making when trading in pesticides which included. Results indicated that agrodealers have a positive perception towards ICIPE 20, and they consider it more effective than the already existing chemical pesticides such as Collagen. Hence, they were willing to pay more.

The results also provide further support to the view that, by stocking the fungal biopesticide, the significant problems confronted by agrodealers and tomato farmers such as, destructive nature of *Tuta absoluta,* adverse effects of chemicals on human health and the environment, and high cost of chemical pesticides to poor smallholder agrodealers that dominate the pesticide industry, can therefore be addressed by the fungal biopesticide. Assistance from the manufacturers to agrodealers through well-operating hotline numbers and training on sales and service aims at lowering costs and risks to agrodealers. Thus, they become more willing to accept new products from manufacturers. In the survey, 96% of the agrodealers received managerial support. Manufacturers' support to the retailers based on distribution facilities increases retailer incentive to adopt and stock their new products. It can be argued that most small and medium-sized agrovets mainly employ family labour in their businesses since most of the operations don't require much expertise, but rather experience in handling most of the agrovet products. Concluding from an economic perspective, it is not economically feasible to employ many employees on a full-time or rather both part-time and full-time basis. Instead, casuals or part-timers can be called upon during peak sales periods to move the inventory for increased sales volume. Access to credit facilities enables retailers to increase their input stocking capacity and sales. As a result, with a higher number of agrodealers having access to various information based on product characteristics, they are more inclined to stock new products from the manufacturers.

The study estimated the net present value (NPV) of investing in biopesticide at Ksh 3,528. This indicates that chemical pesticides are not effective but expensive due to pest resistance, and

the agrodealers are constantly looking for an effective, safe, and profitable alternative way of controlling the destructive tomato leaf miner. By calculating the benefit-cost ratio (BCR), we recognized the value of the efficiency of investing in the fungal biopesticide since it was more significant than 1. The benefit-cost ratio was found to equal 1.41, meaning that each dollar invested by an agrodealer in the fungal-based biopesticide can generate an additional value of 1.41 Kenyan shillings.

As noted above, cost-benefit analysis requires a stream of costs and benefits to calculate incremental net benefits. This involves projecting future flows of costs and benefits, discounting them, and then applying a decision criterion to decide whether a project is worthwhile and capable of generating returns in both the short-run and long run. Using the common indicators that assess economic viability, this study has shown that introducing a fungal-based biopesticide in Mwea, Kirinyaga county can deliver monetary benefits to agrodealers reliant on agrovet business to generate income. The results also support the view that adopting the fungal biopesticide, *Tuta absoluta* menace, and the hazardous nature of synthetic pesticides within the agrovet business environment can easily be solved. The poor-resourced agrodealers who dominate the pesticide value chain business have a chance to expand both locally and regionally to improve their profit potential by commercializing an organic product that is safe for both humans and the environment.

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

I. Agrodealers attached a higher value to the fungal biopesticide (ICIPE 20) as an alternative pest management practice for the leaf miner. Thus, implying that there is much concern about the destructive nature of the pest. Moreover, the over-application of synthetic chemicals due to pest resistance was pointed out as contributing to the high cost of pesticides.

II. The percentage awareness of biopesticides was low among agrodealers and this was mainly contributed by the level of education among the agrodealers. Further, the principal component analysis depicted dominant factors in the components which represented three different aspects namely: The effectiveness of biopesticides in crop protection over synthetic pesticides, the general effect of biopesticides on human health and the environment, and the commercialization aspect of pesticides respectively.

III. Based on the regression analysis, the study results show that years of schooling of the agrodealers, access to social networks, access to credit facilities, access to information were positively influenced by willingness to stock except the age of the agrodealers.

IV. The gross margin analysis indicated a positive net present value, thus suggesting that chemical pesticides are expensive due to pest resistance, and the benefit-cost ratio (BCR) also revealed efficiency in investing in the fungal biopesticide since it was greater than 1.

5.2 Recommendations

The study recommends that;

I. There is potential for the fungal based biopesticide to be used in crop protection against tomato leaf miner *Tuta absoluta.* Hence, a need for the Ministry of Agriculture, Livestock, and Fisheries (MALF) to sensitize tomato farmers on the importance of adopting biopesticides in crop protection.

II. There is need for creating awareness and disseminating information on the effectiveness of the fungal based biopesticide in tomato production, and the negative effects of synthetic pesticides on human and the environment. Thus, the MALF is obliged to provide more extension services and training to tomato farmers on the adverse effects of chemical pesticides on human health and the environment. Moreover, making the farmers aware of

none pesticide practices that can be used in crop protection other than synthetic pesticides seems to reduce the hazardous nature of chemical residues in food products.

III. The Ministry of Agriculture, Livestock, and Fisheries need to come up with initiatives through which agrodealers can easily access credit facilities without necessarily providing collateral. This will enable the agrodealers to invest more in Biopesticides, and improve their availability to the tomato farmers. agrodealers should also be encouraged to form groups and networks, which can help improve their bargaining power in various value chains. Since there are high initial investments and certifications in chemical pesticides, the market outlet for biopesticides has heavily diminished.

IV. Through the Ministry of Agriculture, Livestock, and Fisheries, the government needs to upscale the manufacture of biopesticides, their certification, and advertisement to improve their use in crop protection.

5.3 Area for Further Research

I. Future research should focus on assessing the agrodealer stocking decisions and actual use of pesticides in the farms to provide accurate policy recommendations, since findings derived from this study suggest that adopting either chemical or biopesticides by farmers in crop protection majorly depends on agrodealers stocking decisions.

II. Generalization of results cannot adequately extend to other agrodealers outside Kirinyaga County. Based on this fact, a broad-based study covering all agrodealers countrywide be done to find out the feasibility of stocking biopesticides.

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APPENDICES

Appendix A: Questionnaire: Agrodealer Survey 2020

Market survey questionnaire Modules for project: -Combating the invasive tomato leaf miner, *Tuta absoluta* through the Implementation of eco-friendly IPM approach on tomato in East Africa (*Tuta* IPM)

Introduction statement/consent:

Dear Sir/Madam, I am working on behalf of the International Centre of Insect Physiology and Ecology (icipe) and Egerton University. We are conducting a study to find out the feasibility of stocking a fungal based biopesticide (ICIPE 20) by Agro-dealers in Kirinyaga County, Kenya. The information provided will assist in formulation of policies and programs that will improve crop protection and dissemination of sustainable alternative ways for improved tomato yield in the Country. The information provided will be treated with strict confidentiality. Taking part in this study is voluntary. If you choose not to take part, you have the right not to participate and there will be no consequences. Thank you for your kind co-operation

AGRO-DEALER IDENTIFICATION

County Sub county Town

Name of enumerator Name of agricultural input trader Date of interview:

GPS reading of the agricultural input trader business center.

SECTON A: DEMOGRAPHIC DETAILS

A.1. Gender: ☐ Male (1) ☐ Female (2) (*Tick where appropriate*)

A.2. Main occupation (*Tick where appropriate*)

1. Farmer	2. Trader	3. Both farmer and trader	4. Others (specify)

A.3. Age of the input trader ……. Years

A.4. Complete years of schooling…….. (Years)

SECTION B: TRADERS KNOWLEDGE AND PERCEPTIONS ON BIOPESTICIDES

B.1. Have you heard about Non-chemical pesticides for control of tomato insect pests [_____] 0=No1=Yes (This is a method of controlling pest such as insects, mites and weeds using pesticides derived from natural materials as animals, plants, bacteria and certain minerals)

B.2. Have you been visited by an agricultural extension agent or others in the last 3years on Non-synthetic means of controlling pests [____] 0=No 1=Yes

B.3a. Have you heard about Non-pesticide **practices** for control of **Leaf miner (*Tuta absoluta)*** in tomato production [_____] **0=**No; 1=Yes

B.3b. If **YES,** tell us which non-pesticides practices you know and/or used to control **Leaf miner (*Tuta absoluta)***

	Non-pesticide practice for controlling Tuta Absoluta	**Do you know this[component] 0=No; 1=Yes**	**Have you ever used this [component] 0=No; 1=Yes**
1.	Planting resistant varieties		
2.	Selecting healthy seeds or sanitizing seed treatment		
3.	Soil tillage		
4.	Crop rotation with non-host crop		
5.	Adjust planting/harvesting dates to reduce pest damage		
6.	Adjust irrigation timing/amount to reduce pest damage		
7.	Grow tomato under insect net or net house		
8.	Pick and destroy infected plant or plant parts		
9.	Orchard sanitation (collecting fallen infested fruits and disposing away from the farm)		

10.	Use Pheromones traps for scouting, monitoring and mass trapping		
11.	Hang sticky traps		
12.	Biological control using parasitosis/natural enemies		
13.	Using a barrier crop		
14.	Using water traps		
15.	Others non-pesticide control methods (specify)		

B.4 Are you aware of the use of biopesticides in management of *Tuta absoluta*? 1=Aware 0= Not aware (If not aware go to question 6)

B.5.Where did you learn about it? 0=Extension officer 1= Fellow trader 2= Media 3=Own experience 4= others (specify)

B.6.Would you recommend to farmers the use of biopesticides in management of *Tuta absoluta*? 1=Yes 0= No

B.7. Do you prefer the use of biopesticides in crop protection?

Preference rank 0=Most preferred 1= preferred 2= Less preferred 3= Leased preferred 4= others

B.8. Have you ever stocked biopesticides for management of pests? ……. 1=Yes 0=No

B.9. Do you have in stock any biopesticide for pest management? …….(1=Yes 0=No) (If No, go to question 11)

B.10.If yes, tell us which biopesticides are in stock and pests they are used to control

Biopesticides	Targeted pest/s

B.11.Now, I'm going to read you some statements about use of biopesticides in controlling *Tuta absoluta*. Kindly indicate whether you strongly agree, agree, Neutral, disagree or strongly disagree with the statements

Statement	**Strongly agree**	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
Biopesticides are effective in controlling *Tuta absoluta*					
Biopesticides are safe to both humans and the environment					
I am willing to trade in biopesticides					
Biopesticides contributes to high yield as compared to synthetic pesticides					
Biopesticides can replace synthetic pesticides					

B.12. When trading in synthetic and biopesticides, are the following characteristics important in your decision making?

Characteristics	**Very important**	**Important**	**Neutral**	**Not important**	**Not very important**
Price					
The type of pesticide					
Effect on trader's health					
The demand					

B.13a. Have you received any training on tomato production using biopesticides in the last two years?

[_____] 0=No, 1=Yes

B.13.b If Yes, who provided the training ……

0= Extension officer 1= Cooperatives 2= Workshops 3= Media 4= NGOs

B.14. For how many years have you been operating the Agrovet…….. (Years)

SECTION C: TRADERS WILLINGNESS TO STOCK BIOPESTICIDES

C.1. Trader origin

1. Urban area	2. Local area	3. Other; specify

C.2. Are you willing to stock the fungal based biopesticides? ---------- (1=Yes, 0=No)

C.3 If No, Fill in the table below based on your opinion towards stocking (1= Yes, 0= No)

Descriptions	Responses
I cannot afford the biopesticide	
I need to know farmers opinions about it	
I agree but costs are high	
Yes, if costs are reduced	
I agree but current situation is satisfactory	
Yes if its compulsory	

C.4. Which is the most used pesticide for management of *Tuta absoluta*?

0= Collagen 1= Occasion star 2= Avuant 3= Belt 4=other, specify

C.5.At what price do you purchase it per kg? (Use table below)

	Name of the pesticide	Ksh/kg
1		
2		
3		

C.6.Are you willing to purchase the fungal based biopesticides per kg at same price as chemical pesticides? ..... (1=Yes, 0= No)

C.6.b. If YES, would you be willing to pay Ksh…… (*Enumerator choose randomly any of the percent given below for the bid and calculate the amount in monetary terms e.g.* x+ (10% of x)

(0= 5% 1= 10% 2= 20% 3= 30% 4= 50%)

% Change	1. +5%	2. +10%	3. +20%	4. +30%	5. +50%

C.6.c If NO, would you be willing to pay Ksh…… (*Enumerator choose randomly any of the percent given below for the bid and calculate the amount in monetary terms e.g.* x-(10% of x) (1=yes 0=No) If No, go to question 8

(0= 5% 1= 10% 2= 20% 3= 30% 4= 50%)

% Change	6. -5%	7. -10%	8. -20%	9. -30%	10. -50%

C.7.What discount rate is preferred? …….. (0= 5% 1= 10% 2= 20% 3= 30% 4= 50%)

C.8.Why are you not willing to stock the fungal based biopesticide?

0= Expensive 1= Need more training 2=No space for stocking 3= Risky business 4=If its profitable 5= Less in the market 6= other, specify……..

C.9 If YES, to question C.6, When would you be willing to buy the bipesticide?

0. Imediately	1. After 1 year	2. After 2 years..	3. After how many yaers? Specify….	4. Other (specify)….

C.10.How soon are you willing to start trading in the fungal based biopesticide? ……..

0= Immediately 1= after 1 year 2= after 2 years 3= after how many years, specify 4= other, specify

SECTION D: CAPACITY TO STOCK BIOPESTICIDES

D.1. Do you have any type of contracts with the farmers……. (0=No, 1=Yes)

D.2. Do you have access to credit facilities such as financial institutions? ….. (0=No, 1=Yes)

D.3. Do you have access to effective information on biopesticides (0=No, 1=Yes)

D.4. Do you have access to credit and financial support institutions? ..... (1=yes, 0=No)

D.5. Do you need credit for your business operations i.e. stocking decisions …… (1=yes, 0=No)

D.6..Do you have access to specialized storage facilities for stocking your merchandise? ---------- (1=yes, 0=No)

D.7.Does Managerial support such as training on pesticides handling, exist from manufacturers? ---------- (1=yes, 0=No)

D.8.Does promotional support (Promotional activities by manufacturers e.g advert costs, discounts etc) exists between retailers and manufacturers? ------ (1=yes, 0=No)

(If No, go to question 14)

D.9. If yes, fill in the table below

Promotional activities by manufacturers	Tick
Discounts	
Advertisement	
Transport	
Training	

D.10. Do you have access to physical distribution facilities such as trucks? (1= Yes, 0=No)

D.11. Have you received any training on the knowledge of handling biopesticides? (1= Yes, 0=No)

D.12. Have you dealt with biopesticides before?(1= Yes, 0=No)

D.13. If yes specify the number of years

1. One year	2. Two years	3. Three years	4. Others, specify

D.14. How would you rate the type of information on biopesticides that you get access to?

0= highly effective, 1= Effective, 2= Non effective

D.15 Do you have employees ……. (1=yes, 0=No)

D.16 Are they employed on part time or full time basis ….. (1=yes, 0=No)

D.17 If they are part timers, how much do you pay them ….. (Ksh)

D.18 What are the costs of loading and offloading the pesticides ……. (Ksh)

SECTION E: COSTS AND BENEFITS OF PESTICIDES

E.1.At what price do you purchase pesticides used for management of *Tuta absoluta* per kg? ---------- (Kshs)

	Name of the pesticide	Ksh/kg
1		
2		
3		
4		

E.2.At what price and unit do you sell pesticides used for management of *Tuta absoluta* per Kg/Lt/Gms in Ksh ……..

	Name of the pesticide	Ksh/kg
1		
2		
3		
4		

E.3a.Do you use protective gears when handling pesticides in the Agrovet? 1=Yes 0= No (If No, go to question 3d)

E.3b. What do you wear during pesticides handling?..... (1=Yes 0= No)

Ordinary clothing	
Gloves	
Overalls	
Boots	
Face masks	
Hat	
Long sleeved shirt	

E.3c.If yes, what are the costs of the protective gears ……..(Ksh)

E.3d. What other costs do you incur while dealing with your merchandise from the manufacturer to farmers? …….

Cost Incurred	**Amount (Ksh)**

E.4a.Do you advertise your pesticides? 1=Yes 0=No (If No, go to question 6)

E.4b.If yes, what is the cost of advertising…….(Ksh)

E.5. Where do you advertise…… [____] [____][____][____]

1. Television	2. Radio	3. Newspapers	4. Others specify

E.6.What is the time the pesticides generally take in the shelves before sale? (weeks) .....

E.7.What is the mode of transporting the pesticides to the marketing point (tick appropriate)

	Type of transport				
	Bike	Motorbike	Truck	Nissan	Other (specify)
Own transport					

Hired vehicle (individual)					
Hired vehicle (group)					
Public transport					
Buyer transport					
Move by donkey cart					

E.8.What is the number of times you transport your pesticides to the market per week? …… (Ksh)

E.9. What is the cost for a single trip? .....Ksh

E.10.Before selling your product what value adding activities do you performs? (Use table below)

Activity	0=No 1=Yes	Cost
Grading		
Packaging		
Sorting		
Mixing		
Specify (others)		

E.11. Do you have contractual agreements or a guaranteed/ ready market (formal or informal) with any agribusiness outlet e.g. Cooperatives, farmer groups or supermarkets? …… 1= Yes 0= No

E.12. Do you always find the market for Pesticides? …….. 1= Yes 0= No

E.13. If No (D14) what happen to unsold pesticides (*select choices below)* [____] [____][____]

1. lost to spoilage	2. Sell at low price	3. Stored and sold later	4. Other (specify)

E.14. Do you have regular customer, who always buy from you? …….. 1= Yes 0= No

E.15. How far is the marketing point on average? ..... Km

E.16. What are the general problems you experience in moving the products (from the supplier and your consumers? (*select choices below)* [____] [____][____]

1. Lack of transport	2. Small size of transport	3. High transport cost	4. Others (specify)

SECTION F: MARKET INFORMATION

F.1. Do you have access to market information (prices, new pesticides, demands, competition etc)? ……. 1= Yes 0= No

F.2. Do you receive these market information prior to sale? ……. 1= Yes 0= No

F.3. what are your sources of information

Sources	Type of information (provided)						
	Type	Prices	Date for sale	Buyer	Market demand	Market opportunities	Others (specify)
Buyer							
Extension officers							
Fellow traders							
Media							
Others (specify)							

F.4. how often do you receive the information? [___]

1.Daily	2.Weekly	3.Monthly	4.Annually	5.Others (specify)

F.5. how do you want information to be delivered? (*can select more than one means* [___] [____] [___]

1.Through media	2.Through cellphone	3.Through extension officer	4.Through trader groups	5. Other Specify

F.6. Do you perform price surveys, before selling ……1= Yes 0= No

F.7. How is price set during sales? [___] [____] [___]

1.I set the price	2.We negotiate	3.It is market driven	4.It is dictated by the buyer	5. Other specify

F.8. How important are the following statement as regards how you decide the sale price of your pesticides? (*state if very important, important or not important*)

	Very important	Important	Not important
a) It depends on the price of other local farmers b) It depends on the market we sell to c) It depends on the production costs d) It depends on the concentration of the market e) It depends on the transaction costs			

F.9. List what you consider as the major problems you face in marketing your products

1……

2……

3…….

4……

F.10. Suggest ways in which such problems can be addressed

1……

2……

3…….

4……

Appendix B: A snapshot of abstract of publication and manuscripts under review

Article

Agro-Dealers' Knowledge, Perception, and Willingness to Stock a Fungal-Based Biopesticide (ICIPE 20) for Management of *Tuta absoluta* in Kenya

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Abstract: In sub-Saharan Africa (SSA), tomato is an economically important crop that contributes not only to employment and income, but also food security. Like the rest of the SSA countries, tomato production in Kenya is constrained mainly by pests and diseases, key among them being the tomato leaf miner (*Tuta absoluta*), which can cause 80–100% losses if not properly managed. To suppress this pest, the International Centre of Insect Physiology and Ecology (ICIPE) and partners are introducing a fungal-based biopesticide (ICIPE 20) in an Integrated Pest Management (IPM) approach as a sustainable alternative to the sole use of synthetic pesticides. This study was carried out before the introduction of the biopesticide to assess its commercial feasibility among agro-dealers, using Kirinyaga County in Kenya where tomato production is predominant, as the study area. Specifically, the study assessed the knowledge, perception, and willingness to stock biopesticide using a market survey involving 141 agro-dealers. Successful commercialization of a new product is assumed to be the cumulative result of traders' and buyers' knowledge and perceptions about the product. The results show that a higher proportion of agro-dealers were willing to pay for ICIPE 20 at a higher price than Coragen®, the most popular insecticide for management of *T. absoluta*. The regression analysis revealed that individual characteristics such as age, education, access to social networks and credit facilities, and information are correlated to the agro-dealer's knowledge, perception, and willingness to stock the biopesticide. Training agro-dealers may promote greater uptake of the biopesticides through enhancing their knowledge and perception towards the effectiveness of the product.

Keywords: integrated pest management; *Tuta absoluta*; fungal-based biopesticide; willingness to stock; Kenya; Africa

check for updates

Citation: Ogutu, F.; Muriithi, B.W.; Mshenga, P.M.; Khamis, F.M.; Mohamed, S.A.; Ndlela, S. Agro-Dealers' Knowledge, Perception, and Willingness to Stock a Fungal-Based Biopesticide (ICIPE 20) for Management of *Tuta absoluta* in Kenya. *Agriculture* **2022**, *12*, 180. https://doi.org/10.3390/agriculture12020180

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Abstract

Trading in chemical pesticides has proved to be inefficient despite the fact that agro-dealers have invested much in them. Apart from their high cost of production, these chemicals pose a great threat to human health and the environment. Biological control measures such as biopesticides have therefore been recommended as a more sustainable alternative to synthetic chemicals. However, despite the efficiency of biopesticides, the agrodealers capacity to stock, and the costs and benefits associated with stocking these biopesticides have not been studied fully. To improve Agro-dealers income in the pesticides industry, ICIPE and partners are developing a fungal based biopesticide, (*Metarhizium anisopliae isolate)* that is aimed at improving the competitiveness of biopesticides value chain by improving the income of chain actors. This study is conducted *ex-ante* the release of the biopesticide (ICIPE 20). The study was conducted in two sub-counties namely Mwea East and Mwea West. The two were purposively selected based on the predominance in tomato production. A census of agro-dealers in the two sub counties was conducted by enumerating all the 141 agro-dealers obtained during a pre visit, with the help of sub-county agricultural officers. Primary data was obtained through observations, interviews and semi-structured questionnaires to assess the Agro-dealers' capacity to stock this biopesticide and the potential costs and benefits associated with stocking biopesticides among agrodealers in Kirinyaga County. The results show that a ratio of the sum of the biopesticides discounted benefits to the sum of the discounted costs generated 1.41, which is a ratio greater than 1 hence justifies the relevance and profitability potential of investing in the fungal based biopesticide. The net present value on the other hand was found to be positive (3528.22) thus reflecting the opportunity cost of funds invested. the fungal based biopesticide therefore offers the prospect of monetary benefits to agrodealers.

Keywords: Agrodealers; Fungal biopesticide; Capacity to stock; Cost and benefits; Kenya

Appendix C: Research permit

Our Ref: icipe_NACOSTI_Affiliation_DM503_01_2021

Francis Omondi Ogutu
Ogutufrancis45@gmail.com
254706171982

21/01/2021

Dear Francis Omondi Ogutu

SUBJECT: RESEARCH AFFILIATION

I am pleased to inform you that your application for Research Affiliation with the International Centre of Insect Physiology and Ecology (*icipe*) to conduct research on a project titled: Assessment of the feasibility of stocking a fungal based biopesticide by Agrodealers in Kirinyaga County, is hereby approved for a period of one (1) year with effect from 21 January 2021 to 20 January 2022.