EFFECTS OF GROSS MARGIN, FARMER PERCEPTION AND SOCIO ECONOMIC CHARACTERISTICS ON CHOICE OF *Tuta absoluta* MANAGEMENT METHODS IN TOMATO PRODUCTION IN MWEA, KIRINYAGA COUNTY

POLINE WAWIRA MWANIKI

A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Award of the Degree of Masters of Science in Agricultural Economics of Chuka University

CHUKA UNIVERSITY

SEPTEMBER, 2022

DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented for an award of a diploma or conferment of a degree in this or any other University.

Signature……MPA……………………… Date ..05-09-2022…………………………………

Mwaniki Poline Wawira
NM25/51128/21

Recommendation

This thesis has been examined, passed and submitted with our approval as University supervisors.

Signature………………………… Date 05/09/2022……………………………………

Prof. Geofrey Kingori Gathungu, Ph.D
Chuka University

Signature………………………… Date ..05/09/2022……………………………………

Dr. Martin Kagiki Njogu, Ph.D
Chuka University

COPYRIGHT

DEDICATION

This thesis is dedicated to my late Mother, Sicily Muthoni and my loving guardians Mr and Mrs Humphrey Wachira.

ACKNOWLEDGEMENTS

To be begin with, I would want to convey my thankfulness to God for enabling me to partake and finish this thesis. Prof. Geofrey Kingori Gathungu and Dr. Martin Kagiki Njogu, my supervisors, have been extremely helpful and supportive throughout the process of completing this thesis. I owe them an outstanding debt of gratitude for their unwavering support, patience, inspiration, and advice during the course of my education.

I would like to show my appreciation to the personnel of the Departments of Agricultural Economics, Agribusiness Management, and Agricultural Extension and Education for continued guidance and assistance during my study. Mr. Dave Ireri deserves special recognition for his bright ideas, and assistance throughout this research. Finally, I want to offer my most tremendous appreciation toward my brother and cousins, and peers for their unwavering care, counsel, psychological advice, and devotions, and who have shown their constant love and support.

ABSTRACT

One of the major concern of tomato farmers globally is the effect of Tomato leaf miner (*Tuta absoluta*) (Lepidoptera: Gelechiidae) an invasive insect pest which continue to affect tomato production. However, in Kenya, there is scarce information on the effect of tomato farmers' gross margin, perception and socio-economic characteristics on management methods of *T. absoluta* in Mwea, Kirinyaga County. The broad objective of this study was to determine the contribution of tomato farmers' gross margin, perception and socio-economic characteristics to the choice of management of *T. absoluta* in Mwea, Kirinyaga County. The study employed the adoption and diffusion of innovation decision and utility expected theory. The target population was 2300 open field and 20 green-house tomato farmers in Mwea. Descriptive research design was used in the study and multistage sampling procedure was used to get a sample of 303 respondents; 283 tomato small scale farmers and 20 green house farmers. Through a survey, tomato farmers were randomly interviewed using semi structured questionnaires. Primary data on tomato sales, revenue, variable costs, perception on most efficient method of managing *T. absoluta* and tomato farmers' socio-economic characteristics was collected. Socio demographic data and crop protection data was analyzed using descriptive statistics using SPSS version 26 and econometric analysis was done using Stata version 17. The average gross margin for the respondent per kilogram in one acre was at an average KES 11.44 with a minimum of KES 0.92 and a maximum of KES 132 and multiple regression model was employed to analyze the influence of tomato small scale farmers gross margin on choice of management method and crop rotation was significant at (*P*-value=5%) and had a positive relationship with the tomato small scale farmers gross margin. Weeding was significant at (*P*-value=5%) with a negative relationship with the small scale tomato farmers gross margin. Principal component analysis was used to estimate farmers' perception and respondents' aspects on knowledge, effectiveness of control, awareness, technicality on use and cheap had strong factor loading on component 2. Some of the respondents perceived that hired employee health, knowledge and complete control aspects had a strong factor loading on component 4. Technical, environment effect and cheap had strong factor loading on component 5. The multivariate probit model estimates showed that gender, education, age, land size, household income and extension significantly affected farmers' choice of pest control methods in the management of *T. absoluta*. The negative coefficients showed that an increase in either one of socio-economic factors will help increase tomato yields which are reduced by *T.absoluta*. The study encourages tomato small scale farmers to use other pest management methods such as use of crop rotation and weeding so as not to rely on use of chemical pesticides alone to control *T. absoluta*. Tomato small scale farmers should join tomato farmers group and organizations whereby they can be trained more on tomato pest management practices. National and County policymakers should adopt policies to encourage the use of integrated pest management methods to avoid use of excess chemical pesticides in tomato production.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ANOVA:	Analysis of Variance
CIA:	Central Intelligence Agency
FAO:	Food and Agriculture Organization
GM:	Gross Margin
ICIPE:	International Centre of Insect Physiology and Ecology
IPM:	Integrated Pest management
KALRO:	Agriculture and Livestock Research Organization
KEPHIS:	Kenya Plant Health Inspectorate Services
KPHC:	Kenya Population and Housing Census
MVP:	Multivariate Probit Model
PCA:	Principal Component Analysis
SPSS:	Statistical Package for Social sciences
STATA:	Statistics and Data Analysis tool

CHAPTER ONE
INTRODUCTION
1.1 Background to the Study

Tomato (*Solanum lycopersicum* L.) originated in the Andean region, of South America which includes Chile, Bolivia, Ecuador, Colombia, and Peru (Melomey *et al.,* 2019). The actual site of the origin is unknown but it has been hypothesized to be Peru and Mexico (Zhang *et al.,* 2021). The five largest tomato producers in the worldwide are China, India, the United States of America, Turkey, and Egypt. (Gilbertson *et al.,* 2017). In sub Saharan Africa, countries like Egypt and Kenya the tomato producers whereby tomato is done in open fields as well as greenhouses (Mwangi *et al.,* 2020; Mwenda *et al.,* 2022). Tomato is one of the most economically valued vegetable in the world, with a projected yearly production of 182 million tonnes value of US$ 87.9 billion (Rwomushana *et al.,* 2019). Tomato crop is used for commercial purposes and nutritional value, prevalent production, and as a model plant for research (Guan *et al.,* 2018; Melomey *et al.*, 2019). Tomato is rich in vitamins (A and C), minerals (iron, phosphorus, lycopene, beta-carotene), water, and has a moderate number of calories. They can be used fresh or processed into a range of products such as juice, sauce, and puree (Kumar *et al.,* 2020).

Tomato production plays an important role in Africa because it provides employment opportunities for women, who make up more than 60% of the labor force along the continent (Woldemichael *et al.,* 2017), important vegetable for nutrition value and also source of income for smallholder farmers. After potato, tomato is the second most valuable and produced vegetable in Kenya. Tomato is accounted for by 14% of total vegetable produced in Kenya and it is grown in green house technology and open fields. Kirinyaga, Kajiado, and Taita Taveta are Kenya's primary tomato-producing countie (Mwangi *et al.,* 2020). In Kirinyaga County, tomato production is done in Mwea East and West, Kirinyaga West and Central sub-Counties.

However, tomato production in the world is severely hampered by biotic and abiotic constraints such as diseases and insect pests (Zhou *et al.,* 2021). Higher numbers of pests affect tomato production economically and among them being *T. absoluta. T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *T. absoluta* is considered one of the most devastating pests affecting tomato and has invaded several tomato-producing regions worldwide, resulting in the globalization of commerce and trade (Colmenárez *et al.,* 2022). This migratory pest was originally recorded in Eastern Spain in late 2006 (Urbaneja *et al.,* 2007) and has since expanded across Europe, the Mid East, Parts of northern America, and Sub-Saharan Africa. *T. absoluta* was initially documented in Africa in 2008 and 2009 (Harbi *et al.,* 2012), then expanded to Egypt in 2010 (Moussa *et al.,* 2013), and lastly to Sudan and South Sudan in 2011. (Pfeiffer *et al.,* 2013; Brevault *et al.,* 2014). The pest arrived in Ethiopia and Kenya in 2012, most likely from Sudan or Yemen (Goftishu *et al.,* 2014). Tanzania, Uganda, and Kenya are currently home to this species (Tonnang *et al.,* 2015). *T. absoluta* had first been discovered in Kenya in 2014 as a result of past research carried out by research organizations such as the International Centre of Insect Physiology and Ecology (ICIPE), Kenya Agriculture and Livestock Research Organization (KALRO), National Plant Protection Organization (NPPO), and Kenya Plant Health Inspectorate Services (KEPHIS).

Tuta absoluta is a devastating agricultural pest that have global concern and has spread widely across continents resulting to substantial economic damages, in tomato cultivation and in Africa the problem is much severe to the extent that farmers are abandoning the crop (Zekeya *et al.,* 2022). *Tuta absoluta* has been reported whenever temperatures rise due to a variety of interconnected developments, which include accelerated level of overpopulation, industrialization, and demographic changes (Heeb *et al.,* 2019). Furthermore, lack of co-evolved natural predators helps describe why pest demographic trends are greater in freshly destroyed regions than in indigenous places where carnivorous predators are more widespread. This is especially true for migrant predatory insects like *T. absoluta* (Mansour *et al.,* 2018). Because of the steady, continual increased carbon dioxide atmospheric concentrations, *T.absoluta* move by colonizing suitable habitats (Sridhar *et al.,* 2020).

It is extremely hard to manage *T. absoluta* because of its varied hostage range. Some of the host plants include: pepper (*Capsicum annuum* L.), long-spined thorn apple (*Datura ferox* Kunth) (Tropea *et al.,* 2012), Devil's trumpet (*Datura stramonium*), tobacco (*Nicotiana tabacum* L.) (Vargas, 1970) and the American nightshade (*Solanum americanum* Miller) (Fernandez & Montage, 1990). Although *T.absoluta* prefer tomato over other solanaceous crops, it was encountered on beans (*Phaseolus vulgaris*) in Italy which acted as an alternative host (Eppo, 2009), *Lycium* sp. *Malva* sp. (Caponero, 2009). *T. absoluta* also has high reproduction potential with a complex life cycle that involves both sexual and asexual (Parthenogenetical) reproduction leading to very rapid developmental rates at optimum temperatures (Lanzoni *et al*., 2002; Cocco *et al*., 2012).

Tuta absoluta is a serious insect pest of tomato and other Solanaceae family crops that spreads through seedlings, diseased tomato fruit, and containers. It has become a significant concern for tomato growers (Roge, 2022). *Tuta absoluta* is a severe danger to tomato production globally, affecting yield and quality in open fields and greenhouses. The invasion of *Tuta absoluta* has harmed tomato harvests in Kenya, and tomato-growing areas such as Mwea keep reporting significant rates of the pest (Seplyarsky *et al.* 2010; Desneux *et al.* 2011; Konan *et al.* 2021). It can damage all plant sections, including the leaves, leaf veins, stems margins, the sepals, and green and white flowers (Estay, 2000). The pests lay eggs, hatches, and young larvae pierce the leaves, stems, and fruits of tomatoes as they feed and mature, forming mines and galleries that reduce tomato performance and productivity by affecting the plant's photosynthesis capabilities. If not managed, the galleries on tomato fruits expose them to severe infection by pathogens, resulting in fruit rot (Ekesi *et al.,* 2011) and yield losses of up to 100%. (Desneux *et al.,* 2010).

Farmers globally and in sub Saharan Africa use various choices of management methods to control *T. absoluta* which has been affecting tomato production (Desneux *et al*., 2021). These methods range from chemical, biological, cultural control methods and use IPM. However, the choice of each management method is affected by various factors and farmers keep into consideration on a number of aspects before choosing the method to use to control *T. absoluta.* For example, farmers consider the cost of management methods, the effect on the farmers, customers and the environmental effect among others (Mahmoud *et al.,* 2021; Senthoorraja *et al.,* 2022). Further, the availability of the choice, modern technology, farmers' socio-economic characteristics as well as their attitudes also affect the choice of management methods.

Kenya tomato farmers in tomato producing areas like Nakuru, Kajiado among other areas have been using a combination of control measures, such as physical, cultural, and biological approaches, as well as the use of registered pesticides to control *T. absoluta* (Ogutu *et al*., 2022). The use of chemical control can have a positive and negative impact on human well-being and the environment (Shahbaz *et al.,* 2017). Bio-pesticides that use beneficial microbial agents could reduce reliance on pesticides and chemical pesticides in management of *T. absoluta*. Integrated pest management systems and microbial agents may be able to meet pressing needs in the management of *T. absoluta* in tomato production. (Sayed & Behle 2017).

Tomato farmers in Mwea East and West, Kirinyaga County use biological pest control choices such as use of predators and natural enemies as some of the methods to reduce tomato destruction by *T. absoluta* (Yadav *et al.,* 2022). Konan *et al*. (2021) in their study described predatory mirids such as *Nesidiocoris tenuis* and *Macrolophus pygmae* as some of the natural enemies used to control *T. absoluta.* Farmers also rely on use of cultural control methods whereby they use methods such as crop rotation, use of improved seed varieties, irrigation. Further, the use of Intergrated pest management programs like use of selective host plants, use of selected insecticides and pesticides such as help in controlling *T. absoluta*.

Tuta absoluta characteristics like pesticide resistance, leaf-mining behaviour, and increased survival rate make it difficult to control using pesticides alone. The use of resistant varieties combined with insecticides has been discovered to be effective and it lessens the use of insecticides in management of *T. absoluta* in tomato (Nderitu *et al.,* 2019; Sawadogo *et al*., 2022). Farmers in Mwea East and Mwea West Sub-Counties have also been using parasites such as parasitic wasps to control *T. absoluta*. Small scale farmers have also been using cultural control methods such as transplanting, use of various tomato varieties such as curled leaves varieties and crop rotation as well. This study therefore pursued to look at some of the factors affecting the choice of each management methods used by tomato farmers in managing *T. absoluta* in Mwea East and West Sub-Counties, Kirinyaga County.

1.2 Statement of the Problem

Tuta absoluta is a challenge to both open fields and greenhouses tomato farmers and it affects the quality and yields of tomato production in Mwea, Kirinyaga County. *T. absoluta* causes up to 100% yield loss during serious outbreaks. Small scale tomato farmers have been using chemical, cultural and biological methods to control *T. absoluta*. Mechanical management, improved seeds varieties, and crop rotation are examples of different pest control strategies. Use of improved seeds varieties, cultural control and use of bio pesticide have been used to give a means of reducing the usage of agrochemicals. The specific choice of management methods used to control *T. absoluta* in Mwea include: crop rotation, scouting of pests, weeding, the use of certified seed, and the destruction of alternate hosts, among other things. The choice of *T. absoluta* management method may be affected by institutional, production, marketing, gross margin, farmers' perception and socio-economic characteristics. However, there exists little or no information on the effect of gross margin, farmers' perception and socio-economic characteristics on the choice of management of *T. absoluta* in Mwea.

1.3. Objectives of the Study

1.3.1 Broad Objective

The broad objective of this study was to analyze the influence of gross margin, farmers' perception and socio-economic characteristics on the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County.

1.3.2 Specific Objectives.

The study specific objectives comprised of:

i. To analyze the effect of gross margin on the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County.
ii. To determine the effect of farmers' perception on the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County.
iii. To determine the effect of farmers' socio-economic characteristics on the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County.

1.4 Research Questions

i. How does the farmers' gross margin affect the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County?
ii. How does the farmers' perception affect the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County?
iii. How does the farmers' socio-economic characteristics affect the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County?

1.5 Significance of the Study

This study contributes toward scholarly work on effect of farmers' gross margin, farmers' perception and farmer socio-economic characteristics affecting the choice of management methods of *T. absoluta* in tomato production in Mwea. Assessing tomato farmers' gross margin analysis, perception and farmer socio-economic characteristics on the choice of management of *T. absoluta* will also aid in understanding the underlying causes that may influence technical efficiency on management methods of *T. absoluta* in Mwea. The study findings provide necessary information useful to the farmers, agricultural stakeholders and policy makers to enhance food security in Kenya. The study findings will help in sustainable tomato production as a tactical approach for necessary steps to realize Vision 2030 for the agriculture industry, as well as goals of sustainable development for zero hunger, healthy life, and well-being of the citizens through income obtained from tomato production. This will have a significant impact on small-scale farmers in Mwea, Kirinyaga County.

1.6 Scope of the Study

This study concentrated on analysis of farmers' gross margin, farmers' perception and socio-economic characteristics affecting the choice of management of *T. absoluta* in tomato production among open field small scale farmers and all greenhouses. The study focused on small scale and all greenhouse tomato farmers particularly those who planted tomato in 2021-2022 cropping season. The study was done in Mwea East and West Sub-Counties, Kirinyaga County.

1.7 Limitations of the Study

This study was limited by tomato production seasonality and some farmers had abandoned tomato farming in greenhouses. The study was also limited by the information shared by farmers and some farmers may have exaggerated information or hidden some necessary information and in some cases respondents were not able to give correct records on prices and earnings due to lack of farm records.

1.8 Assumptions

This study anticipated that the respondents provided honest information freely and gave responses to the research tool. Farmers had not changed the technology used in tomato production.

1.9 Operational Definition of Terms

Choice of Management:	These includes ways that farmers may choose to manage *T. absoluta* in tomato and they include physical, biological, chemical, and cultural methods.
Farmers' Perception:	Farmers' opinions, awareness, understanding and attitude towards the choice of management of *T. absoluta* in tomato production.
Greenhouse Tomato Farmers:	Farmers who produce tomato in enclosed space.
Gross Margin:	Deduction of variable expenses from total revenue.
Management of *T. absoluta*:	A method of reducing *T. absoluta* populations to an acceptable level in tomato production.
Open Field Tomato Farmers:	Farmers who practice tomato production in open space.
Small scale Tomato Farmer:	Farmers who do their tomato farming in approximately less than one acre of own or hired land.
Socio-economic Factors:	Aspects that affect tomato farmers influencing the adoption of different pest control methods in the managing of *T. absoluta*. They include access to land, access to credit by farmers, farmers' farming experience, education. Group membership, the household income among others.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Tomato Production

The tomato production industry is among the best advanced, globalized, as well as innovative field globally as a result of the agronomical practices, processing, market range, and general productiveness organization (processed or fresh tomato consumption) differ by country (Lopez *et al.*, 2021). Tomato can be regarded as a rapid crop due to its fast growth, with a maturation period which ranges between (90-150) days. It is a vegetable that is not bothered by the length of the day. The optimal mean daily temperature for growth is 18^{o} to 25 ^{o}C, with night temperatures ranging from 10^{o} to 20 ^{o}C. Greater temperature fluctuations for day and night, on the other hand, have a negative impact on yield. Frost is a major threat to the crop. Temperatures above 25 ^{o}C, combined with high humidity and strong wind, which result in a lower yield. Night-time temperatures beyond 20 ^{o}C, combined with high humidity and little sunlight, result in excessive vegetative growth and poor fruit production (FAOSTAT, 2021). High humidity promotes the growth of pests and diseases, as well as the rotting of fruits. As a result, dry climates favour tomato production.

The world's leading tomato producers are Turkey, China, United States and European Union (FAOSTAT, 2019). Tomato production around the world has steadily increased since 2000, increasing by more than 54% until 2017 (FAO, 2017). The processed and fresh tomato that is produced globally is approximated to be 170 million tonnes. Currently, global annual tomato production has gradually decreased for the past few years and is now projected to be around 123 million tons, with a total production area of around 4.5 million ha. This decline is due to tomato pests and diseases and *T. absoluta* is a key pest contributing to decline in tomato farming.

China has been reported to be world's largest tomato producer, United States is second, followed by India, European Union as well as Turkey (Gatahi, 2020). According to a study conducted by (CIA, 2017) China, United States, India, European Union and Turkey produce roughly 70% of world tomato production. Mexico has been reported as the worldwide largest tomato exporter, seconded by United States, Spain and Netherlands (Central Intelligence Agency). Netherlands and Spain account for 25.1%

($2.1 billion) 19% ($1.6 billion) and 12.6 % ($1.1 billion) of the world's total tomato exports totaled, respectively (CIA, 2017).

According to FAO (2018) in Sub-Saharan Africa, Kenya has been reported as the foremost tomato producer, and it produces an approximate of 410,033 tons per year but the yield would be more if some of the pests such as *T. absoluta* could be reduced. Farmers produce in large scale, small scale and medium scale in open fields and green houses. Some of the tomato leading areas include Kirinyaga, Kajiado, Makueni and Nakuru counties among others. According to previous research, for instance Zhou *et al*. (2021), tomato farming is severely hampered by diseases and insect infestations which are as a result of abiotic and abiotic stresses limitations. Table 1 shows tomato production trends globally from the year 2016- 2020 while Table 2 show the tomato production trends in Africa from 2016-2020.

Table 1: Tomato production trends in the world from 2016-2020

Year	Tomato yield (tons)	Size of land(ha)	Output in tons per/ha
2016	177382876	4854457	365402
2017	178024027	4876142	365092
2018	180231376	5004555	360135
2019	183014805	4999181	366090
2020	186821216	5051983	369798

FAOSTAT (2022)

Table 2: Tomato production trends in Africa from 2016-2020

Year	Tomato yield (tons)	Size of land(ha)	Output in tons per/ha
2016	19943527	1329580	149999
2017	19912703	1397417	142496
2018	20856566	1574434	132470
2019	21825390	1569862	139027
2020	22228893	1577885	140878

FAOSTAT (2022)

Advanced occurrences of insect pests, mainly migratory pests, are reported each time temperatures rise due to a variety of interconnected developments, including greater levels of increasing population, industrialization, and mobility (Heeb *et al.,* 2019). Production, on either hand, had declined significantly due to several barriers, including; biological, high temperature, unpredictable rain, bad soils and organisms (Ochilo *et al.,* 2019). Notable biotic factors such as arthropod pests, fungal,viral and bacterial diseases have a high economic value on tomato production (Gilbertson *et al.,* 2017). Table 3 shows tomato production trends in Kenya from 2016-2020.

Table 3: Tomato production trends in Kenya from 2016-2020

Year	Tomato yield (tons)	Size of land (ha)	Output in tons per/ha
2016	410033	1329580	410033
2017	507142	1397417	507142
2018	599458	1574434	599458
2019	567941	1569862	567941
2020	1046181	1577885	1046181

FAOSTAT (2022)

The IPM strategies ranging from combining resistant crops, biological control methods and selective insecticides have been used in various parts of Kenya including Mwea to control *T. absoluta*. Tomato producers have effectively adopted associated assistance to developing countries like the distribution of sticky pheromone traps, the availability of biological agents and the presentation of professional assistance by specialists. These pest control methods offer a path forward to reduce the use of chemicals, resulting in enhancing people health and nutrition and environmental preservation the natural world despite the government's efforts as well as non-governmental organizations (Nderitu *et al.,* 2020). Combination of these control methods have been reported as being operative in management of *T. absoluta* but their effect on tomato yield is unknown.

The pest control methods used by farmers, for example insecticides, biological and cultural control methods help to manage pest damage by the most egregious pests (Radcliffe, 2021). Further, Despotović *et al*. (2019) described integrated pest management as an approach that promotes natural pest population control by employing suitable strategies such as the enhancement of natural enemies, the introduction of pest-resistant crops as well as through the use of insecticides appropriately. Adopting ecologically friendly pest control approaches has been portrayed as a binary decision between adopting or rejecting alternate pest management solutions (Kinuthia *et al.,* 2019). Particular approaches were combined earlier before analyzing the elements impacting the uptake choice, which provided significant insights into the drivers of crop management method adoption (Catherine *et al.,* 2019).

In the case of pest outbreaks in crop production, synthetic pesticides can be helpful. However, a study on synthetic pesticides by Torres & Bueno (2018) found that wide ranging insecticides are often hazardous to both useful creatures and the ecosystem. Rather than elimination, farmers should employ pesticides to lower insect pest infestations to a level that does not cause economic impact (Wangari *et al.,* 2020; Van den Berg *et al.,* 2022). Through greater interaction of resistant crop varieties and insecticides, it has been proven to control the pest effectively as compared to resistance insecticides caused by uneven crop parts cover, unbalanced micronutrients, and dangerous substances which interferes with the insect's survival and prosperity as well as consumption while boosting insecticide performance.

Chemical pesticides have negative impacts to humans, non-target animals and they are harmful on the environment (Abdel-Raheem *et al.*, 2015). Combining pest management strategies that reduce pesticide use while conserving natural enemies is critical for an environmental sustainability. Increasing reliance on pesticides in controlling *T. absoluta* has resulted in pesticide resistance which complicate the management. From this, alternative measures must be implemented in this regard to moderate the impacts of this (Wangari *et al.,* 2020). The use of resistant host plants together with insecticides has been reported to decrease insecticides usage while improving insecticide usefulness through improved coverage of plant parts, lack of nutrition, and toxic substance obstruct the insect's growth and development (Sosa *et al.,* 2019).

Combining predators with selective insecticides provides the best control methods and together with IPM programs, it has led to decrease of *T. absoluta*, less use of insecticides and fewer negative effects on human health (Heuvelink, 2018). Past studies for instance Bueno *et al.* (2017) shows that chemicals are supposed to overpower pests to a required economic level, and thus product documentation is required to use products that are not harmful to beneficial organisms. Various strategies are underway to reduce insecticide usage in tomato farms and these strategies range from cultural control strategies which vary from use of resistant varieties, crop rotation, early planting, intercropping, spacing and use of improved seeds varieties and environmental plant material environmental destruction of infested plant material (Zekeya *et al.,* 2017; Abbes *et al.,* 2012).

According to Miranda *et al.,* 2005; Arnó *et al.,* 2009 study, use of IPM strategy is effective to control *T. absoluta*. Parasites, predators (Chailleux *et al.,* 2013; Mollá *et al.,* 2014) and baits (Michereff *et al.,* 2000; Mollá *et al.,* 2011) are examples of physical and biological agents that can be used to build an efficient integrated pest management. As stated by Abbes *et al.,* the routine of pheromone traps in conjunction by means of entomophagous fungi and bacteria is prevalent in IPM projects (2012). In America and Europe, parasitoids and predators have been used in IPM programmes and are commercially available (Abes *et al.,* 2014; Al-Jboory *et al.,* 2012; Cely *et al.,* 2010; Zappala *et al.,* 2013).

Tomato production is affected by various challenges and some of these challenges include cost of production, pests and diseases, abuse of chemicals as well as irregular production systems (Osei *et al.,* 2022). Some of the problems tomato farmers face in tomato production include pests and diseases. The pests range from aphids, cutworms, stink worms , tomato pests, cutworms, tomato hornworms, whiteflies, slugs, flea beetles, spider mites, nematodes, moths, and *T. absoluta* (Reddy, 2018). Further various diseases include; end rots, cankers, early mildews, tomato blights and viruses. Gatahi (2020), emphasized on high costs of inputs, postharvest losses, marketing, pests and diseases as some of the major challenges affecting tomato production globally for both open field and greenhouses production. Developing countries which are the leading tomato producers are faced with high cost of production as a major challenge in producing tomato.

2.2 Effect of Tomato Farmers' Gross Margin on Choice of Management Methods

The overall returns are assessed by deduction of the costs used in the crop production and growing a crop from the overall income obtained from the crop and it is used to measure the profitability of a crop by smallholder farmers (Ndossi *et al.,* 2021). These costs range from those incurred during land preparation, purchase of farm inputs, crop protection, payment of labour, weeding, water management, harvesting, post-harvest practices and marketing. Overhead costs such as interest rates, insurance and living costs are not considered when assessing the gross margin of a farm because such costs need be incurred regardless of whether the crop has been produced (Ganiu, 2019). Gross margin is not accurate for measuring a farm profit but it is an important tool for farm accounting and approximating the expected profits and losses of a specific crop (Ankrah *et al.,* 2021).

Estimation of a whole farm profit requirements; overhead costs must be considered in addition to enterprise gross margins. Direct costs include the land preparation, planting materials, fertilizer, sprays, casual labor, contract harvesting, on farm post-harvest, processing and transport to the market (Ndossi *et al.,* 2021). The overhead costs include wages on permanent employees, lease payments, farm insurance, repairs to water supplies, taxation, administrative costs, depreciation of machinery and any other cost that is not direct to crop production.

2.3 Farmers' Perception on the Choice of Management Methods of *T. absoluta* in Tomato

Attitudes and perceptions of the farmers towards each choice of pest management practice adoption are affected by the demographical attributes and socio-status of the farmer and also the attributes they perceive each technology has. Farmers' understanding and attitudes toward adoption of technology or using the available technology portrays a key part in the decision making of the farmer (Maina *et al*., 2021). The farmers' awareness and being able to acquire information influences the adoption of technology and this affects the choices adopted by farmers.

According to Ochago (2018), farmers need knowledge to improve their skills on pest management strategies so as to select and use appropriate pest control methods. The skills gained influences the policies and perceptions of farmers when it comes to pest control interpreting data as well as the application. Indeed, recent evidence suggests that farmers' knowledge, attitudes, and practices, particularly in developing countries, influence their choice of pesticides over alternative methods (Damalas & Khan, 2016). Past studies shows that the concentrated use of insecticides in tomato farms appears to provide the best value crop at market sight and helps make returns for the farmers and the brokers (Asante *et al.,* 2013). Lack of information, negative perceptions and poor practices about insecticides are some of the key explanations why farmers depend on insecticides (Schreinemachers *et al.,* 2017).

Farmers' perceptions on various aspects such as food safety, cost, availability of pest control methods, ease of use and knowledge of various pest control methods are critical components of a long-term action plan for the control of invasive tomato *T. absoluta* (Materu *et al.,* 2016). Farmers around the world use a variety of methods such as chemical, biological, cultural and a combination of all methods which is integrated pest management (IPM) control methods to control *T. absoluta* in tomato. However, the primary mechanism to manage *T. absoluta* is the application of insecticides (Campos *et al.*, 2017; Zekeya *et al.*, 2017).

Farmers are conscious of the significant attributes of biological pesticides and use them with varying levels of contentment, this is according to a study performed by Moseh *et al.* (2008) in Italy, Germany, and Israel to examine farmers' attitudes and experiences about the use of bio-pesticides in strawberry farming. According to a study by Damalas & Koutsoubos (2017), in Europe, Greek agriculturalists' awareness of insecticides and perceptions about their danger mitigation was linked to protection. The Common Agricultural Policy (CAP) of the European Union (EU) encourages the long-term use of plant protection products through several mechanisms, including agro-environmental initiatives, subsidies and green direct payments not tied to producing.

The EU believes that an optimum insecticide policy need contain tax schemes based on ecological and well-being of the individuals as well as of standards and that these taxes must be classified based on toxic contents (Alexoaei *et al.,* 2022). Many farmers still regard bio-pesticides as undesirable because they are assessed based on their instantaneous effect on pests (Anani *et al.,* 2020). Despite this, bio-pesticides account for only 5% of the total plant protection market. However, consumers prefer healthier food products, and the awareness of environmental impacts makes it an ecofriendly solution for more sustainable agriculture. It is evidence for the estimation of an annual bio-pesticide growth rate is at 8.64 % (Abbey *et al.,* 2020).

Chepchirchir *et al.* (2021) study reported that farmers' perception in choosing pest control methods depends on the health effects, profitability and environmental aspects. Some farmers perceive that non-pesticides are better off as compared to use of chemicals since they are concerned with short term and long effects of the chemicals on farmers' health, animals and the environment. Farmers' pest management methods are also influenced by factors such as risks of each management method as well as the marketability of the products produced. Farmers also face obstacles on their intuition, knowledge and experience as they choose each of the pest management methods (Rincon *et al.,* 2021).

2.4 Effect of Farmers' Socio-economic Characteristics Affecting the Choice of Management of *T. absoluta* in Tomato

Farmers' social economic characteristics such as age, gender, education level and training, group membership, land and loans accessibility, farmers' experience and income among others affect the choice of management of pests (Balasha, 2019; Kinuthia *et al.,* 2019; Cocco *et al.*, 2021). Various socio-economic farmer characteristics affect the farmers' choice of *T. absoluta* management. Some of these factors include; education level, training and extensional services for the farmer, land accessibility, farmers' group membership, household income, farmers' experience and expertise. According to Mwangi *et al*. (2015) the adoption of these pest control methods in the management of *T. absoluta* is hindered by farmers' experience and credit access.

2.4.1 Farmers' Education Level and Training

Vegetable crops are regarded as commercially significant since they belong to the category of intensive agriculture, which allows for a bigger profit margin than traditional crops. Agricultural extension can help enhance crop productiveness (Mohamed *et al.,* 2021). Farmers' desire to embrace environmentally friendly processes has been proven to be significantly affected by the usage of additional expertise or extension services (Ulhaq *et al.,* 2022). Farmers have their own methods, skills, and ideas for solving a problem in even the most practical way possible. Technological advances have a significant role in plant productivity. Agricultural education and extension services should be regarded as the primary technological dissemination instrument, with the success of many emerging technology adoption and implementation reliant on this function (Mohammadrezaei & Hayati, 2015).

Farmers' empowerment through formal education would help them understand the need for a shift to new technology as well as the impact of chemicals used to control pests on the environment, farm, and farmer (Onyimbo *et al.*, 2021). Extension workers play an important role in providing farmers with the needed information on agriculture and consulting services, and their roles are critical when they encounter new issues, such as insect outbreaks (Tambo *et al.,* 2019). Due to constraints such as a high number of farmers as compared to trainers, they may be constrained in their ability to give timely and useful data from large numbers of farmers.

There is a significant effect between farmer education and environment conservative conduct amongst farmers (Despotović *et al.*, 2019). Education has been reported as one of the key factors affecting farmers' willingness to accept the uncertainties regarding new technologies and innovative sources of information (Mittal & Mehar, 2016). According to empirical evidence, community knowledge can be just as operational as formal extension lead in disseminating agricultural information (Shikuku, 2019). Advisors not only provide information, but also assist farmers receive education on the adoption of agricultural environment protection, rendering them increasingly accessible and accepted (Lastra-Bravo *et al.,* 2015). It has been hypothesized that trainees' subjective norms (normative beliefs) are closely related to their level of education and age, and that these variables are a good proxy for trainees' ability to evaluate other people's suggestions and willingness to perform actions suggested by others (Kazeem *et al.,* 2017).

2.4.2 Group Membership

Small-scale farmers in underdeveloped nations have low acceptance and adoption rates and limited accessibility to agricultural commodities and marketplaces (Sinyolo & Mudhara, 2018). This member status is available to any agricultural organisation, including savings clubs, marketing organizations, and marketing groups/collection centres (Knaresboro *et al.,* 2019). Past studies have observed that belonging to an organization may have a good or detrimental effect on IPM adoption since it allows for debates concerning chemical pesticides and pest management approaches. By acknowledging farmers' accomplishments, caring for their health, and serving as an ultimate key criterion for farmers' supportive resources, organizations’ establish a crucial connection for farmers (Bisht *et al.*, 2020).

2.4.3 Access to Agricultural Credit

Agriculture loans, along with modern technology, is a necessary input for increased farm productivity and it can be obtained with minimal savings not only by small scale farmers but also by large scale farmers (Saqib *et al.,* 2018). Farmers' accessibility to official sources of loans differs significantly from their access to informal sources, however large-scale farmers have better access to formal credit than small-scale farmers because the former have assets and a better credit history (Sekyi *et al.,* 2019; Balana & Oyeyemi, 2022). Small-scale farmers have limited access to credit from both formal and informal sources, including friends, fellow farmers, landlords and relatives. Chandio *et al.* (2020) study reported that limited access to credit by farmers hinder them from adopting modern and efficient technologies in agricultural production. The effects of socio-economic factors such family size, age, farmer's experience, size of land and income on agricultural credit access have not been well documented in the literature as described by Linh *et al.* (2019).

2.4.4 Access to Land

Small-scale farms are an essential element in farming, and they play an important role in providing other organic and common benefits, such as the sustainable agriculture of agricultural biodiversity and the improvement of indigenous nutrition safety (Grasswitz, 2019). Some of the small-scale farmers do not own land and they rely on leased land and this may hinder them in adopting some of the pest control strategies because they do not own land permanently (Gao *et al.,* 2018). Farm size is also frequently tested as a factor influencing the adoption of sustainable practices in the management of pest in crops and the general influence of farm size in adoption of pest management practices is not clearly documented (Despotović *et al.,* 2019). The existing literature shows that there is a significant effect on the size of the land and application of pesticides in pest control. Big farms yield higher returns that may also motivate producers to embrace sustainable farming techniques (Liu & Brouwer, 2022).

2.4.5 Farmers' Experience and Expertise

Farmers are focused on previous experiences, which make it challenging to embrace new knowledge because of the focus on the continuation and gradual expansion (Futemma *et al.,* 2020). There is no evidence that the farming experience stimulates or hinders the adoption of agricultural technologies (Yang *et al.,* 2022). Farmers are facing situations that are not only uncertain (weather, rainfall) but also interdependent (weather directly impacts insect populations) and localized (neighbors' choices on how to resolve insect pests may impact their predominance). Specific information and expert knowledge, often based on experience instead of scientific results, are incredibly significant in farming, where farmers are facing uncertain situations such as weather but also mutually dependent (weather affects insect populations) and localized (neighbors' decisions on whether and how to address insect (Noy & Jabbour, 2020). However, policymakers, especially those pushing agricultural technology use and involvement of field farmer schools, want precise responses (Mcfadden *et al.,* 2022).

Experience is dependent on adoption innovative farming techniques; additionally, if researchers must continue to developing superior technologies, these technologies that are effective and efficient (Ainembabazi & Mugisha, 2014). The experience of the farmer can negatively or positively affect the adoption of different pest control methods depending on various factors such as size of land, previous methods used, extent of extension services offered among other factors (Kwadzo & Quayson, 2021). It has been discovered that older farmers have more experience with farming processes due to improvement in technologies and also capital formation. Elderly producers, on the other hand, are more risk averse and more vulnerable as physical energy declines. As a result, the impact of age on technology adoption is uncertain (Kassie *et al.,* 2015).

2.4.6 Farmers' Age and Gender

Age and gender have an important influence on the choice of management of pests. The influence can either be negative or positive depending on each pest management practices (Knaresboro, 2019). Further, Abunyuwah *et al.* (2019) study found that usage of pesticides depends on the farmers' age and as farmers grow old, there is a reduction in usage of pesticides. Younger farmers misuse pesticides as they perceive more pesticides use will lead to increased productivity. Young farmers are interested in high yields and they presume that use of excess or continued use of pesticides increases the yields.

Past studies shows that gender plays a significant role on the choice of pest management methods. Women put into consideration the households' health as well as farm workers by trying to avoid risks when choosing pest control methods (Misango *et al.,* 2022). Men on the other hand are influenced by economic factors such as increased productivity for more income and reduced cost of pest control practices and social factors such as being recognized as an innovative farmer and producing safe products for the consumers (Constantine *et al.*, 2020).

2.4.7 Availability of Income

Income plays an important role especially when farmers are faced with different choices of pest management in their farms for increased farm productivity. Zheng *et al*. (2019) study shows that farmers use different criteria when allocating income to their farm activities. Accessibility and financial criteria is used by farmers who have off-farm income and other incomes. Abdallah *et al.* (2021) study describes how viable agronomic practices affect the on-farm revenue and nutrition safety. Some of the sustainable practices include intercropping, zero tillage as well as use of manure and they seem to affect farm production in terms of food security and income as compared to dis-adoption of these practices.

2.5 Theoretical Framework

The study adopted a two stage theory; decision adoption and diffusion of innovation theory and expected utility theory. Rodgers (1962) study on technology adoption used adoption and diffusion of innovation theory. According to Ochieng *et al*. (2021), repeated learning and training is required between the farmers and other stakeholders involved in dissemination of information on adoption of an available technology. Globally biotechnological technologies have spread to varied degrees throughout social systems like agricultural communities, academics, independent farmers, and internet society (Wyckhuys *et al.,* 2018). Long-term agricultural growth necessitates the adoption of sustainable agricultural practices at the farm, village, and regional levels (Sartipi, 2020). Researchers, policymakers, extension services, and the private sector must collaborate to achieve sustainable development and the adoption of these sustainable agricultural practices while preserving the long-term ecological and biological ecosystems.

According to Rodgers (1962); Llewellyn & Brown (2020), adoption and diffusion framework is based on the relative advantage and the process of learning about an innovation. Conceptual framework of diffusion of a technology is composed of five sequential stages through which individual’s passes when exposed to an innovation. These stages include knowledge, persuasion, decision, implementation and confirmation. Adoption of a technology is based on their effectiveness and comparative advantage and these aspects include four major elements of technology adoption. Llewellyn & Brown (2020) in their studies described these elements as follows: General intelligence qualities of the invention, demographic features that affect individual's opportunity to comprehend well about invention, comparative benefit of employing the invention, and comparative benefit of the advancements.

The expected utility theory is often employed investigate the choice mechanisms of farmers on adoption of technologies (Babcock & Hennessey, 1996; Maina *et al.*, 2021). Farmers will adopt a technology if the utility of the technology is perceived to be more than non- adoption. The adoption decision is a binary choice that is influenced by observed farmers characteristics, attitudes and risks associated with associated with a technology, (z_i) and the error term $(^{\varepsilon}{}_{i})$.

$$I^*{}_i = \beta z_{i+\varepsilon_i}, I_i = 1 \; if \; I^* > \ldots\ldots (1)$$

where; I_i is the binary choice variable that equals 1 if the i^{th} household adopt a pest control method and 0 otherwise. β shows a vector of parameters to be estimated. z describes a vector of observable household characteristics and intrinsic factors such as farmers' perceptions and ε_i is the error term.

2.6 Conceptual Framework

The choice of pest management is affected by various factors and some of these factors include the gross margin factors, farmer's perceptions and socio-economic factors. These factors may directly or indirectly affect the farmers' choice of pest management practice that will at least lead to reduction of *T. absoluta* (Nakhungu *et al.,* 2021). Tomato production gross margin involves costs and expenses used so as to the produce quality and high yields. Some of the direct costs used tomato production include the following: land preparation, planting materials (tomato seeds and seedlings), fuel, fertilizers, pesticides (sprays), casual labour, harvesting, post-harvest on farm, transportation to the market and other expenses directly involved in tomato production. To determine the gross margin in tomato production the variable costs are deducted from total returns from each choice of pest management.

Various socio economic factors that affect the choice of *T. absoluta* management include age, gender, income and household size, access to credit, education level, farm produce and scale of operation. Past studies for instance Boulestreau *et al.* (2020) shows that socio-economic characteristics contribute to choice of pest management practice adopted by the farmers. Farmers' perceptions describe the opinions, awareness and attitudes of the farmers towards various pest management practices as described by Sadique (2020). Some of the external factors that affect the choice of management of *T. absoluta* include government agricultural policies such as input policies including fertilizers, planting materials among others and climatic conditions. The tomato essential provisions are entrenched inside the agriculture act that govern this segment and Agricultural Pests Act 36 (CAP.346) and Ministry of Agriculture, Livestock and Fisheries (2021). Figure 1 shows how all these factors affect the choice of *T. absoluta* management practices adopted by farmers so as to reduce it in tomato production.

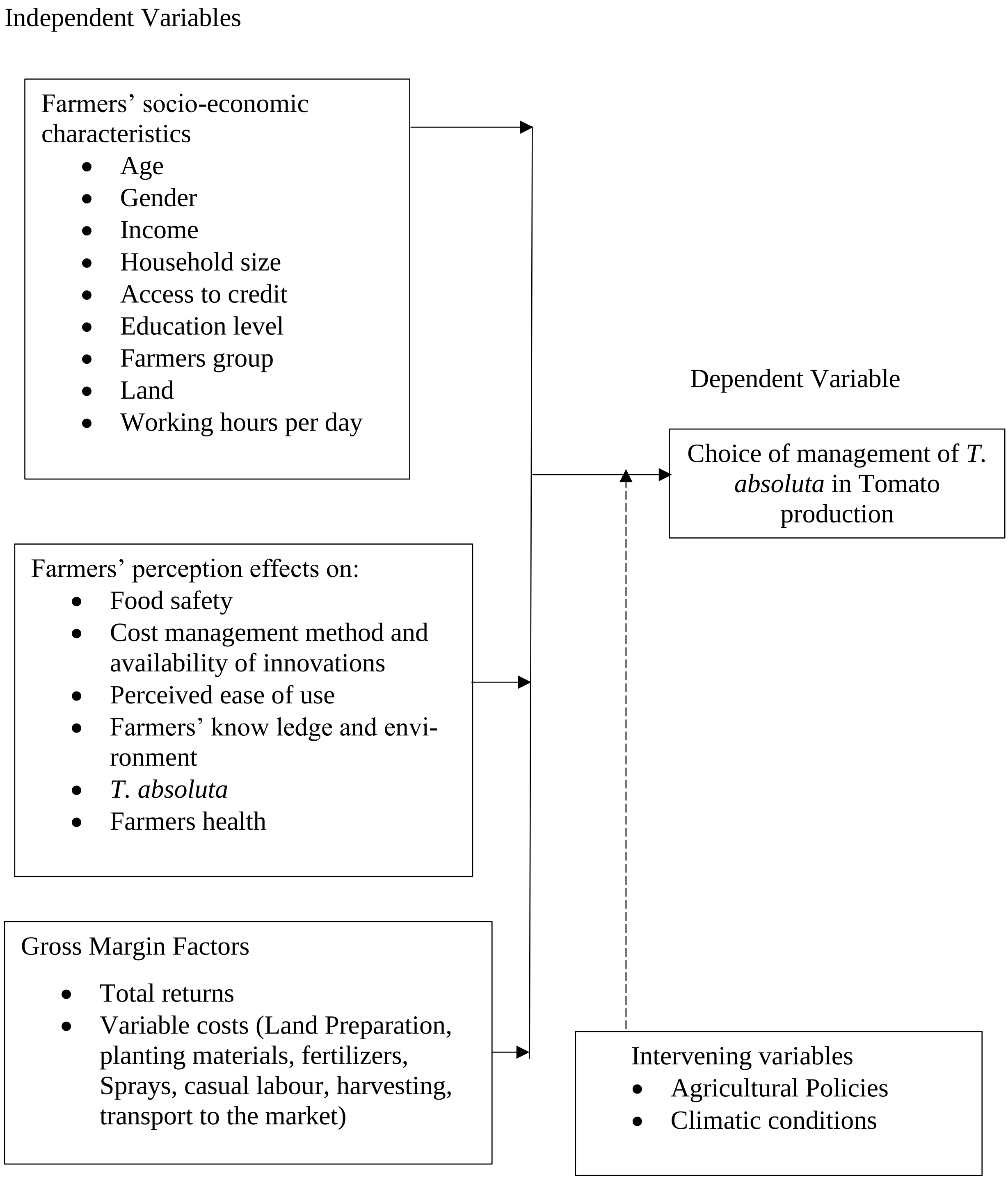


Figure 1: Conceptual Framework.

Source: Author's conceptualization.

CHAPTER THREE

METHODOLOGY

3.1 The Study Area

Kirinyaga County have 5 Sub-Counties which include; Kirinyaga Central, Kirinyaga West, Kirinyaga East, Mwea East and West as showed in (Figure 2). Tomato production is done in all the 5 sub-Counties but most tomato farmers are in Mwea East and West Sub-Counties.

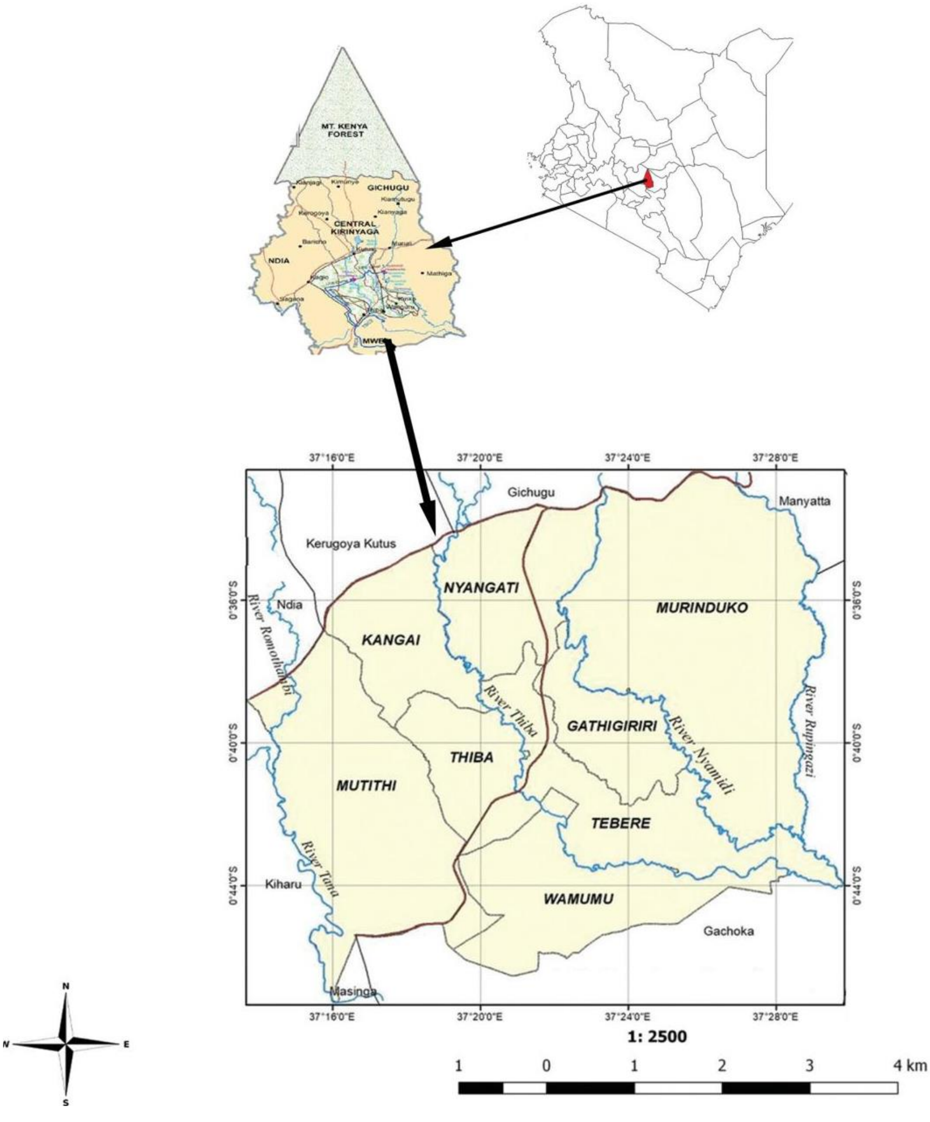


Figure 2: Map of Mwea from Map of Kenya showing Mwea East and Mwea West Sub-Counties.
Source: Geocurrent (2019)

Mwea has 2 Sub-Counties namely Mwea East and West and a population of 237,382 (KHPC, 2019). Mwea is located about 100 km of Nairobi at an elevation of 1160 m above sea level. Mwea has 8 wards namely Murinduko, Tebere, Gathigiriri and

Nyangati, Kangai, Mutithi, Thiba and Wamumu and tomato production is done in all them.

The area receive rain for 2 seasons; whereby long rains are experienced in (March-May), whereas short rains occur in (October- November). Thiba and Nyamidi rivers provide water for irrigation throughout the year (Narita *et al.,* 2020). Mwea receives an average annual rainfall amount about 930 mm and the temperatures lie between (14 °C-31 °C) with a humidity ranging from 55% to 70% (Akoko *et al.,* 2020). The soils are deeply, medium textured loamy soils which are productive and well drained with a pH between 6.0 and 7.0 which favours tomato production. Some of the agricultural practices done in the area include crop and vegetable production as well as livestock and fisheries farming (Nakhungu *et al.,* 2021). The region climatic data favors vegetable production especially tomato production hence it is a suitable area for the survey.

3.2 Research Design

The survey used a descriptive cross-sectional design as described by Sharifzadeh *et al*. (2018) with minor modification, to understand the gross margin, farmers' perception and farmer socio-economic characteristics on choice of management of *T. absoluta* among small scale tomato farmers in Mwea. Cross sectional descriptive research design aims at accurate and systematic description of a population without manipulation of the variables through observation and measurement (Pandey & Pandey, 2021).

3.3 Target population

The study concentrated on open field small scale tomato farmers in Mwea. According to Kirinyaga County Ministry of Agriculture, crop department, there are approximately 1200 tomato farmers in Mwea West Sub County and 1100 in Mwea East Sub County. In both Sub-Counties, 70% of the farmers are small scale tomato farmers, 25% account for medium scale tomato farmers and 5% include the large scale farmers. There were approximately 20 greenhouses in Mwea region before the farmers ceased production of tomato in greenhouses (Kirinyaga County Ministry of Agriculture, 2022). However, during the study, it was observed that no farmer was growing tomato in the greenhouse.

3.4 Sample Determination and Sample Size

The sample size was computed using a formula as described by Krejce and Morgan (1970) as shown below:

$$n = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)} = \frac{3.841\times2300\times0.7(1-0.7)}{0.05^2(2300-1)+3.841\times0.7(1-0.7)} = 283 \text{ respondents} \ldots\ldots\ldots.(2)$$

where:

n = Required sample size

X^2 =The table value of chi-squire

N = Population size

P = Population proportion (assumed to be 0.70) 70% of the total tomato farmers

d^2 =The degree of freedom (0.05)

Greenhouse tomato farmer's population was to be 20 farmers in Mwea and all the farmers were to be sampled because they were less than 30 hence a total sample size was to be 303 respondents.

3.5 Sampling Procedure

The survey employed a multistage sampling procedure. During first stage, Mwea East and West Sub-Counties were particularly selected because they are the leading tomato production areas in Kirinyaga County and they have reported *T. absoluta* as a challenge in tomato production. In a second stage a sampling frame was used to obtain the sample from Mwea East Sub-County (Murinduko, Gathigiriri, Nyangati and Tebere). Kangai, Mutithi, Thiba and Wamumu in Mwea West Sub-County was sampled. The third stage involved simple proportionate random sampling of tomato small scale farmers from the sample wards and the respondents were purposively selected. The Ministry of Agriculture, Livestock and Fisheries Development extension list of small scale tomato farmers in the designated wards were used whereby a sample of two hundred and eighty-three small scale tomato farmers in Mwea East and West Sub-Counties was selected.

$$\text{Sample size} = \frac{Target\ population}{Total\ popultion} \times \text{Sample size} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. (3)$$

Table 4: Sampling frame for small scale tomato farmers

Mwea East Sub-County (1100 tomato farmers)				Mwea West Sub-County (1200 tomato farmers)			
Ward	Target population	sample	Greenhouse (10)	ward	Target population	sample	Greenhouse (10)
Murinduko	275	34	3	Kangai	310	39	3
Gathigiriri	300	37	3	Mutithi	280	35	2
Nyangati	275	29	2	Thiba	320	40	3
Tebere	250	31	2	Wamumu	290	36	2
Total	1100	131	10		1200	150	10

Source: Kirinyaga County Ministry of Agriculture, Livestock and Fisheries Development Office

3.6 Research Tool

The research tool was semi-structured questionnaire (Appendix I) which was adopted to collect the data from the respondents. The tool had both open end and close end questions for taking the data during the survey. This enabled the respondents to give their answers freely towards the research tool.

3.7 Pilot Survey

A preliminary study was done in Buuri Sub-County, Meru County two weeks prior to the actual study because the area had similar climatic conditions as those of Mwea East and West Sub- counties which are favorable for tomato production. The pilot study helped in identifying some challenges in the questionnaire and to identify some of the ambiguous questions, phrasing, length and sequence of the questionnaire in order to adjust them. The pilot survey also helped in knowing respondents' reactions and range of answers towards the tool. The pilot study participants were 25-30 respondents and this is the minimum requirement for performing statistical study according to Mugenda & Mugenda, (2003).

3.7.1 Validity

The Validity of the questionnaire that is the face, content and concept validity was done by the assistance of academic supervisors and specialists from the field so as to check whether the questionnaire was legible, clear and comprehensive and whether the results represented the construct questions.

3.7.2 Reliability

The study Cronbach Alpha coefficient was α = 0.89 (Table 5) whereby 17 items were analyzed to test reliability of the questionnaire. Cronbach Alpha coefficient minimum of 0.7 was used as a reference to test for internal consistency reliability of the questionnaire or retain the items provided (Brown, 2002; Kapp et al., 2021). Mensah & Onyancha (2022) reported that if: $\alpha > 0.9$ - excellent, $\alpha > 0.8$ - good, $\alpha > 0.7$- acceptable, $\alpha = 0.6$ - questionable, $\alpha = 0.5$ =poor, and $\alpha < 0.5$ = unacceptable.

Table 5: Results of the Cronbach Alpha Coefficient

Average interitem covariance:	0.2961337
Number of items in the scale:	17
Scale reliability coefficient:	0.8926

3.8 Data Collection

The study was conducted in Kirinyaga County between March and April 2022. A semi structured questionnaire was administered to the farmers in a face to face interviews. During the survey primary data on tomato sales and total revenue, variable costs, perception on most efficient method of managing *T. absoluta* and tomato farmers' socio-economic characteristics affecting the choice of management of *T. absoluta* in tomato were collected using the structured questionnaire (Appendix I).

3.9 Data Analysis

Information obtained was categorized, tabulated and analysis was done using descriptive statistics by use of SPSS version 26 while econometric analysis using Stata version 17. Gross Margin with multiple regression model, principal component analysis and multivariate probit models were used to analyze data on gross margin, farmers' perceptions and socio-economic characteristics respectively.

3.9.1 To Analyze the Effect of Farmers' Gross Margin on the Choice of Management of *T. absoluta* in Tomato Production in Mwea, Kirinyaga County

Gross margin analysis tool was employed to determine the choice of farmers' management methods. Gross margin analysis tool was used for farm budgeting, planning and management (Rickards & McConnel, 1967; Ankarah *et al*. 2021). Gross margin model was used to estimate financial returns and it served as a simple proxy for profitability in production (Abu *et al.*, 2011). Gross margin model was used because of its simplicity and lack of data to compute profits for small-scale farms conditions. Gross Margin analysis tool have been widely used to assess the economic performance of smallholder agricultural production systems (Benu *et al.*, 2010).

Gross margin was calculated as the gross value of production less the variable costs directly attributing to generating the value of an individual enterprise. However, the gross margin did not take into account the fixed costs (Conradie & Landman, 2013). The gross margin model was stated as follows:

$$GM_{Tomato} = (TR_{Tomato} - TVC_{Tomato}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

where:

GM_{Tomato} =Gross margin (Tomato enterprise)

TR_{Tomato} =Total Revenue (From Tomato sales)

TVC_{Tomato} =Total Variable Costs (in tomato enterprise)

Total tomato variable costs included: land preparation, planting materials (tomato seeds and seedlings), fuel, fertilizers, pesticides (sprays), weeding, staking, casual labour, harvesting, post-harvest on farm, transportation to the market. Table 6 showed the gross margin variables.

Nkadimeng *et al*. (2021) study employed multiple regression for analysis of cattle farmers' gross margin. The multiple regression model was therefore used to analyze the effect of tomato gross margin on choice of management of *T. absoluta* whereby;

$$Y_i = \beta\theta + \beta 1X1 + \beta 2X2 + \beta 3X3 + \beta 4X4 + \ldots + \beta 18X18 + \mu \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \ldots.(5)$$

where;

Y_i = Gross margin, $\beta\theta$ = constant of the equation

β_i = Coefficients of independent variables

X_i = Independent variables

μ = error term or unexplained variations

Table 6: Gross margin variables

Variables	Description	Measurement	Proposed direction/ Output
Landprep	Land preparation	Man days	+ / -
nurseryprep	nurserybed preparation	Man days	+ / -
Plantmtrls	Planting materials	Grams	+ / -
Fuel	Fuel	Litres	+ / -
Fert	Fertilizers	Kilograms	+ / -
Pestcds	Pesticides	Litres	+ / -
hiredlabour	Casual labour	Wages per day	+ / -
Staking	Staking	Cost	+/-
Watering	Watering	Cost	+/ -
Cultural activities	Cultural activities example weding	Cost	+/ -
Harvesting	Harvseting	Cost	+/ -
Pest management practices	Pest management practices	Cost	+/ -

Source: Author description

The management choices (X1 to X18) represented: chemical pesticides, plant incorporated protectants (PIP), Intercropping, mulching, desuckering / pruning, uprooting and destruction of crop residue, fertilizer application, pheromone traps, predators, crop rotation, parasite, bio-insecticides, weeding, bio-nematicides, IPM techniques, staking and others.

3.9.2 To Determine the Effect of Farmer's Perception on the Choice of Management of *T. absoluta* in Tomato Production in Mwea, Kirinyaga County

The farmers' decision and perception on choice of management of *T. absoluta* was analyzed by using principal component analysis (PCA). Factor analysis was further used to reduce farmers' choices of management criteria in the pest control process to more manageable levels as described by Hair *et al.* (2013). Principal component analysis was applied using varimax rotation with a cutoff of 1 for eigenvalues and factor loading greater than 0.50. Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy test was employed to determine whether there are significant differences in the importance of each extracted factor related to farmer's perception on choice of management *T. absoluta* use criteria and to rank factors in the event of differences.

Perceptions can be given in binary responses whereby the perception can be described as explanatory variables with a relationship between a binary dependent variable and set of independent variables, whether binary or continuous (Petrescu-Mag *et al.*, 2019). The dichotomous dependent variable was calculated as follows for the survey, Y is a variable having two values, a decision to use a certain pest management practice or not to.

0= Decision not to adopt a certain pest management practice
1 = Decision to adopt a certain pest management practice.

Various opinions and practices of pest management methods such as cultural control methods, physical and mechanical control, biological and chemical control were estimated. Farmers' opinions and criteria used to select the choice of management of *T. absoluta* was ranked using a 5- point likert rating scale using factor analysis. These factors included; Performance and effectiveness, awareness and information criteria, technical and operation criteria, environmental criteria and financial accessibility criteria when selecting choice of pest management to control *T. absoluta.* Table 7 shows the variables that were used in analysis of farmers' perceptions on choice of *T. absoluta* management practices.

Table 7: Farmers' perception variables

Variables	Description	Measurement	Proposed direction/ Output
Farmerknowledge	Farmers' knowledge	Years	+ / -
Easeuse	Ease of use	1= Easy 2=Hard	+ / -
Foodsafety	Food safety		+ / -
Availabilitycontrol	Availability of control method	1= Yes 2=No	+ / -
Attitudpractices	Attitude and practices	Negative or positive	+ / -
Cost	Cost	Kenya shillings	+ / -

Source: Author description

3.9.3 To Determine the Effect of Farmers' Socio-economic Characteristics on the Choice of Management of *T. absoluta* in Tomato Production in Mwea, Kirinyaga County

Multivariate Probit Model (MVP) was used to analyze farmers' socio- economic characteristics. MVP was used for the study of binary responses which involved multiple choices (Chen *et al.,* 2018). MVP description was used to analyze how socio-economic farmer characteristics factors affecting the choice of management of *T. absoluta* among small scale tomato farmers. The empirical specification of the decision-making process over different pest control methods and socio economic factors affecting management of *T. absoluta* can be analyzed using multinomial or multivariate regression analysis (Greene, 2003).

One of the basic assumptions of multinomial models is the freedom of inappropriate options, which means that the error terms of the choice equivalences are jointly exclusive (Chen *et al.,* 2018). As a result, MVP model allowed for the possibility of up-to-date correlation of many variables that influence the dependent variables. MVP approximation has been used by past surveys to analyze factors that influence agricultural technology adoption. Being a member of a group is a binary variable that represents the primary decision maker's membership status (Mwaura, 2014). Table 8 shows socio-economic variables and their expected output:

Table 8: Farmers' socio-economic variables

Variables	Description	Measurement	Proposed Direction/ Output
Age	Age	Years	+ /−
Gender	Gender	Male=1, Female =0	+ /−
Group membership	Group membership	Yes or No	+ /−
Land	Land	acres	+ /−
Farm experience	Farmers' experience	Years	+ /−
Credit access	Credit access	Yes or NO	+ /−
Income	Income	Kenya shillings	+ /−
Extension services	Extension		+ /−
Input sourcing	Input source		+ /−

Source: Author description

3.10 Ethical Consideration

The study maintained integrity to guarantee the secrecy and disclosure of respondents' data. An introduction letter (Appendix II) telling the respondents the nature of the study was provided by the researcher. The study ensured confidentiality to the responses of the willing respondents. The study also conformed to Chuka University Institutional Ethical requirements and approval (Appendix III). A research permit was acquired from National Commission for Science, Technology and Innovation (NACOSTI) so as to get permission to effectively collect data for the study (Appendix IV). Permission was also sought from the Ministry of Education, the County Commissioner and County Director of Agriculture, Kirinyaga County to collect data (Appendix V). Informed consent from individual small scale tomato farmers was sought.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Questionnaire Response Rate

Questionnaire response rate by the respondents in Mwea East and West Sub-Counties is indicated on Table 9. A total of 161 and 122 respondents in Mwea East Sub-County and Mwea West Sub-County, respectively filled the questionnaire. This shows a sample of 283 respondents. The respondents were drawn from 8 wards as shown in Table 9 and the findings showed that Kangai had the leading number of respondents (20.49%). The questionnaire return rate for the respondents interviewed was adequate (Table 9).

Table 9: Response Rate of the Respondents

What is your current Sub county?	Frequency	Percentage
Mwea East	161	56.89
Mwea West	122	43.11
Total	283	100
Did the respondent agree?	**Frequency**	**Percentage**
Yes	283	100
Total	283	100
What is your current ward?	**Frequency**	**Percentage**
Kangai (Mwea west)	58	20.49
Wamumu (Mwea west)	28	9.89
Mutithi(Mwea West)	17	6.01
Thiba (Mwea West)	38	13.43
Murinduko (Mwea east)	39	13.78
Gathigiriri (Mwea east)	29	10.25
Nyangati (Mwea east)	50	17.67
Tebere (Mwea east)	24	8.48
Total	283	100

The high return rate was achieved because all the respondents were followed up on a regular basis through direct interactions and making phone calls. Vergani *et al.* (2022) stated that if the return rate of the questionnaire is over 80%, it is termed as being adequate.

4.2 The Type of Tomato Production Site

This study aimed to know the type of tomato production site, whether greenhouse or open field. It was observed that there was currently no farmer producing tomato in the greenhouse. The study observed that most farmers 99.65% of all the respondent produced tomato in open field while one of the respondent had a greenhouse earlier before abandonment 0.35 % (Table 10).

Table 10: Tomato small scale production site

Tomato production site	Frequency	Percentage
Open field	282	99.65
Greenhouse (Before abandonment)	1	0.35
Total	283	100

The respondent urged that greenhouse could not be used for tomato production because of the high temperatures in Mwea which could not favor tomato production. The respondents attributed high cost of setting greenhouses as one of the major reason why they preferred producing tomato in open fields. Mwangi *et al.* (2020) reported that most farmers produced tomato in open fields probably because they had limited information and knowledge on use of tomato production technologies such as setting up of greenhouses and the setting cost was also very high.

4.3 Descriptive Statistics of the Small Scale Tomato Farmers

4.3.1 Socio Demographic Characteristics of the Respondents

The study observed that, majority 78.8% of small scale tomato farmers were male while 21.20% were female (Table 11). The study observed that men most likely had greater access to farm resources than their female counterparts. It was also reported that male are more actively involved in production of tomato than female and therefore gender inequality existed in the study area. It was further observed that in African background, most females do not own land and must be at home to support their families and take care of the children. The findings are in line with those of Kinuthia *et al.* (2019) who observed that small scale tomato farmers in Kenya is dominated by men.

Table 11: Gender of tomato small scale tomato farmers

Gender of the respondent	Frequency	Percentage
Female	60	21.20
Male	223	78.80
Total	283	100

When studying the age, it was observed that tomato small scale farmers' mean age was approximately 39.73 years (Table 12). The study findings are in line with Tambe *et al.*

(2019) survey findings which recorded that majority of farmers were between the ages of 31 and 40, with 86.50 % being male. It was also observed that farmers had at least an average mean age of 10 years of schooling which showed that most tomato farmers had attained elementary schooling (at least primary school education) which is vital in forming farming decisions such as crop management practices.

Table 12: A Summary of Household Characteristics

Variable	Observations	Mean	SD	Min	Max
Decision maker years of schooling	283	10.57	2.91	5	18
Decision make age	283	39.73	7.03	23	57
Number of dependents	283	4.2	1.2	2	12
Income dependent	283	1.58	0.74	0	5
Children under 18	283	1.47	0.98	0	11
Years of experience	283	5.23	3.35	1	22

Note: SD= Standard Deviation

The respondents had a mean of at least 5.23 years of experience. The respondents had an average of 4 household members and a farming experience of 4 years. Majority of farmers had made an average of at least 3 contacts with the extension officers. Considering education achievement, the findings showed that farmers had different level of education at 5.39% for primary school from standards 1 to 6, 25.80% for standard 7, 16.61% for standard 8 or secondary school under form 4, and 37.10% for secondary form 4 and 15.19% for college or higher education (Table 13). These findings showed that most of the respondent's at least acquired secondary education which is very important in decision making in the farm. Paltasingh & Goyari (2018) study suggested that farmer education has an important effect on agricultural production under technological advancements, and it has a strong inception influence on agricultural production.

Table 13: Highest Education level of the decision maker

Level of education of the decision maker	Frequency	Percentage
Primary standard (1- 6)	15	5.30
Primary standard 7	73	25.80
Standards 8, or secondary school	47	16.61
Secondary form 4	105	37.10
College or higher	43	15.19
Total	283	100

The survey results showed that majority of the respondents at 80.92% stated that the household heads were responsible for making farm decisions (Table 14). These decisions ranged from land preparation, planting, tomato crop routine management practices such as irrigation, weeding and crop protection until the tomato crop reached the market. From the survey findings, it was observed that 5.30% of the respondents indicated that the spouse to the household made farm decisions. The findings also showed that 13.43% and 0.35% reported that the household head and spouse jointly and farm managers, respectively made farm decisions. These study results contrasts with Acosta *et al.* (2020) who reported that men who were household heads, were perceived as decision makers and male partners regarded women as having sole decision-making power with only tasks traditionally performed by women, such as cooking as well as weeding.

Table 14: Household decision maker income source

What is the main decision maker's income source?	Frequency	Percentage
Government employment	20	7.07
Employed in business	13	4.59
Unemployed	26	9.19
Self-employed	161	56.89
Casual labour	20	7.07
Others	43	15.19
Total	283	100

Other income source	Frequency	Percent of responses	Percent of cases
Remittances	3	1.32	2.17
Pension	2	0.88	1.45
Own-business	72	31.72	52.17
Farm paid labour	61	26.87	44.2
Crop Farming	25	11.01	18.12
Livestock	22	9.69	15.94
Farming	21	9.25	15.22
Other	21	9.25	15.22
Total	227	100	164.49

4.3.2 Farm Household Characteristics

4.3.2.1 Household Income

The respondents gave out diverse sources of income for their household and farm undertakings. The survey findings showed that 7.07% of the respondents were government employed, 4.59% were employed in business, 9.19% were unemployed, the majority at 56.89% were self-employed, 7.07% were casual laborers and 15.19% received their incomes from other sources (Table 15).

Table 15: Tomato farmer's organization

Is the household head a member of tomato farmers organization		Frequency	Percentage
No		201	71.02
Yes		82	28.98
Total		283	100
Reason for farmer organization	**Frequency**	**Percent of responses**	**Percent of cases**
Access to inputs	20	13.70	24.39
Access to output markets	49	33.56	59.76
Extension services	75	51.37	91.46
Finances	2	1.37	2.44
Total	146	100	178.05
Benefits derived from Farmer organization	**Frequency**	**Percent of responses**	**Percent of cases**
Get higher output prices	26	20.63	31.71
Reduced inputs	22	17.46	26.83
Collective selling	0	0.00	0.00
Lobbying	1	0.79	1.22
Bargaining power	6	4.76	7.32
Access credit/loans	14	11.11	17.07
Pool resources for various reasons	24	19.05	29.27
Reduced inputs cost	8	6.35	9.76
Others	25	19.84	30.49
Total	126	100	153.66

Most of the respondents who were self-employed were mostly in their farms and were involved on tomato farming which was one of the main cash crop for their households and the income obtained was used for paying school fees, running family errands and purchasing of basic needs. Some of the farmers stated that they use the money for farm activities such as land preparation, irrigation, crop protection, and payment of labour.

The study findings are in line with those of Ali *et al*. (2020) who observed that majority of farm source of income was from self-employment in tomato farms and tomato production is their key basis of revenue. In this study it was observed that some of the farmers had multiple sources of income which ranged from remittances (2.17%), pension (1.45%), own business (52.17%), farm paid labour (44.2%), crop framing

(18.12%), livestock (15.94%) and farming (15.22%) [Table 15]. It was observed that owning business was the key basis of income for the households in the study area.

4.3.2.2 Tomato Farmer Organization

The findings of this study showed that most respondents (71.02%) did not belong to a tomato farmer's organization or group (Table 16). This was one of the reasons which contributed to difficulties for the extension officers to disseminate facts to the farmers. Only 28.98% of the farmers belonged to a tomato group. The farmers gave varied reasons on why they belonged to a tomato farmers' organization which ranged from access to inputs 24.39%, access to output market 59.76%, access to extension services 91.46% as well as obtaining finances 2.44% from the farmer's organizations (Table 16). The study further observed that most farmers 31.71% benefited from the farmer organization by getting higher output prices. The study further observed that other benefits derived from the farmers organization included reduced inputs, collective selling bargaining power, access credit/loans and pooling resources for various reasons (Table 16). The study results were in line with those of Mwenda *et al*. (2022) who recorded that belonging to a group was a linked to the usage of pest information obtained from radio programs, and other ICT-based pest information services.

Table 16: Training related to tomato production last two seasons

Training related to tomato production for the last two seasons	Frequency	Percentage
No	158	55.83
Yes	125	44.17
Total	283	100

Source of training	Frequency	Percent of responses	Percent of cases
Private trainers	23	10.80	18.40
Extension officers	101	47.42	80.80
Colleague farmers	60	28.17	48.00
Online platforms	14	6.57	11.20
Field day	8	3.76	6.40
Farmers seminar	6	2.82	4.80
Others	1	0.47	0.80
Total	213	100	170.40

4.3.2.3 Access to Training

The findings observed that most respondents at 55.83% did not while 44.17% of the respondents had at least accessed training related to tomato production over the last two seasons (Table 17). The study observed that most farmers explained that they did not have time to go to trainings because they were busy with farm activities and the only trainers who visited their farms were marketers who came to advertise their products such as chemical pesticides. Mitra & Sharmin (2019) in their study reported that teaching and schooling aid people to understand the importance of obtaining emerging innovations and some farm practices such as applying seed, irrigation, and fertilizer on time. From the response cases, the study findings showed that most of the respondents 80.80% acquired training from extension officers. The study findings further observed that other sources of training for the small scale tomato farmers ranged from private trainers 18.40%, colleague farmers 48.00%, online platforms 11.20%, field day 6.40% and farmers' seminar 4.80% (Table 17).

Table 17: Information access on tomato production on phone

Do you receive tomato production from your phone?		Frequency	Percentage
No		182	70.82
Yes		75	29.18
Total		257	100
Information kind	**Frequency**	**Percent of responses**	**Percent of cases**
Tomato production information	13	33.33	50.00
General farm production Information	5	12.82	19.23
Pest control information	2	5.13	7.69
Others	6	15.38	23.08
Total	39	100	150
Information source on control of *T. absoluta*	**Frequency**	**Percent of responses**	**Percent of cases**
Colleague farmers	220	31.84	77.74
Family/Relatives	42	6.08	14.84
Marketers/ sales representatives	182	26.34	64.31
Extension officers	98	14.18	34.63
Radio/TV	120	17.37	42.4
others	29	4.20	10.25
total	691	100	244.17

The study finding are in consistent with those of Goeb *et al.* (2022) who reported that tomato small scale farmers in Zambia accessed training from their fellow farmers, extension officers, private trainers as well as online platforms.

4.3.2.4 Information Access

The findings of the study showed that most farmers acquired information regarding pest management practices from colleague farmers. Majority of the respondents 70.82% did not receive any information regarding tomato production on phone but a few 29.18% received information from their mobile phones (Table 18). This can be expounded by the respondents' explanations, most farmers had no smartphones which could easily access information on the internet. Further, most respondents explained that they only used their phones to contact tomato buyers or get market information from their colleague farmers.

Table 18: Credit access to the small scale tomato farmers

Have you accessed credit last tomato production season		Frequency	Percentage
No		218	77.03
Yes		65	22.97
Total		283	100
Loan Source	Frequency	Percent of responses	Percent of cases
Formal bank	5	6.17	7.69
Microfinance institution	7	8.64	10.77
SACCO	18	22.22	27.69
Community group	8	9.88	12.31
Informal sources	18	22.22	27.69
Mobile money	24	29.63	36.92
Other	1	1.23	1.54
Total	81	100	124.62
Reasons for loans	Percent responses	Percent of cases	
Farm inputs	66.67	95.38	
School fees	8.60	12.31	
Land	4.30	6.15	
Expand business	2.15	3.08	
Farm implements/equipment	18.28	26.15	
Total	100	143.08	

The study findings are consistent with those of Mauti *et al*. (2021) who reported that the most of tomato growers in Mwea use mobile phones to access market information. During the study it was also reported that half of the tomato growers (50%) received tomato production information, 19.23% on general farm production information and 7.69% on pest control information. The survey findings also depicted that majority of the respondents 77.74% from the response cases accessed information on control of *T. absoluta* from their colleague farmers (Table 18). The study findings are consistent those of Mathinya *et al*. (2022) study who reported that most small-scale farmers obtained information from their fellow farmers in South Africa.

4.3.2.5 Credit Access

Regarding credit accessibility by tomato small scale growers, the findings showed that most farmers 77.03% did not access loans or credit that could at least helped them in tomato production and protection while only 22.97% accessed credit (Table 19). The reasons for failing to access credit were identified as being fear of default as well as lack of information on some of the sources for the credit. The study results are consistent with those of Mulume *et al.* (2022) who reported that there was low rate of credit access among tomato growers in Democratic Republic of Congo due to low total income of the household, gender, and tomato farmers' participation in a co-operative. It was further observed that those who had acquired credit obtained it from mobile money 36.92%, while others obtained loans from formal bank, Microfinance institution, SACCO, community group and informal sources such as borrowing from neighbors (Table 19).

The findings also observed that most of the respondents 95.38% acquired loans for purchase of farm inputs. Further, the respondents acquired loans for payment of school fees, renting land, expanding business as well as purchase of farm implements such as pipes and knapsack sprayers (Table 19). The findings are line with those of Mohammed *et al*. (2019) who observed that most tomato farmers had accessibility to loans and the reasons for loans was to purchase some of the farm inputs such seeds, pesticides and for used for payment of labour.

Table 19: Land ownership

Type of land ownership	Frequency	percent of responses	Percent of cases		
Owned	232	64.09	81.98		
Rented in/lease	92	25.41	32.51		
Family	38	10.5	13.43		
Total	362	100	127.92		
Variable	Observations	Mean	SD	Min	Max
Total land Size	283	3.31	1.74	0.0025	7
Land under Agriculture	283	2.61	1.49	0.25	6
Land under crops	283	2.43	1.49	0.25	6
Land under tomato	283	0.70	0.29	0.025	1

Note: SD= Standard deviation

4.3.2.6 Land Access by Tomato Small Scale Farmers

The findings showed that 81.98% of the tomato small farmers owned land, 32.51% rented land and those who practiced farming on family land accounted were 13.43%. It was also observed that that tomato small scale farmers had an average land size of 3.31 with the least be 0.0025 and maximum of 7 acres whereby about 2.61 with a minimum of 0.25 and a maximum of 7 acres was used for agricultural purposes. It was further observed that the area under crop was an average size of 1.49 acres with a minimum 0.25 and a maximum of 6 acres. The maximum area under tomato production was 1 acre and the average land size was at least 0.70 acres (Table 20). Mwangi *et al*. (2020) observed that the average land size in acres for open field small scale farmers is 0.7096 which demonstrates that the farms are subdivided and that tomato production competed with other crops. Tambe *et al.* (2019) also observed same results that majority of tomato producers owned less than one acre for tomato production.

In this study it was reported that most of the farmers 97.53% cultivated tomato and other crops which were widely cultivated in the region included maize 91.87%, beans 58.30%, banana 31.45%, and rice 26.15% (Table 21). The respondents gave some of the reasons for the wide growing of tomato which varied from availability of water for irrigation from River Nyamindi and Thiba as well as water recycled from rice irrigation. The study findings are consistent with those of Ogutu *et al*. (2022) study who reported that most farmers in Mwea region grew tomato crops and other crops in the region included rice cultivation, maize and beans. The study also sought to identify methods that the tomato small scale farmers use to prepare land. It was observed that most tomato small farmers 81.27% used tractor which can be explained by the fact that the land used for tomato production is difficult to use other methods because of the previous planted crops such as rice.

Table 20: Crops grown by the households

What type of crops does the household grow?	Frequency	Percent of response	Percent of cases
Maize	260	22.79	91.87
Millet	5	0.44	1.77
Sorghum	5	0.44	1.77
Beans	165	14.46	58.30
Banana	89	7.80	31.45
Peas	4	0.35	1.41
Potato	42	3.68	14.84
Sweet potato	21	1.84	7.42
Cassava	2	0.18	0.71
Rice	74	6.49	26.15
Cotton	1	0.09	0.35
Vegetables	61	5.35	21.55
Sugar cane	5	0.44	1.77
Butternut	1	0.09	0.35
Melons	3	0.26	1.06
Tomatoes	276	24.19	97.53
Nappier	23	2.02	8.13
Cowpeas	3	0.26	1.06
Green grams	11	0.96	3.89
Avocado	8	0.70	2.83
Yams	4	0.35	1.41
French beans	67	5.87	23.67
Passion	4	0.35	1.41
Groundnuts	6	0.53	2.12
Chillies	1	0.09	0.35
Total	1141	100	403.18

It was also observed that 14.84% of the respondents prepared land manually while 3.89% prepared land using animal drawn ploughs (Table 22). The findings are in consistent with those of Shiikiba *et al.* (2021) who found that most farmers rely on tractors in tomato production. When identifying the source of planting materials, it was observed that most of the respondents (92.93%) had no nursery bed and only 7.07% had nursery beds) for tomato seedlings. It was observed that most tomato small scale farmers acquired their seedlings from Agricultural Organizations (44.88%) where the tomato seedlings are ready for transplanting or they purchased the seed and took to

Agricultural propagating organizations (42.4%). The respondents argued that seedlings from agricultural organizations could easily adopt to their soil after being transplanted and the seedlings were healthy as compared to those prepared to those planted in their farms.

Table 21: Land preparation methods for tomato production

Land preparation	Frequency	Percentage
Manually	42	14.84
Tractor	230	81.27
Animal drawn	11	3.89
Total	283	100

Table 22: Tomato nursery bed

Do you have a tomato nursery bed?		Frequency	Percentage
No		263	92.93
Yes		20	7.07
Total		283	100
Seeds/ Seedlings source	Fre-quency	Percent re-sponses	Percent of cases
Agrovets	62	16.10	21.91
Fellow farmers	44	11.43	15.55
Agricultural Organizations	127	32.99	44.88
Seeds company	32	8.31	11.31
Agricultural propagating organiza-tions	120	31.17	42.40
Total	385	100	136.04

Further on the variety of tomato planted, it was reported that most farmers used Zara F_1 (70.00%) and Rio grande (50.00%) tomato variety in their farm. Other tomato variety used included Cal J, Money maker, The Elgon, Commando F_1, Victory F_1, Anna F_1 , Ansal F_1 and Noeville F_1 (Table 23).The study results are consistent to those of Nuwamanya *et al*. (2022) who observed that most tomato farmers in Kirinyaga county grew F_1 tomato variety because of their high resistant to diseases.

4.4 Descriptive Statistics of Tomato Small Scale Farmers Crop Protection Problems, Control Methods and Routine Management

4.4.1 Tomato Small Scale Farmers Crop Protection Problems

Most of the respondents (89.40%) reported that the major challenge in tomato crop protection was *T. absoluta*, tomato blight (66.43%) and black spot (25.09%). The other tomato problems that were encountered by the respondents included aphids, blister beetles, cutworms, whiteflies, flee beetles, leaf hoppers, bacterial wilt, spider mites, nematodes, american bollworm, slugs and snails black spot, powdery mildew, blossom end rot, and false coding moth (Table 24). The respondents argued that *T. absoluta* was a major challenge because it was resistant to chemicals and it spread fast during the dry season. The study findings are similar to those of Ogutu *et al.* (2022) study who observed that *T. absoluta* was a key challenge among tomato farmers in Kirinyaga.

Table 23: Tomato Variety

Tomato Variety	Frequency	Percent of responses	percent of cases
Rio grande	10	18.87	50
Money maker	2	3.77	10
Cal J	1	1.89	5
The Elgon	9	16.98	45
Zara F_1	14	26.42	70
Commando F_1	1	1.89	5
Victory F_1	1	1.89	5
Anna F_1	1	1.89	5
Ranger F_1	3	5.66	15
Terminator	9	16.98	45
Ansal F_1	1	1.89	5
Noeville F_1	1	1.89	5
Total	53	100	265

4.4.2 Effect of Routine Management Practices

4.4.2.1 Staking

Regarding tomato staking, it was reported that most respondents (89.05%) stake tomato at 4 weeks after transplanting. It was observed that 6.71% and 4.24% stake tomato at 2 and 6 weeks, respectively (Table 25). The respondents gave some of the reasons for staking tomato as to make it easier to carry operations such as weeding, watering and harvesting. Staking also helped the tomato fruits from rotting when they come into contact with the soil which causes leaves and fruit spoilage staking improves fruit set, fruit quality, and marketable yield and also facilitates harvesting and staked plants are less likely to fail than unstacked plants which contract diseases. Lamptey & Koomson (2021) reported that most farmers' stake tomato at 4 weeks because it helps in improving tomato growth and management practices such as spraying, watering and also harvesting becomes easier. Sharma *et al*. (2018) study reported similar findings which indicated that staked tomato gave better fruit set.

Table 24 : Pest and diseases problems affecting tomato production

Tomato problems	Frequency	Percent of responses	Percent of cases
Tuta absoluta(Tomato leaf miner)	253	33.20	89.4
Aphids	26	3.41	9.19
Blister beetles	3	0.39	1.06
Cutworms	17	2.23	6.01
Whiteflies	21	2.76	7.42
Flee beetles	3	0.39	1.06
Tomato blight	188	24.67	66.43
Leaf hoppers	2	0.26	0.71
Bacterial wilt	30	3.94	10.6
Spider mites	27	3.54	9.54
Nematodes	7	0.92	2.47
American bollworm	1	0.13	0.35
Slugs and snails	9	1.18	3.18
Black spot	71	9.32	25.09
Powdery mildew	73	9.58	25.8
Blossom end rot	27	3.54	9.54
False Coding moth	4	0.52	1.41
Total	762	100	269.26

Table 25: Tomato staking stage

At what stage do you stake your tomato?	Frequency	Percentage
2 weeks after transplanting	19	6.71
4 weeks	252	89.05
6 weeks	12	4.24
Total	283	100

4.4.1.2 Irrigation

The survey findings showed that most respondents 43.84% used water from the river for irrigation. Other sources of water included wells 27.9%, surface water 27.9%, borehole 2.9%, spring or streams 15.22%, treated water 16.30%and canals 31.52 % (Table 26). The study observed that the main of source of water for irrigation was River Nyamindi and River Thiba. The study findings are similar to those Narita *et al.* (2020)

who observed that River Nyamindi and Thiba provided water for irrigation throughout the year for irrigation.

Table 26: Water sources for tomato irrigation

Source of water	Frequency	Percent of responses	Percent of cases
Surface water	9	2.31	3.26
Well	77	19.79	27.90
River	121	31.11	43.84
Borehole	8	2.06	2.90
Spring/stream	42	10.80	15.22
Treated water	45	11.57	16.30
Canal	87	22.37	31.52
Total	389	100	140.94

4.4.1.3 Weeding

The respondents practiced different weed control methods. Majority of the respondents 98.94% used hand weeding methods in their tomato farms A few respondents 1.41% used chemical control method to remove weeds in their farms. The study observed that most farmers use hard weeding because it was expensive to purchase chemicals for the pests and diseases control so they preferred hand weeding. The study observed that weeding was done on average 3 times, least being 1 and the highest being 6 times (Table 27). Morrison *et al*. (2022) study observed that most tomato farmers used hand weeding method in management of weeds in their farms.

Table 27: Tomato weeding

Weeding method	Frequency	percent of responses	Percent of cases		
Hand weeding	280	98.59	98.94		
Chemical	3	1.41	1.41		
Total	283	100.00	100.35		
Variable	Observations	Mean	SD	Min	Max
Weed times	283	3.18	0.67	1	6

Note: SD= Standard deviation

4.4.1.4 Harvesting

It was observed that all the respondents 100% harvested tomato manually by handpicking. Majority of the respondents 60.78% graded tomato by the brokers or the aggregator’s characteristics as majority sold their tomato to brokers 98.23% while

0.35%, 0.71% and 0.71 % sold to exporters, wholesalers and other buyers, respectively (Table 28). The respondents urged that it was cost saving to them as they could not incur transport cost as most of them did not have any means of transport to the market. Further, they urged that it was time consuming to go to the market and one could not identify the buyers who were well known by the brokers. The study results are in line with those of Mauti (2021) who reported that most farmers in the region sold tomato to middlemen or the brokers and few farmers sold to traders directly to consumers. Further, the study observed that other characteristics that were considered for tomato grading included similar varietal characteristics, small, large, medium and extra-large sizes (Table 28). The study findings are consistent to Kotamraju *et al*. (2021) study who reported that tomato grading in India is according to tomato similar tomato sizes such as being small, medium and large.

Table 28: Tomato harvesting, grading and selling

How do you harvest tomato		Frequency	Percentage
Manually		283	100
Total		283	100
How do you grade tomato product	**Frequency**	**Percent of responses**	**percent of cases**
Similar varietal characteristics	138	39.32	48.76
Small	7	1.99	2.47
Large	20	5.7	7.07
Medium	6	1.71	2.12
Extra-large	6	1.71	2.12
Brokers/ aggregator characteristics	172	49	60.78
Other	2	0.57	0.71
Total	351	100	124.03
Who do you sell your tomato to?		**Frequency**	**Percentage**
Aggregator/broker		278	98.23
Exporter		1	0.35
Wholesaler/traders		2	0.71
Other buyer		2	0.71
Total		283	100

4.4.3 Farm Pest Control Records

In this study more than half of the respondents 78.80% did not have pest control records and 21.20 % had pest control records (Table 29). The respondents gave varied reasons for not keeping the pest control records and these included, fear of associating themselves with losses, time constraint, procrastination, illiteracy of the employed individuals in the farm and also forgetfulness. The findings are line with those of Omotesho *et al.* (2022) study who reported that most farmers in Nigeria did not keep farm records due to forgetfulness and lack of knowledge.

Table 29: Respondent's records on pest control methods

Do you maintain pest control records	Frequency	Percentage
No	223	78.80
Yes	60	21.20
Total	283	100

4.4.4 Use of Agrochemicals

The study observed that most farmers 93.99% used pesticides to control pests while about 6.01% used other alternative pest control methods (Table 30). The other alternative pest control methods included use of certified seedlings from the agricultural organizations, crop rotation, staking and proper tomato routine management practices such as weeding. This can be explained by the respondent's claims that some of the pests such as *T. absolut*a can only be controlled using chemical pesticides. The results show that the frequency of use of chemical pesticides is very high among tomato small scale farmers. Colmenárez *et al.* (2022) study findings indicated that application of pesticides remains the principal approach, although the well-documented literature indicates the negative impacts of chemical pesticides on the environment and their low efficacy, even in locations where *T. absoluta* is an introduced species.

Table 30: Pesticides use by tomato small scale farmers

Did you use pesticides/ agrochemicals in tomato production last season	Fre-quency	Percent-age
No	17	6.01
Yes	266	93.99
Total	283	100

The study findings showed that tomato crop protection is labor intensive. Most of the respondents used hired labour (77.39%) while 22.61% used family labour (Table 31). The respondents explained that it was tedious for them to take part in all farm activities and they preferred hiring some individuals who helped with crop protection activities such as pesticides application and weeding. The study findings are similar to Aloysiu *et al.* (2021) study who reported that tomato crop production was labour intensive as it involved various farm activities which ranged from routine management practices such as weeding, irrigation and chemical application.

Table 31: Labour Source for crop protection

Source of labour used in crop protection practices?	Frequency	Percentage
Family	64	22.61
Hired	219	77.39
Total	283	100

4.4.5 *Tuta absoluta* Encounter with the Farmers

The findings reported that majority of the respondents 67.19% encountered *T. absoluta* infestation a few seasons ago, 24.9% encountered *T. absoluta* a few years ago while 7.91% encountered the pest during the previous cropping season (Table 32).

Table 32: *Tuta absoluta* encounter with the farmer

when was *T. absoluta* first encountered	Frequency	Percentage	
The previous cropping season	20	7.91	
A few cropping seasons ago	170	67.19	
A few years ago	63	24.9	
Total	253	100	
Tuta absoluta spread	Frequency	Percent of responses	Percent of cases
From neighbors farm	64	13.01	25.30
Seeds/seedlings	63	12.80	24.90
Infested fruits and packaging	10	2.03	3.95
Crop rotation	11	2.24	4.35
Immediately after transplanting	216	43.90	85.38
During dry season	121	24.59	47.83
Containers	3	0.61	1.19
Others	4	0.81	1.58
Total	492	100	194.47
Damage area	Frequency	Percent of responses	Percent of cases
Leaf	180	41.76	71.15
Fruit	173	40.14	68.38
Fruit and leaf	72	16.71	28.46
Other tomato parts	6	1.39	2.37
Total	431	100	170.36

Some of the respondents urged they were not able to identify the pest and therefore they could not tell when the pest was first identified in their farms. Majority of the response cases (85.38%) depicted that *T. absoluta* started spreading immediately after transplanting. Further, the study results also showed that *T. absoluta* spread from respondents' neighbors' farm, seedlings, infested fruits and packaging, crop rotation, during dry season, and through containers. The respondents further explained that *T. absoluta* damage areas were leaf 71.15%, fruit 68.38%, leaf and fruit 28.46 and other tomato areas 2.37% such as stems (Table 32). Mkonyi (2021) study reported similar results whereby the study highlighted some of the methods which *T. absoluta* spread in tomato fields and they included spread from neighboring tomato fields and the pest destroyed tomato fruit, leaves and stems.

4.4.6 Choice of *Tuta absoluta* Management Methods

This study sought to identify the pest management choices used tomato small scale farmers. Majority of the respondents 97.53% reported that they used chemical pesticides to manage *T. absoluta* and additional pests and diseases in tomato production while a few farmers 2.47% used alternative pest control methods (Table 33). Zekeya *et al.* (2022) indicated that controlling *T. absoluta* by use of chemical pesticides is tricky due to development of rapid resistance and alternative control options such as biological controls are scarce or expensive and only a handful of microbial agents are currently registered for the management of the pest in Africa.

Table 33: Chemicals pesticides use by tomato small scale farmers

Chemical pesticides (1)	Frequency	Percentage
No	7	2.47
Yes	276	97.53
Total	283	100

This study also sought to identify some of the methods that the farmers used to control tomato problems such as pests and diseases. The study observed farmers used multiple choices to control the problems and most farmers 97.53% used chemical pesticides. Other methods used ranged from Plant Incorporated Protectants (PIP), Intercropping, Mulching, Desuckering / pruning, Uprooting and destruction of residues, Fertilizer application, Predators, Crop rotation, parasites, Bio-insectides, Weeding, Bio-nematicides, IPM techniques, Staking and Bio-herbicides (Table 34). The study results are similar to Chepchirchir *et al*. (2021) study which reported that most tomato farmers in Kenya used chemical pesticides to control *T. absoluta.*

Table 34: List of pest management methods used by tomato small scale farmers to control *T. absoluta*

Pest management methods	Frequency	Percent of responses	Percent of cases
Chemical pesticides	276	41.13	97.53
Plant Incorporated Protectants (PIP)	2	0.30	0.71
Intercropping	17	2.53	6.01
Mulching	31	4.62	10.95
Desuckering / pruning	31	4.62	10.95
Uprooting and destruction of residues	25	3.73	8.83
Fertilizer application	10	1.49	3.53
Predators	1	0.15	0.35
Crop rotation	86	12.82	30.39
parasites	11	1.64	3.89
Bio-insectides	8	1.19	2.83
Weeding	82	12.22	28.98
Bio-nematicides	4	0.60	1.41
IPM techniques	22	3.28	7.77
Staking	62	9.24	21.91
Bio-herbicides	2	0.30	0.71
Others	1	0.15	0.35
Total	671	100	237.1

Regarding utilization of pesticides to control *T. absoluta* in tomato, it was reported that 90.11% of the respondents used chemical pesticides to control the pest while 9.89 % did not use pesticides (Table 35). Majority of the respondents (*57.08*%) used Occasion star to control *T. absoluta*. The respondents argued that *T. absoluta* had become resistant to other chemical pesticides such as coragen® but ocassiona star®, controlled the pest effectively as compared to other chemical pesticides. The study results are consistent to Nguetti *et al.* (2018) study who reported that 96.2% used chemical pesticides to control pests and diseases for tomato production. Most of the respondents cited some of the chemical pesticides used ranged from Tihan®, Merit®, Occasional Star®, Coragen®, Level®, Oshothane®, Indoxacard®, Dudu accelamectin®, Akuku® and Belt® among others. The study results contradicted Ogutu *et al.* (2022) study which reported that tomato farmers in Kenya use various chemical pesticides to effectively Control *T. absoluta* and most farmers in Kirinyaga use Coragen®, to maintain the pest.

Table 35: Pesticide use on *Tuta absoluta*

Did you use agrochemicals during last production to control *T. absoluta?*			Frequency	Percentage
No			28	9.89
Yes			255	90.11
Total			283	100
Chemical name	**Frequency**	**Percent of responses**	**Percent of cases**	
Tihan®	110	21.28	45.83	
Merit®	36	6.96	15.00	
Occassion star®	137	26.50	57.08	
Coragen®	95	18.38	39.58	
Level®	13	2.51	5.42	
Oshothane®	14	2.71	5.83	
Capro®	4	0.77	1.67	
Victory®	5	0.97	2.08	
Indoxacard/Indox®	60	11.61	25.00	
Abamectin®	1	0.19	0.42	
Benocab®	1	0.19	0.42	
Indokin®	9	1.74	3.75	
Total	517	100	215.42	

The harm triggered by *T. absoluta* was observed to be an average of 53.88 % with a minimum of 2% and a maximum of 100% which contributed to a yield loss of about 35.43% with a minimum of 10% and maximum of 90% (Table 36). Zekeya *et al.* (2022) observed that *T. absoluta* causes damage and loss in tomato ranging from 50-100% in South America, Europe and Africa where management options are most limited. The respondents explained that the pest destroyed the plant at early stage and if not easily noticed, no crop was harvested. Further, the respondents also explained the brokers could not buy the infested fruit hence the farmers reported losses and it discouraged them from planting tomato crop. Mansour *et al.* (2018) made the same observations that *T. absoluta* caused a damage level to up to 100% in East Africa especially for open field tomato production due to its high spread rate.

Table 36: *Tuta absoluta* damage level on tomato and yield loss

Variable	Observations	Mean	SD	Min	Max
Damage level	253	53.88	22.90	2	100
Yield loss	253	35.43	16.54	10	90

Note: SD= Standard Deviation, Min= Minimum, Max= Maximum

4.5 Analyzing the Effect of Farmers' Gross Margin on the Choice of Management of *T. absoluta* in Tomato Production in Mwea, Kirinyaga County

4.5.1 Tomato Production Revenue

During the study the total revenue was generated from the relationship between the total yield sold in kilograms and the price per kilogram (Kenya shillings [KES]). The mean total revenue in one acre was KES 511275.60 with a minimum of KES 64000 and a Maximum of KES 1520000. It was observed that the respondents sold a mean of 8903.53 Kilograms of tomato with a minimum of 1000 and a maximum of 19000 kilograms. The study results are in line with those of Chepchirchir *et al*. (2021) who reported that the average tomato yield in Kenya in one acre is 14 tonnes/acre for the hybrid variety using irrigation, 8 tonnes/acre using hybrid variety and 6 tonnes/acre using open pollinated variety. The average price per kilogram was KES 57.59 with a minimum of KES 40 and a maximum of KES 100 (Table 37). The farmers explained that the sold tomato in kilograms to the brokers and the prices varied during the seasons, at times it was very low and at times very high. The farmers further explained that they sold the tomato according to the brokers grading and prices. The study results are in line with those of Mauti (2021) study who reported that an average price for tomato in Kenya is KES 44 per Kg.

Table 37: Tomato revenue generated from tomato yield sold and price per kilogram

Variable	Observations	Mean	SD	Min	Max
Total revenue	283	511275.60	207154.5	64000	1520000
Tomato yield sold	283	8903.534	3410.641	1000	19000
Price per kg	283	57.59364	6.934923	40	100
GM per acre	283	461131.10	198554.30	-5500	1415000
GM per kg	283	11.44	9.12	0.92	132

Note: SD= Standard Deviation, Min= Minimum, Max= Maximum

The Gross margin was computed by deducting the total costs from the total revenue. From the findings the study concluded that the average gross margin for the respondent is KES 461131.10 per acre with a minimum of KES -5500 and a maximum of KES 141500 while the gross margin per kilogram in one acre was at an average KES 11.44 with a minimum of 0.92 and a maximum of 132. The study observed that tomato production was profitable among the small scale farmers as observed in the value of the gross margin (Table 37). Mbogo (2020) study reported that the average gross margin for the open field tomato small scale farmers in the region was KES 11.23.

4.5.2 Tomato Production Costs

Agricultural farm inputs are important in tomato crop production and these inputs range from labor, seeds, agrochemicals, stakes and transportation cost to the market. Holding land as a fixed factor of production, the results of the study observed that the average costs of inputs used by the respondents in one acre was KES 113226.20 with a minimum of KES4800 and KES 204200 (Table 38). The average costs were as follows in KES: manual labour 8102.38, Tractor cost 5232.61, Animal land preparation cost 2745.46, certified seeds cost 13937.50, crop protection 10229.68, stakes costs 14863.25, Staking labour cost 5869.44, Agrochemicals cost 25848.15, *T. absoluta* agrochemicals 16546.93, Water fuel for irrigation 8833.78, Labour irrigation 10738.98, weeding labour 10210.41, harvesting labour 27049.89 and the transport cost 370.09 (Table 39). The study results are line with those Mbogo (2020) study who reported that tomato production costs in the region included the direct costs.

4.5.3 Effect of Tomato Small Scale Farmers Gross Margin on Choice of Management Methods

Regarding the influence of gross margin on choice of *T. absoluta* management, a multiple regression model was used. Study findings showed that the R^2 in the regression analysis indicated that the variations for different pest control methods was 0.10 which showed that 10% of the variations on choices of management methods explained the gross margin while the F- statistic was 1.75 and significant at 0.01 (Table 39). The study findings are consistent with those of Stephenson *et al.* (2020) who reported that the multiple regression model illustrates 10.5% of variance in gross margin, which is determined as total value minus total cost of pest management strategies.

Table 38: Tomato Inputs Costs in Kenya Shillings (KES)

Variable	Observations	Mean	SD	Min	Max
Total costs	283	113226.2	41535.19	4800	20420
Manual labour cost	42	8102.38	5216.13	0	20000
Land preparation tractor cost	230	5232.61	1951.49	1000	12000
Land preparation animal cost	11	2745.46	750.15	1500	4000
Certified seeds cost	16	13937.50	5078.96	6000	20000
Crop protection labour cost	283	10229.68	8811.72	0	12000
Stakes costs	283	14863.25	5246.36	1000	21000
Staking labour cost	283	5869.44	4202.76	400	20000
Agrochemicals cost	243	25848.15	12708.81	1000	55000
Agrochemicals to control *T.absoluta*	254	16546.93	7316.82	0	42000
Fuel cost for irrigation	74	8833.78	5895.86	800	40000
Irrigation Labour cost	59	10738.98	4483.96	1500	35000
Weeding labour cost	269	10210.41	3970.97	1200	30000
Harvesting labour cost	283	27049.89	14021.90	1500	66000
Market transport cost	204	370.09	1407.42	0	10000

Note: SD= Standard Deviation, Min= Minimum, Max= Maximum

The study observed that two out of the eighteen hypothesized variables namely crop rotation and weeding were significant. Crop rotation was significant at (P-value=5%) and had a positive relationship with the tomato small scale farmers gross margin. Weeding was significant at (P-value=5% but had a negative relationship with the small scale tomato farmers gross margin. The coefficient of crop rotation was positive implying that the more the farmers practiced crop rotation, the gross margin increased. The coefficient for weeding was negative implying that the reduction in number of weeding times for the tomato affected the gross margin of the farmers in controlling *T. absoluta.*

The study results further observed that use of chemical pesticides, plant incorporated protectants, intercropping, desuckering or pruning, uprooting and destruction of crop residue, fertilizer application, predators, parasites, bio-insectides, IPM techniques, staking and bio-herbicides were not significant (Table 39). The study results reported a similar observation as Chepchirchir *et al*. (2021) study who observed that tomato farmers relied on several alternate pest management strategies which ranged from selection of healthy tomato seeds and planting resistant varieties. Further, they observed that crop rotation had a significant and positive relationship on control of *T. absoluta*.

Table 39: Effect of tomato farmer gross margin on choice of *T. absoluta* management methods

Gross margin	Coefficient	SD	t-value
Chemical pesticides	42578.05	80609.75	0.53
Plant Incorporated Protectants (PIP)	-53034.4	141037.2	-0.38
Intercropping	-4920.94	51808.49	-0.09
Mulching	-78330.1	48164.44	-1.63
Desuckering / pruning	17734.86	45968.51	0.39
Uprooting and destruction of crop residue	17352.58	48850.18	0.36
Fertilizer application	-32942.6	65028.21	-0.51
Predators	25156.35	208081.9	0.12
Crop rotation	56140.11**	26392.21	2.13
Parasites	20512.61	63176.56	0.32
Bio-insectides	28361.68	76895.25	0.37
Weeding	-74051.7**	33579.62	-2.21
Bio-nematicides	234558.9	144983	1.62
IPM techniques	-24870.9	50066.86	-0.5
Staking	-46264	35461.19	-1.3
Bio-herbicides	-197726	198389.7	-1
Other	65608.76	195738.6	0.34
_cons	439173.1	80808.21	5.43

Equation	Observations	Parms	RMSE	R-sq	F	P
Gross margin	283	18	194169.1	0.1013	1.757738	0.0336

*, ** and *** represent 1%, 5% and 1% respectively. Note: SD = Standard Deviation

4.6 Effect of Tomato Farmers' Perception on the Choice of Management of *T. absoluta*

4.6.1 Summary Statistics for the Aspects Used to Measure Farmers' Perception on the Choice of Management of *T. absoluta*

This study further tried to understand the perception of the respondents on the choice of *T. absoluta* management methods. The study used a five likert scale of minimum and maximum 1-5 respectively whereby the value represented (1= strongly disagree, 2=disagree, 3=uncertain, 4=agree, 5= strongly disagree). The aspects used to identify the tomato small scale farmers' perception varied from household and employee health, chronic illness, farmer knowledge, effective control, complete control, food safety, environment safety, water quality, biodiversity, soil contamination, performance, awareness information, technical, environment effect as well as if they regarded the management method as being cheap (Table 40). Sadique (2022) study reported that farmers considered various aspects which ranged from knowledge, experience, health as well as the cost in adopting integrated pest management for vegetable production in Bangladesh.

Table 40: Summary statistics for the aspects used to measure perception

Variable name	Observations	Mean	SD	Min	Max
Household health	283	2.9187	0.9474	1	5
Hired employee health	283	2.8763	0.9503	1	5
Chronic illness	283	2.8975	0.9603	1	5
Acute illness	283	2.9222	0.9307	1	5
Farmer knowledge	283	3.5795	0.8272	1	5
Effective control	283	3.6572	0.8161	1	5
Complete control	283	2.7491	1.0471	1	5
Food safety	283	3.0353	1.0029	1	5
Environment safety	283	2.8551	0.9912	1	5
Water quality	283	2.8233	0.9914	1	5
Biodiversity	283	2.8057	0.9641	1	5
Soil contamination	283	2.8481	1.0356	1	5
Performance	283	3.3816	0.9124	1	5
Awareness information	283	3.5618	0.8664	1	5
Technical	283	3.8233	0.8694	1	5
Environment effect	283	3.7915	0.79156	1	5
Cheap	283	2.7279	1.1670	1	5

Note: SD= Standard Deviation, Min= Minimum, Max= Maximum

4.6.2 Principal Component Analysis Model to Classify the Aspects Farmers Perceived to be Affecting the Choice of Management Methods to Control *T. absoluta in* Tomato Production

The study further classified the aspects into components (1 to 17) [Table 41] to represent summary statistics of the aspects the farmers used to measure perception. Each aspect had a minimum of 1 and a maximum of 5 while the average mean for each aspect was described as: household (2.9187) and employees health (2.8763), chronic (2.8975) and acute (2.9222) illness, farmer' knowledge (3.5795), effective control (3.6572), complete control (2.7491), food safety (3.0353), environment safety (2.8551), water quality (2.8233), biodiversity (2.8057), soil contamination (2.8481), .

Table 41: Principal components for tomato small scale farmers' perception on choice of T. absoluta management methods

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Comp6	Comp7	Comp8	Comp9	Comp10
Household health	0.2866	-0.1465	0.188	-0.2926	-0.0979	0.0044	0.0294	-0.1319	0.2212	0.3662
Hired employee health	0.2938	-0.1487	0.2533	-0.3393	-0.0389	0.0285	0.0144	-0.064	0.1422	0.2279
Chronic illness	0.3032	-0.1362	0.2789	-0.247	-0.0186	0.1016	0.0305	-0.088	-0.0067	-0.1731
Acute illness	0.2958	-0.1723	0.2449	-0.1341	0.0079	0.0519	0.0992	0.0122	-0.1558	-0.4224
Farmer knowledge	0.1347	0.3438	0.4138	0.3934	-0.1565	-0.2352	-0.087	0.035	0.0566	0.1451
Effective control	0.1782	0.3435	0.403	0.2607	-0.2017	-0.0712	0.1455	0.2287	-0.0633	0.0259
Complete control	0.1866	-0.0545	-0.0398	0.5003	0.1242	0.5466	-0.0531	-0.4925	0.2624	0.1666
Food safety	0.2944	-0.0045	-0.0713	0.1136	-0.0117	0.0067	-0.2214	-0.3288	-0.5668	-0.2082
Environment safety	0.325	-0.0359	-0.1529	0.1396	-0.0057	-0.0946	-0.2235	0.0854	-0.0614	-0.269
Water quality	0.3181	-0.0796	-0.2281	0.1244	-0.0251	-0.1786	-0.1903	0.1791	0.153	-0.0473
Biodiversity	0.2942	-0.129	-0.3086	0.1272	-0.0358	-0.1967	-0.0451	0.2409	0.2052	0.1221
Soil contamina-tion	0.2869	-0.0927	-0.3149	0.0502	-0.1035	-0.2116	0.1357	0.0379	0.101	0.1311
Performance	0.1888	0.2824	-0.3267	-0.116	-0.2782	0.1774	0.4718	-0.0399	-0.4417	0.3238
Awareness infor-mation	0.1469	0.4645	-0.1647	-0.1779	-0.0791	0.4508	0.1001	0.2195	0.3801	-0.4125
Technical	0.1252	0.4025	-0.0324	-0.2831	0.3836	0.1271	-0.5807	0.1489	-0.1683	0.3174
Environment ef-fect	0.1119	0.3667	-0.0662	-0.101	0.5093	-0.4635	0.319	-0.4431	0.1763	-0.1353
Cheap	0.1403	-0.2102	0.1158	0.2127	0.6363	0.1923	0.3597	0.4465	-0.1754	0.1092

Variable	Comp11	Comp12	Comp13	Comp14	Comp15	Comp16	Comp17	Unexplained

Household health	-0.4139	0.1776	0.0204	0.0287	0.5169	0.2084	-0.2232	0
Hired employee health	-0.0974	0.0249	-0.1329	0.0377	-0.4622	-0.2991	0.5488	0
Chronic illness	0.3159	-0.042	0.0211	-0.2668	-0.3313	-0.0424	-0.6455	0
Acute illness	0.4282	-0.081	0.0927	0.2636	0.4146	0.1794	0.3425	0
Farmer knowledge	0.2174	0.5112	0.2833	-0.165	-0.0092	-0.0001	0.0933	0
Effective control	-0.2367	-0.5847	-0.2257	0.1888	-0.0134	-0.0052	-0.1064	0
Complete control	0.152	-0.144	-0.0789	0.0332	0.0378	-0.0096	0.0389	0
Food safety	-0.4395	0.1194	0.2512	0.2112	-0.222	0.0895	-0.0314	0
Environment safety	-0.1213	0.0758	-0.3604	-0.39	0.3363	-0.54	0.0246	0
Water quality	0.029	0.0538	-0.392	-0.1525	-0.2241	0.6762	0.1018	0
Biodiversity	0.1786	0.1307	0.0518	0.6577	-0.0705	-0.2735	-0.2536	0
Soil contamina-tion	0.0111	-0.4346	0.6129	-0.3522	0.0171	-0.0097	0.125	0
Performance	0.2297	0.1545	-0.2216	-0.0613	0.0426	0.0059	0.0119	0
Awareness infor-mation	-0.2222	0.1663	0.1947	0.0237	-0.0678	0.0211	0.033	0
Technical	0.2019	-0.1822	0.0697	0.0147	0.0999	0.0175	0.0005	0
Environment ef-fect	-0.0007	-0.0137	-0.1146	0.055	-0.0001	-0.0092	-0.0178	0
Cheap	-0.1615	0.1479	0.0736	-0.0943	-0.0385	0.019	-0.0093	0

Note: Comp= Components

performance (3.38160, awareness information (3.5618), technicality on use (3.8233), environment effect (3.7915) and cheap (2.7279) aspects (Table 41). The findings are similar to those of Moinina *et al*. (2018) study who reported that farmers' knowledge among other aspects such as awareness, performance and health were key factors that farmers considered before adopting pest management in apple production in Morocco.

4.6.3 Eigen Values for the Principal Components

The farmer aspects were further analyzed using principal component analysis method so as to be able to understand their perceptions towards pest management methods used to control *T. absoluta*. The Eigen values were used in the study so as to further reduce the components into fewer aspects which gave the relation and factor loadings (Table 42). The components which had eigen value more than 1 were retained used for further analysis. These components involved household health (6.7274), hired employee health (1.8040), chronic (1.4165) and acute illness (1.2541) and farmer's knowledge (1.1132) [Table 42]. The study observed that the farmers gave some of the aspects they considered most before application of chemical pesticides and most farmers said that they considered their health as well as that of their employees and they could not use a method to control *T. absoluta* if they had no knowledge on it or heard of the method. Jahin *et al.* (2020) study employed this technique so as to retain components that described the data without distorting the interpretations.

The orthogonal varimax rotation approach was used to obtain at the 5 major components which were used to classify fewer highly interrelated techniques under each cluster for easier understanding and generalization about the group. The study findings showed that chronic diseases (0.30320, Environment safety (0.3250) and water quality (0.3181) had strong factor on component 1. The study also observed that the respondents' aspects on knowledge (0.3438), effectiveness of control (0.3435), awareness (0.4645) and technicality on use (0.4025 had strong factor loading on component 2. It was further reported that farmers perceived that hired employee health (-0.3393), knowledge (0.3934) and complete control (0.5003) aspects had a strong factor loading on component 4. The study results also showed that technicality on use (0.38360), environment effect (0.5093) and cheap (0.6363) aspects had strong factor loading on component 5 (Table 43). Ricolfi & Testa (2021) study used the orthogonal varimax rotation method to classify highly related aspects in clusters for easier understanding.

Table 42: Eigen value for components

Component	Eigen value	Difference	Proportion	Cumulative
Household health	6.7274	4.92337	0.3957	0.3957
Hired employee health	1.8040	0.38749	0.1061	0.5018
Chronic illness	1.4165	0.162435	0.0833	0.5852
Acute illness	1.2541	0.14091	0.0738	0.6589
Farmer knowledge	1.1132	0.337989	0.0655	0.7244
Effective control	0.775176	0.118324	0.0456	0.77
Complete control	0.656852	0.130249	0.0386	0.8087
Food safety	0.526602	0.0270975	0.031	0.8396
Environment safety	0.499505	0.0504188	0.0294	0.869
Water quality	0.449086	0.0469919	0.0264	0.8954
Biodiversity	0.402094	0.060527	0.0237	0.9191
Soil contamination	0.341567	0.0238582	0.0201	0.9392
Performance	0.317709	0.0840788	0.0187	0.9579
Awareness information	0.23363	0.0353726	0.0137	0.9716
Technical	0.198258	0.0470071	0.0117	0.9833
Environment effect	0.151251	0.0181021	0.0089	0.9922
Cheap	0.133148	.	0.0078	1

Further, the study results observed that some of the unexplained aspects from the respondents (Table 43). All components with significant factor loadings (more than, less than, or equivalent to 0.3) were used to analyze the varimax rotation in this scenario. The study observed that each aspect unexplained variations included: household (0.2406) and employee health (0.14230, chronic illness (0.1612), farmer knowledge (0.2009), effective control (0.21300, complete control (0.4271), food safety (0.3932), environment safety (0.2293), water quality (0.21420, biodiversity (0.2311), soil contamination (0.2754), performance (0.3622), awareness information (0.3807), technical (0.3364), environment effect (0.3655) as well as if they regarded the management method as being cheap (0.2615) [Table 43]. The results findings are line with those of Thairu (2020) study who reported that variables with high factor loadings should be retained

The study observed that the overall Kaiser-Meyer-Olkin measure of sampling adequacy was 0.88 (Table 44).The study further observed that each aspect had a KMO result of:

Household (0.9025) and employee health (0.8600), chronic illness (0.8692), farmer knowledge (0.6782), effective control (0.7634), complete control (0.8889), food safety (0.9422), environment safety(0.9169), water quality (0.90150, biodiversity (0.8918), soil contamination (0.9246), performance (0.8708), awareness information (0.7850), technical (0.7704), environment effect (0.7841) as well as if they regarded the management method as being cheap (0.8053)[Table 44].

Table 43: Rotated components with a blank of (0.3)

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Household health						0.2406
Hired Employee health				-0.3393		0.1423
Chronic illness	0.3032					0.1612
Acute illness						0.2504
Farmer knowledge		0.3438	0.4138	0.3934		0.2009
Effective control		0.3435	0.403			0.2130
Complete control				0.5003		0.4271
Food safety						0.3932
Environment Safety	0.3250					0.2293
Water quality	0.3181					0.2142
Biodiversity			-0.3086			0.2311
Soil Contamination			-0.3149			0.2754
Performance			-0.3267			0.3622
Awareness information		0.4645				0.3807
Technical		0.4025			0.3836	0.3364
Environment effect		0.3667			0.5093	0.3655
Cheap					0.6363	0.2615

Note: comp=Component

The study findings were justified to use of PCA because the overall value was more than 0.5. The results are line with those of Sarmento & Costa (2019) who reported that KMO measure indicated that the values 0.00 to 0.49 = unacceptable, 0.50 to 0.59 = miserable, 0.60 to 0.69 = mediocre, 0.70 to 0.79 = middling, 0.80 to 0.89 =meritorious, 0.90 to 1.00= marvelous.

4.7 Parameter Estimates of the Multivariate Probit Model on Effect of Tomato Farmers' Socio-Economic Characteristics on the Choice of Management of *T. absoluta*

During the study, it was observed that several factors influenced tomato small scale farmers' decisions on use a particular choice of management to control *T. absoluta*.

Multivariate probit model was used to evaluate the effect socio-economic characteristics on the choice of management of *T.absoluta*. MVP model contained eight dependent variables and six independent variables (chemical pesticides, intercropping, desuckering, fertilizer application, crop rotation and staking) whereby five variables (education in years, age of the decision maker, years of experience, area under agriculture and the household income) were continuous variables and three were dummy variables (respondent gender, accessibility to loans as well as extensional training) [Table 45], after dropping some of the management choices which were highly skewed.

Table 44: Kaiser-Meyer-Olkin measure of sampling adequacy

Variable	KMO
Household health	0.9025
Hired Employee health	0.8600
Chronic illness	0.8692
Acute illness	0.8963
Farmer knowledge	0.6782
Effective control	0.7634
Complete control	0.8889
Food safety	0.9422
Environment safety	0.9169
Water quality	0.9015
Biodervisty	0.8918
Soil contamination	0.9246
Performance	0.8708
Awareness information	0.7850
Technical	0.7704
Environment effect	0.7841
Cheap	0.8053
Overall	0.8756

Note: KMO= Kaiser-Meyer-Olkin measure of sampling adequacy

The likelihood ratio test of x^2 (positive) reject the null hypothesis of error term correlation, and this justified MVP model to be employed. Respondent gender, years of schooling, decision maker age, years of experience, area under agriculture, credit access, household income and access to extension services influenced the choice of management methods (Table 45).

Table 45: Multivariate Probit Results

	Chemicalpesticides	Intercropping	Desuckering	Fertilizerapplication	Croprotation	Staking
Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Respodentgender	-0.407(0.649)	-0.156(0.349)	0.907(0.453)*	-0.617(0.304)**	0.396(0.224)*	0.467(0.254)*
Education years	0.45(0.212)**	-0.022(0.052)	-0.041(0.052)	-0.059(0.047)	0.031(0 .030)	0.036(0.033)
Decisionmakerage	-0.158(0.064)**	-0.033(0.031)	0.057(.021)**	-0.039(0.026)	-0.008(0.016)	0.026(.031)
Years' experience	-0.0003(0.074)	0.139(.048)**	0.030(0.040)	0.147(0.045)**	0.043(0.031)	0.000(0.058)**
Area agriculture	0.929(0.390)**	-0.054(0.113)	0.189(0.136)	0.07(0.096)	0.157(.064)**	0.197(0.073)*
Credit access	-0.811(0.866)	0.060(0 .388)	-0.257(0.345)	-0.108(0.346)	0.222(0.203)	-0.533(0.278)
Household income	0.034(0.743)	-0.676(0.356)*	-0.465(0.260)*	-0.052(0.284)	-0.19(0.177)	-0.397(0.193)**
Extension services	0.81(0 .959)	-0.669(0.366)*	-0.128(0.292)	0.000(.338)	0.146(0.201)	0.08(0.208)

*, ** and *** represented 10%, 5% and 1% level of significance respectively. Number of observations = 283, Wald chi2 (88) = 220.71, Log likelihood = -621.567, Prob > chi2 = 0.0000, Likelihood ratio test of rho=0, Chi2 (55) = 124.961, Prob > chi2 = 0.0000.

The study findings showed that the respondent gender variable had a significant (P-value=10%) and positive relationship with tomato small scale farmers' choice on use of desuckering method to control *T. absoluta*. Further, it was observed that gender had a significant (P-value = 5%) and a negative relationship with fertilizer application. Additionally, gender also had a significant (P-value=5%) and positive relationship on crop rotation and staking as methods that the respondents used to control *T. absoluta* (Table 45). The study observed that women were more inclined to like the pesticides management techniques and these required less attention than other IPM strategies. The survey findings are similar to Misango *et al*. (2022) study which observed that gender had a positively and significant (P-value at 5%) association with adoption of various technologies used to control pests. Obeten *et al*. (2021) study results also reported that chemical control outcome category, the variable 'Gender' had a negative and significant effect, indicating that male compared to female farmer have a lower liking for farming relative to use pesticides management strategies in pest management as well as the tactics are used.

The study results further observed that education variable described the number years of schooling for the decision maker in the farm. The findings showed that education had a significant (P-value= 5%) and a positive relationship with use of chemical pesticides but failed to explain *T. absoluta* management choice of intercropping, desuckering, fertilizer application, crop rotation as well as staking. (Table 45). The study results showed that an additional year in years of schooling improves the respondent's awareness on use of chemical pesticides. Education was not significant in other choices of pest management (Table 45). The findings are line with those of Donkoh *et al*. (2019) study who reported that higher education status created more awareness to the farmers to adopt use of various practices in the farm.

Regarding the age of the decision maker, the study findings showed that age had a significant (P-value=5%) but negative relationship with use of chemical pesticides. The results further showed that age also had a significant (P-value=5%) and a positive relationship with use of desuckering pest management choice (Table 45). An increase in year of the respondent led to less use of chemical pesticides and age an increase in age explains that the respondents were more experienced and preferred other IPM management choices as compared to use of chemicals. Age did not explain other choices that is intercropping, fertilizer application, crop rotation and staking. These survey results showed that the young people used more chemicals than the elderly (Table 45). The study findings are consistent with Obetan *et al*. (2021) study which reported that as age increases, the preference for farmer to use IPM techniques is relative among maize framers in Abuja.

Further, the survey investigated the influence of farmers' experience on choice of pest management methods to control *T. absoluta*. The study observed that experience had a significant (P-value=5%) and positive relationship with intercropping, fertilizer application and staking management methods (Table 45). Years of experience had no relationship with chemical pesticides use, desuckering and crop rotation. This can be explained by the fact that the more the experienced the tomato small scale farmers were, the more they had knowledge on use of various cultural methods to control *T.absoluta*. The study results contradicted with those of Tong *et al*. (2022) who reported that the more experienced the farmers, the less they adopted IPM techniques in China. The results also showed that extensional training and accessibility had an insignificant relationship with all the variables except intercropping pest management method which was significant at (P-value=1%) and a negative relationship (Table 45). This showed that reduction extensional training and accessibility led to less use of intercropping pest management method to control *T. absoluta* due to lack of knowledge. The study results were consistent with Tong *et al.* (2022) study which reported that farmers had less accessibility to extension services and the government promoted it among tomato farmers in China.

Further, the study sought to determine how the size of land affected the pest management methods to control *T. absoluta* in tomato. That is depicted by the area under agriculture influenced use of chemical pesticides, crop rotation and staking. The area under agriculture was significant at (P-value=5%) and had a positive relationship with chemical pesticides use and crop rotation while staking was significant at (1%) [Table 45]. The study findings observed that an increase in size of land affected these management choices. The survey findings were consistent to Maja & Ayano (2021) study who reported that that land scarcity can lead to reduction in agriculture intensification and adoption of new technologies such as use of IPM techniques.

The study also investigated the effect of income on *T. absoluta* management methods. The study results observed that income had a significant and a negative relationship with intercropping, desuckering and staking. It was also observed that household income was significant (P-Value at 1%) and had negative relationship with intercropping and desuckering while Staking was significant at (P-value 5%) [Table 45). The study observed that farmers used income from multiple choices to purchase chemical pesticides which they explained that was much effective as compared to cultural and biological control methods. The findings were consistent to Porras *et al.* (2021) study who observed that income was significant to integrated pest management methods.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of the Findings

The aim of the study was to analyze effects of tomato farmers' gross margin, perception and socio-economic characteristics on choice of *Tuta absoluta* management methods in Mwea, Kirinyaga County. The study employed cross-sectional descriptive research design to obtain data and understand the gross margin, farmers' perception and farmer socio-economic characteristics on choice of management of *T. absoluta* among small scale tomato farmers in Mwea**.** The study projected a sample of 303 tomato small scale farmers whereby 283 respondents practiced tomato farming in open field and greenhouse target was 20 respondents who had ceased tomato production in greenhouses.

The study sought to investigate the effect of tomato farmers' gross margin on the choice of management of *T. absoluta* in Mwea, Kirinyaga County. Gross margin analysis was done by generating the tomato farmer gross margin and a multiple regression model was used to analyze the effect of tomato farmers' gross margin on the choice of management of *T. absoluta*. The mean average total revenue in one acre of the total tomato sold was 511275.60 KES with a minimum of 64000 KES and a Maximum of 1520000 KES. The average production costs of tomato in one acre is 113226.20 KES with a minimum of 4800 and 204200 KES. The gross margin per kilogram in one acre was at an average 11.44 KES with a minimum of 0.92 and a maximum of 132 KES. Two out of the eighteen hypothesized variables namely crop rotation and weeding were significant. Crop rotation was significant at (P-value 5%) and had a positive relationship with the tomato gross margin whereas weeding was significant and had a negative relationship with the tomato gross margin. The coefficient of crop rotation was positive implying that the more the farmers practiced crop rotation, the gross margin increased. The coefficient for weeding was negative implying that weeding for the tomato did not affect the gross margin of the farmers in controlling *T. absoluta.*

The study further aimed at investigating the effect of tomato farmer's perception on the choice of management of *T. absoluta* in Mwea, Kirinyaga County. Principal component analysis model was used to classify the aspects that the farmers perceived to be affecting the choice of management methods used to control *T. absoluta*. The aspects were further analyzed using principal component analysis method so as to be able to understand the tomato small scale farmers' perceptions towards pest management methods used to control *T. absoluta*. The Eigen values were used so as to further reduce the components into fewer comments which gave the relation and factor loadings. The components which had eigenvalue more than 1 were retained and used for further analysis. The study findings showed that chronic diseases, Environment safety and water quality had strong factor on component 1. The respondents' aspects on knowledge, effectiveness of control, awareness, technicality on use and cheap had strong factor loading on component 2. Some of the respondents perceived that hired employee health, knowledge and complete control aspects were had a strong factor loading on component 4. Technical, environment effect and afforadability had strong factor loading on component 5.

With regard to farmers' socio-economic characteristics on the choice of management of *T. absoluta* in Mwea, Kirinyaga County, a multivariate probit model was used and the respondent gender variable showed a significant (P-value=10%) and positive relationship with tomato small scale farmers choice on use of desuckering method to control *T. absoluta*. Gender had a significant (P-value = 5%) and a negative relationship with fertilizer application. Additionally, gender also had a significant (P-value=5%) and positive relationship crop rotation and staking as methods that the respondents used to control *T. absoluta*. Education had a significant (P-value= 5%) and a positive relationship with use of chemical pesticides.

Age of the decision maker had a significant (P-value=5%) but negative relationship with use of chemical pesticides. The variable age also had a significant (P-value=5%) and a positive relationship with use of desuckering pest management choice. experience had a significant (P-value=5%) and positive relationship with intercropping, fertilizer application and staking management methods. The area under agriculture was significant at (P-value=5%) and had a positive relationship with chemical pesticides use and crop rotation while staking was significant at (1%). household income had a significant and a negative relationship with intercropping, desuckering and staking. Household income was significant (P-Value at 1%) and had negative relationship with intercropping and desuckering. The results estimates showed that Staking was significant at (P-value 5%). Access to extension services had no a significant relationship with all the variables except intercropping pest management method which was significant at (P-value=1%) and a negative relationship.

5.2 Conclusions

The study results concluded that:

i. Tomato farmers' returns on management choice of *T. absoluta* can be increased by employing crop rotation and weeding. Chemicals use, plant incorporated protectants, intercropping, desuckering or pruning, uprooting and damage of crop residue, fertilizer application, predators, parasites, bio-insectides, IPM techniques, staking and bio-herbicides were not significant
ii. Farmers perceive that household health, hired employee health, chronic and acute illness and farmer's knowledge are some of the key aspects they consider when choosing the pest management choice to use to control *T. absoluta*.
iii. The effect of gender, education, age, experience, land size, loan accessibility, household revenue and extensional services have a significant with positive or negative relationship with the various pest management methods used to control *T. absoluta*.

5.3 Recommendations

The study recommended that:

i. Tomato small scale farmers should are encouraged to use other pest management methods such as use of crop rotation and weeding so as not to rely on use of chemical pesticides alone to control *T. absoluta*.
ii. Tomato small scale farmers are encouraged to seek more training from various sources so as to be able get deeper understanding on control of *T. absoluta* which is spreading very fast and reducing tomato yields.
iii. Tomato small scale farmers are encouraged to join tomato farmers group and organizations whereby they can be taught more on tomato pest management practices by extension officers and other trainers.
iv. County and National government policymakers should adopt policies that encourage the use of integrated pest management methods to avoid use of excess chemical pesticides in tomato production.

5.4 Suggestion for Further Research

The suggestions include:

i. Determine socioeconomic characteristics influence on choice of tomato farmer's gross margin on choice of pest management in Kenya.

ii. Determine consumers` opinions of chemical pesticide use in tomato production on food safety and consumers' health in Kenya.

REFERENCES

Abbes, K., Biondi, A., Zappalà, L., & Chermi, B. (2014). Fortuitous parasitoids of the invasive tomato leaf miner *Tuta absoluta* in Tunisia Phytoparasitica 42:85-92.

Abbes, K., Harbi, A., & Chermiti, B. (2012). The tomato leafminer *Tuta absoluta* (Meyrick) in Tunisia: current status and management strategies. EPPO Bull. 42:226-233.

Abbey, L., Abbey, J., Leke-Aladekoba, A., Iheshiulo, E. M. A., & Ijenyo, M. (2019). Biopesticides and biofertilizers: types, production, benefits, and utilization. *Byproducts from Agriculture and Fisheries: Adding Value for Food, Feed, Pharma, and Fuels*, 479-500.

Abdallah, A. H., Abdul-Rahaman, A., & Issahaku, G. (2021). Sustainable agricultural practices, farm income and food security among rural households in Africa. *Environment, Development and Sustainability,* 1-34.

Abdel-Raheem, A., Ismail, A., Abdel-Rahman, S., Abdel-Rhman, E., & Naglaa, F. (2015). Efficacy of Three Entomopathogenic Fungi on Tomato leaf miner, *Tuta absoluta* in Tomato crop in Egypt. *Journal of Agriculture Research*. 1(2):015-021.

Abu, G., Abah, D & Okpachu, A. (2011). Analysis of cost and return for Sesame production in Nasarawa State: Implication for sustainable development in Nigeria. *Journal of Sustainable Development in Africa*. 2011; 13(3): 238–249.

Abunyuwah, I., Ahiale, D., & Blay, K. (2019). Determinants of farmers' pesticide usage patterns in tomato production in Ghana. A case study of Akomadan.

Acosta, M., Wessel, M., Van, S., Ampaire, L., Twyman, J., Jassogne, L., & Feindt, H. (2020). What does it mean to make a 'joint'decision? Unpacking intra-household decision making in agriculture: Implications for policy and practice. *The journal of development studies*, *56*(6), 1210-1229.

Adewuyi, S., Phillip,B., Ayinde,A & Akerele, D. (2010). Analysis of Profitability of Fish Farming in Ogun State, Nigeria. *Journal of Hum*an *Ecology*. 2010; 31(3): 179–184.

Ahmed, M.H. (2015). Adoption of multiple agricultural technologies in maize production of the Central Rift valley of Ethiopia. *Studies in Agricultural Economics, 117* (3), pp. 162–168.

Ainembabazi, H., & Mugisha, J. (2014). The role of farming experience on the adoption of agricultural technologies: evidence from smallholder farmers in Uganda. *Journal of Development Studies, 50*(5), 666-679.

Akoko, G., Kato, T., & Tu, H. (2020). Evaluation of Irrigation Water Resources Availability and Climate Change Impacts. A Case Study of Mwea Irrigation Scheme, Kenya. *Water, 12*(9), 2330.

Alexoaei, A., Robu, G., Cojanu, V., Miron, D., & Holobiuc, M. (2022). Good Practices in Reforming the Common Agricultural Policy to Support the European Green Deal–A Perspective on the Consumption of Pesticides and Fertilizers. *Amfiteatru Economic*, *24*(60), 525-545.

Ali, S., Khan, J., Jadoon, A., Riaz, M., & Khan, A. (2020). Evaluation of farmer's socioeconomic characteristics influencing tomato output in district Peshawar, Khyber Pakhtunkhwa, Pakistan. Sarhad. *Journal of Agriculture*, *36*(3), 894-899.

Al-Jboory, J., Katbeh-Bader, A., & Al-Zaidi, S. (2012). First observation and identification of some natural enemies collected from heavily infested tomato by *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Jordan. Journal of science in Entomology.

Aloyce, A., Ndakidemi, A., & Mbega, R. (2017). Identification and Management Challenges Associated with *Ralstonia solanacearum* (Smith), Causal Agent of Bacterial Wilt Disease of Tomato in Sub-Saharan Africa. *Pakistan journal of biological sciences: PJBS*, *20*(11), 530-542.

Aloysius, C., Victor, U., Caleb, I., & Odinaka, O. (2021). Technical Efficiency and Technological Gap Ratios of Tomato Production in Northern Nigeria: A Stochastic Meta Frontier Approach. *The Bangladesh Journal of Agricultural Economics*, *42*(1), 1-18.

Anani, O. A., Mishra, R. R., Mishra, P., Enuneku, A. A., Anani, G. A., & Adetunji, C. O. (2020). Effects of Toxicant from Pesticides on Food Security: Current Developments. In *Innovations in Food Technology* (pp. 313-321). Springer, Singapore.

Ankrah, A., Agyei-Holmes, A., & Boakye, A. (2021). Participatory farm budgeting–A case of pineapple farmers in Ghana. *African Geographical Review*, 1-15.

Arno, J., Sorribas, R., Prat, M., Matas, M., Pozo, C., Rodríguez, D & Perdikis, D. (2009). *Tuta absoluta*, a new pest in IPM tomatoes in the northeast of Spain. IOBC/WPRS. Bull. 49:203-208.

Asante, B., Osei, K., Dankyi, A., Berchie, N., Mochiah, M., Lamptey, J, Haleegoah, J. & Bolfrey-Arku, Osei, K. (2013). Producer characteristics and determinants of technical efficiency of tomato based production systems in Ghana. *Journal of Development Agricultural Economics*. 5(3):92-103.

Babcock & Hennessey. (1996). *Expected utility theory*.

Balana, B., & Oyeyemi, A. (2022). Agricultural credit constraints in a smallholder farming in developing countries: Evidence from Nigeria. *World Development Sustainability*, 100012.

Balasha, M. (2019). Drivers of adoption of integrated pest management among small-scale vegetable farmers in Lubumbashi, DR Congo. *American Journal of Rural Development*, *7*(2), 53-59.

Benu, C., Rachaputi & Douglas, C. (2010). The economic performance and management practices of mungbean production systems in Belu, West Timor. Proceedings of the 1st Australian Summer Grains Conference, Gold Coast, Australia, 2010 June 21–24.

Biondi, A., Guedes, C., Wan, H. & Desneux, N. (2018). Ecology, worldwide spread, and managementof the invasive South American tomato pinworm, *Tuta absoluta*: past, present, and future. – *Annual Review of Entomology*, 63: 239–258.

Bisht, S., Rana, C., & Pal Ahlawat, S. (2020). The future of smallholder farming in India: Some sustainability considerations. *Sustainability, 12*(9), 3751.

Brevault, T., Sylla, S., Diatte, M., Bernadas, G., & Diarra, K. (2014). *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae): a new threat to tomato production in sub-Saharan Africa: Short communications. *Africa Journal of Entomology*. 22:441-444.

Brown, D. (2002). The Cronbach alpha reliability estimate. *JALT Testing & Evaluation SIG Newsletter, 6*(1).

Bueno, F., Carvalho, A., & Santos, A. (2017). Pesticide selectivity to natural enemies: challenges and constraints for research and field recommendation. Cienc Rural 47:1–10.

Campos, R.., Biondi, A., Adiga, A., Guedes, N., & Desneux, N. (2017). From the Western Palaearctic region to beyond: *Tuta absoluta* 10 years after invading Europe. *Journal of Pest Science*, *90*(3), 787-796.

Catherine, K., Oscar, A., & Jane, N. (2019). Determinants of intensity of uptake of alternative pest control methods: A case of small- scale tomato farmers in Kenya. *Journal of Development and Agricultural Economics*, *11*(5), 110–121.

Cely, P., Cantor, F & Rodríguez, D. (2010). Determination of levels of damage caused by different densities of *Tuta absoluta* populations (Lepidoptera: Gelechiidae) under greenhouse conditions. *Agronomy*, 28:392-402.

Central Intelligence Agency. (2017). The World Fact book, Field Listing: *Exports – Commodities*. CIA, Washington, DC.

Chandio, A., Jiang, Y., Rehman, A., Twumasi, A., Pathan, G., & Mohsin, M. (2020). Determinants of demand for credit by smallholder farmers': a farm level analysis based on survey in Sindh, Pakistan. *Journal of Asian Business and Economic Studies*.

Chen, D., Xue, Y., & Gomes, C. (2018). End-to-end learning for the deep multivariate probit model. In *International Conference on Machine Learning* (pp. 932-941). PMLR.

Chepchirchir, F., Muriithi, B., Langat, J., Mohamed, A., Ndlela, S., & Khamis, M. (2021). Knowledge, Attitude, and Practices on Tomato Leaf Miner, *Tuta absoluta* on Tomato and Potential Demand for Integrated Pest Management among Smallholder Farmers in Kenya and Uganda. *Agriculture*, *11*(12), 1242.

Chhetri, B. (2018). Tomato Leafminer (*Tuta absoluta*) an emerging agricultural pest: Control and management strategies: A Review. *World Scientific News*, *114*, 30–43.

Chimoita, L., Onyango, M., Kimenju, W., & Gweyi-Onyango, P. (2017). Agricultural Extension Approaches influencing uptake of improved sorghum technologies in Embu County, Kenya. *Universal Journal of Agricultural Research*, 5(1), 45-51.

Cocco, A., Pacheco da Silva, C., Benelli, G., Botton, M., Lucchi, A., & Lentini, A. (2021). Sustainable management of the vine mealybug in organic vineyards. *Journal of Pest Science*, *94*(2), 153-185.

Colmenárez, C., Vásquez, C., de Freitas Bueno, A., Cantor, F., Hidalgo, E., Corniani, N., & Lagrava, J. (2022). Sustainable Management of the invasive *Tuta absoluta* (Lepidoptera: Gelechiidae): an Overview of Case Studies from Latin American countries participating in Plant wise. *Journal of Integrated Pest Management*, 13(1), 15.

Conradie, B & Landman, A. (2013). A comparison of the performance under the field conditions of wooled and mutton sheep flock in low rainfall region of South Africa. Pretoria: CSSR Working Paper No. 331: 2013. (18 pages).

Constantine, K., Kansiime, M., Mugambi, I., Nunda, W., Chacha, D., Rware, H. & Day, R. (2020). Why don't smallholder farmers in Kenya use more biopesticides? *Pest management science*, *76*(11), 3615-3625.

Constantine, L., Murphy, T., & Pratt, F. (2020). The interaction between pests, mixed-maize crop production and food security: a case study of smallholder farmers in Mwea West, Kenya. *Cogent Food & Agriculture*, *6*(1), 1857099.

Damalas, C & Koutsoubos, S. (2018). Farmers' training on pesticide use is associated with elevated safety behavior. *Toxics* 2017, *5*, 19.

Damalas, C & Khan, M. (2016). Farmers' attitudes towards pesticide labels: Implications for personal and environmental safety. *International Journal of Pest Management*, 62(4), 319–325.

Damos, P., Colomar, L., & Ioriatti, C. (2015). Integrated Fruit Production and Pest Management in Europe: The Apple Case Study and How Far We Are From the Original Concept? *Insects*, *6*(3), 626–657.

Desneux, N., Han, P., Mansour, R., Arnó, J., Brévault, T., Campos, M. R., & Biondi, A. (2021). Integrated pest management of *Tuta absoluta*: practical implementations across different world regions. *Journal of Pest Science*, 1-23.

Despotović, J., Rodić, V., & Caracciolo, F. (2019). Factors affecting farmers' adoption of integrated pest management in Serbia: An application of the theory of planned behavior. *Journal of Cleaner Production, 228*, 1196–1205.

Donkoh, A., Azumah, B & Awuni, J. (2019). Adoption of improved agricultural technologies among rice farmers in Ghana: A multivariate probit approach. *Ghana Journal of Development Studies*, *16*(1), 46-67.

Ehiakpor, D. ., Danso-Abbeam, G., & Mubashiru, Y. (2021). Adoption of interrelated sustainable agricultural practices among smallholder farmers in Ghana. *Land Use Policy*, *101*, 105142.

Food and Agriculture Organization. (2017). FAOSTAT Database. *http://faostat3.fao.org/*.

Food and Agriculture Organization. (2019). FAOSTAT Database. *http://faostat3.fao.org/*.

Food and Agriculture Organization. (2014). FAOSTAT: Statistics of Food and Agri-culture Organization of the United Nations. *http://www.fao.org/statistics*.

Food and Agriculture Organization. (2018). FAOSTAT. Production and food supply data.

Food and Agriculture Organization. (2022). FAOSTAT: Statistics of Food and Agri-culture Organization of the United Nations. *http://www.fao.org/statistics*.

Futemma, C., De Castro, F., & Brondizio, E. S. (2020). Farmers and social innovations in rural development: collaborative arrangements in eastern Brazilian Amazon. *Land Use Policy*, *99*, 104999.

Ganiu, I. (2019). Analysis of marketing chanenels, gross margin and postharvest losses of smallholder irrigated tomato farming in kassena-nankana municipality (*Doctoral dissertation*).

Gao, L., Zhang, W., Mei, Y., Sam, G., Song, Y., & Jin, S. (2018). Do farmers adopt fewer conservation practices on rented land? Evidence from straw retention in China. *Land Use Policy*, *79*, 609-621.

Gatahi, M. (2020). Challenges and opportunities in tomato production chain and sustainable standards. *International Journal of Horticultural Science and Technology*, *7*(3), 235-262.

Geocurrents Maps. Map of Kenya. (2019). Geocurrents.

Gilbertson, L., Vasquez-Mayorga, M., & Macedo, M. (2017). Integrated pest management in tomato Cultivation University of California-Davis, USA; and R. Muniappan, Virginia Tech, USA. In *achieving sustainable cultivation of tomatoes* (pp. 443-470). Burleigh Dodds Science Publishing.

Gilbertson, L., Vasquez-Mayorga, M., & Macedo, M. (2017). Integrated pest management in tomato Africa. *Entomologia Generalis*, *38*(2), 83–112.

Goeb, J., Smart, J., Snyder, J., & Tschirley, D. (2022). *Information, pesticide safety behaviors, and toxicity risk perceptions: Evidence from Zambia and Mozambique* (Vol. 2118).

Goftishu, M., Seid, A., & Dechassa, N. (2014). Occurrence and population dynamics of tomato leaf miner *Tuta absoluta* (Meyrick), Lepidoptera: Gelechiidae] in Eastern Ethiopia. *East Africa Journal of Science.* 8:59-64.

Grasswitz, R. (2019). Integrated Pest Management (IPM) for Small-Scale Farms in Developed Economies: Challenges and Opportunities. *Insects*, *10*(6), 179.

Greene, H. (2003). *Econometric Analysis*. Upper Saddle River, NJ: Prentice Hall International, New York University.

Guan, Z., Biswas, T., & Wu, F. (2018). The US tomato industry: An overview of production and trade. *EDIS*, *2018*(2).

Guedes, C & Picanço, C. (2012). The tomato borer *Tuta absoluta* in South America: pest status, management and insecticide resistance. – *EPPO Bulletin* 42: 211–216.

Haig, M. (2020). The concept of income—economic and legal aspects. In *Forerunners of Realizable Values Accounting in Financial Reporting* (pp. 140-167). Routledge.

Hair, S., Black, C., Babin, B., Anderson, E & Tatham, L. (2013). Multivariate Data Analysis. *Pearson Education Limited.* 7th edition: Essex, UK.

Han, P., Bayram, Y., Shaltiel-Harpaz, L., Sohrabi, F., Saji, A., Esenali, T., & Desneux, N. (2019). *Tuta absoluta* continues to disperse in Asia: damage, ongoing management and future challenges. *Journal of Pest Science*, *92*(4), 1317-1327.

Hanafi, A., & Rapisarda, C. (2017). Integrated pest management and good agricultural practice recommendations in greenhouse crops. *Integrated Pest Management in Tropical Regions*, 204.

Harbi, A., Abbes, K., & Chermiti, B. (2012). Evaluation of two methods for the protection of tomato crops against the tomato leafminer *Tuta absoluta* (Meyrick) under greenhouses in Tunisia. *EPPO. Bulluletin.* 42:317-321.

Heeb, L., Jenner, E., & Cock, W. (2019). Climate-smart pest management: building resilience of farms and landscapes to changing pest threats. *Journal of Pest Science*, *92*(3), 951–969.

Heuvelink, E. (2018). Tomatoes, 2nd Edition. In *Google Books*. CABI.

Jahin, S., Abuzaid, S., & Abdellatif, D. (2020). Using multivariate analysis to develop irrigation water quality index for surface water in Kafr El-Sheikh Governorate, Egypt. *Environmental Technology & Innovation*, *17*, 100532.

Kansiime, K., Mugambi, I., Rwomushana, I., Nunda, W., Lamontagne-Godwin, J., Rware, H., & Day, R. (2019). Farmer perception of fall and farm-level management practices in Zambia. *Pest Management Science*, *75*(10), 2840-2850.

Kapp, S., Prematunga, R., & Santamaria, N. (2021). The "self-treatment of wounds for venous leg ulcers checklistThe reliability of the Checklist. *International Wound Journal*, *19*(3), 714-723.

Kassie, M., Teklewold, H., Jaleta, M., Marenya, P & Erenstein, O. (2015). Understanding the adoption of a portfolio of sustainable intensification practices in eastern and southern Africa.

Kassie, M., Zikhali, P., Manjur, K & Edwards, S. (2009). Adoption of organic farming technologies: Evidence from semi-arid regions of Ethiopia. *Natural Resources Forum*, 33: 189– 198.

Kazeem, A., Dare, A., Olalekan, O., Abiodun, E., & Komolafe, L. (2017). Attitudes of farmers to extension trainings in Nigeria: Implications for adoption of improved agricultural technologies in Ogun State Southwest Region. *Journal of Agricultural Sciences, Belgrade*, *62*(4), 423-443.

Kenya National Bureau of Statistics (KNBS). (2019). *Kenya Population and Housing Census*, Volume I.

Kenya Population & Housing Census (KPHC). (2019). Population by County and Sub-County, Volume l1. *Kenya National Bureau of Statistics*, Kenya.

Kinuthia, W. (2019). Determinants of pesticide use and uptake of alternative pest control methods among small scale tomato farmers in Nakuru County, Kenya.

Kinuthia, W., Ayuya, I & Nyaanga, G. (2019). Determinants of intensity of uptake of alternative pest control methods: A case of small-scale tomato farmers in Kenya. *Journal of Development and Agricultural Economics*, 11(5):110-121.

Kinyanjui, G., Khamis, M., Ombura, O., Kenya, U., Ekesi, S., & Mohamed, A. (2021). Distribution, abundance and natural enemies of the invasive tomato leafminer, *Tuta absoluta* (Meyrick) in Kenya. *Bulletin of Entomological Research*, 1-16.

Kirinyaga County Ministry of Agriculture. Crop Production Department. (2021).

Kirinyaga County Ministry of Agriculture. Crop Production Department. (2022).

Knaresboro, M. (2019). *Adoption Determinants and Impacts of Tuta absoluta Integrated Pest Management for Nepali Tomato Farmers* (Doctoral dissertation, Virginia Tech).

Konan, J., Monticelli, L., Ouali-N'goran, M., Ramirez-Romero, R., Martin, T., & Desneux, N. (2021). Combination of generalist predators, *Nesidiocoris tenuis* and *Macrolophus pygmaeus*, with a companion plant, *Sesamum indicum*: What benefit for biological control of *Tuta absoluta*? *Plos one*, *16*(9).

Kotamraju, K., Babu, C., & Maligireddy, R. (2021). Impact of Market Reforms on Technology Adoption and Profitability: The Case of Tomato Farmers in India. *Journal of Applied Economics*, *28*(2), 1-20.

Kuehne, G., Llewellyn, D., Pannell, R., Wilkinson, P., Dolling, J., Ouzman & M. Ewing. 2017. Predicting Farmer Uptake of New Agricultural Practices: A Tool for Research, Extension and Policy. *Agricultural Systems* 156: 115– 125.

Kumar, A., Kumar, V., Gull, A., & Nayik, G. A. (2020). Tomato (Solanum lycopersicon). *Antioxidants in Vegetables and Nuts - Properties and Health Benefits*, 191–207.

Kwadzo, M., & Quayson, E. (2021). Factors influencing adoption of integrated soil fertility management technologies by smallholder farmers in Ghana. *Heliyon*, e07589.

Lamptey, S., & Koomson, E. (2021). The Role of Staking and Pruning Methods on Yield and Profitability of Tomato (Solanum lycopersicum L.) Production in the Guinea Savanna Zone of Ghana. *Advances in Agriculture*, *2021*.

Lastra-Bravo, B., Hubbard, C., Garrod, G., Tol_on-Becerra, A. (2015). What drives farmers' participation in EU agri-environmental schemes? Results from a qualitative meta-analysis. *Environmental Science Policy* 54: 1-9.

Linh, T., Long, H., Chi, L., Tam, L., & Lebailly, P. (2019). Access to Rural Credit Markets in Developing Countries, the Case of Vietnam: A Literature Review. *Sustainability*, *11*(5), 1468.

Liu, H., & Brouwer, R. (2022). Incentivizing the future adoption of best management practices on agricultural land to protect water resources: The role of past participation and experiences. *Ecological Economics*, *196*, 107389.

Llewellyn R. & Brown, B. (2020). Predicting adoption of innovations by farmers: What is different in smallholder agriculture? *Applied Economic Perspectives and Policy*, *42*(1), 100-112.

López, A., Luque, A., Orozco, D., Alencastro, S., Ruiz, A., García, T., & Gradilla, S. (2021). Food loss in the agricultural sector of a developing country: Transitioning to a more sustainable approach. The case of Jalisco, Mexico. *Environmental Challenges*, *5*, 100327.

Macharia, I., Mithofer, D & Waibel, H. (2013). Pesticide handling practices by vegetable farmer in Kenya. *Environment, Development and Sustainability*15:887-902.

Mahmoud, M., Bendebbah, R., Benssaci, B., Toudji, F., Tafifet, L., & Krimi, Z. (2021). Entomopathogenic efficacy of the endophytic fungi: Clonostachys sp. and Beauveria bassiana on *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) larvae under laboratory and greenhouse conditions. *Egyptian Journal of Biological Pest Control*, *31*(1), 1-6.

Maina, K. W., Ritho, C. N., Lukuyu, B. A., Rao, E. J. O., & Mugwe, J. G. (2021). Knowledge, attitudes, and practices of dairy farmers in the adoption of Brachiaria grass in Kenya. *Scientific African*, *13*, e00874.

Maja, M & Ayano, F. (2021). The impact of population growth on natural resources and farmers' capacity to adapt to climate change in low-income countries. *Earth Systems and Environment*, *5*(2), 271-283.

Mansour, R., Brévault, T., Chailleux, A., Cherif, A., Grissa-Lebdi, K., Haddi, K. & Biondi, A. (2018). Occurrence, biology, natural enemies and management of *Tuta absoluta* in Africa. *Entomologia Generalis*, *8*(2), 83-112.

Materu, L., Shao, A., Losujaki, E., Chidege, M., & Mwambela, N. (2016). Farmer's perception knowledge and practices on management of *Tuta absoluta* Meyerick (Lepidoptera: Gelechiidae) in tomato growing areas in Tanzania. *International Journal of Research in Agriculture and Forestry*, *3*, 1-5.

Mathinya, V., Franke, C., Van De Ven, J., & Giller, E. (2022). Productivity and constraints of small-scale crop farming in the summer rainfall region of South Africa. *Outlook on Agriculture*, *51*(2), 139-154.

Matumwabirhi, K. (2020). Effectiveness of Trichoderma Spp., Bacillus Spp. And Pseudomonas Fluorescens in the Management of Early Blight of Tomatoes. *Erepository university of Nairobi.*

Mauti, O. (2021). Role of Information and Communication Technology and Socio-Economic Factors on Marketing of Tomatoes among Smallholder Farmers in Kirinyaga County, Kenya (*Doctoral dissertation, University of Embu*).

Mauti, O., Ndirangu, N., & Mwangi, C. (2021). Choice of Information and Communication Technology Tools in Tomato Marketing Among Smallholder Farmers in Kirinyaga County, Kenya. *Journal of Agricultural Extension*, *25*(3), 81-92.

Mbogo T. (2020). Technical efficiency, profitability and market Diversity among smallholder tomato farmers in Kirinyaga County. (Doctoral dissertation, UoEm).

Mehmood, Y., Arshad, M., Kaechele, H., Mahmood, N., & Kong, R. (2021). Pesticide residues, health risks, and vegetable farmers' risk perceptions in Punjab, Pakistan. *Human and Ecological Risk Assessment: An International Journal*, *27*(3), 846-864.

Melomey, D., Ayenan, A., Marechera, G., Abu, P., Danquah, A., Tarus, D., & Danquah, Y. (2022). Pre-and Post-Harvest Practices and Varietal Preferences of Tomato in Ghana. *Sustainability*, *14*(3), 1436.

Melomey, D., Danquah, A., Offei, K., Ofori, K., Danquah, E., & Osei, M. (2019). Review on tomato (*Solanum lycopersicum*) improvement programmes in Ghana. *Recent advances in tomato breeding and production*, *49*.

Mensah, M., & Onyancha, B. (2022). Ghanaian academic libraries' use of social media: A structural equation modelling approach. *Information Development*, *38*(2), 323-342.

Michereff, M., Vilela, F., AttygalleMeinwald, J., Svatoš, A., Jham, N. (2000). Field trapping of tomato moth, *Tuta absoluta* with pheromone traps. *Journal of Chemical Ecology*. 26:875-881.

Miranda, M., Picanço, C., Zanuncio, C., Bacci, L., Silva, D. (2005). Impact of integrated pest management on the population of leafminers, fruit borers, and natural enemies in tomato. *Ciênc. Rural* 35:204-208.

Misango, G., Nzuma, J, Irungu, P. & Kassie, M. (2022). Intensity of adoption of integrated pest management practices in Rwanda: A fractional logit approach.

Mitra, S., & Sharmin, S. (2019). Risk Attitudes and Financial Profitability of Tomato Farmers-A Study in Bangladesh. *Mitra, S. and Sharmin, S*, 207-217.

Mittal, S., & Mehar, M. (2016). Socio-economic factors affecting adoption of modern information and communication technology by farmers in India: Analysis using multivariate probit model. *The Journal of Agricultural Education and Extension*, *22*(2), 199-212.

Mkonyi, L. (2021). Development of model for early identification of tomato plant damages caused by *Tuta absoluta* (Doctoral dissertation, NM-AIST).

Mohamed, I., Mahmoud, E., Elhaj, M., Mohamed, A., & Ekesi, S. (2015). Host plants record for tomato leaf miner *Tuta absoluta* (Meyrick) in Sudan.

Mohamed, O., Kamel, K., Allam, A., & Mohamed, M. (2021). The Role of Agricultural Extension in Diffusion and Adoption of Biological Control Methods for Tomato Growers in Villages of Matrouh Governorate. *Asian Journal of Agriculture and rural Development*, *11*(2), 210-221.

Mohammadrezaei, M & Hayati, D. (2015). The role of agricultural extension services in integrated pest management adoption by Iranian pistachio growers. *International Journal of Agricultural Extension*, *3*(1), 47-56.

Mohammed, H., Birhane, Z., & Alemayehu, G. (2019). Determinants of market outlet choice decision of tomato producers in Fogera woreda, South Gonder zone, Ethiopia. *Cogent Food & Agriculture*, *5*(1), 1709394.

Moinina, A., Lahlali, R., MacLean, D., & Boulif, M. (2018). Farmers' knowledge, perception and practices in apple pest management and climate change in the Fes-meknes region, Morocco. *Horticulturae*, *4*(4), 42.

Mollá, O., Biondi, A., Alonso-Valiente, M., Urbaneja, A. (2014). A comparative life history study of two mirid bugs preying on *Tuta absoluta* and *Ephestia kuehniella* eggs on tomato crops: implications for biological control. BioCont 59:175-183.

Mollár, O., González-Cabrera, J., Urbaneja, A. (2011). The combined use of *Bacillus thuringiensis* and Nesidiocoris tenuis against the tomato borer,*Tuta absoluta*. BioCont 56:883-891.

Momanyi, N.,Keraka, A., Abong'o, D., & Warutere, P. (2019). Types and classification of pesticides used on tomatoes grown in Mwea irrigation scheme, Kirinyaga County, Kenya. *European Journal of Nutrition & Food Safety*, 83-97.

Morrison, G. (2022). Economic Viability of Weed Management Strategies in High-Tunnel Tomato.

Moser, R., Pertot, I., Elad, Y., & Raffaelli, R. (2008). Farmers' attitudes toward the use of biocontrol agents in IPM strawberry production in three countries. *Biological. Control* 2, *47*, 125–132.

Moussa, A., Baiomy, F., & El-Adl, E. (2013). The status of tomato leafminer; *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in Egypt and potential effective Pesticides. *Academic Journal of Entomology* 6:110-115.

Mukwa, F., Mukendi, J., Adakate, G., Bugeme, M., Kalonji-Mbuyi, A. & Ghimire, S. (2021). First report of the South American tomato pinworm *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) and its damage in the Democratic Republic of Congo. *BioInvasions Record*, *10*(1).

Mulume, S., Dontsop, M., Nyamugira, A., Jean, S., Manyong, V., & Bamba, Z. (2022). Farmers' credit access in the Democratic Republic of Congo: Empirical evidence from youth tomato farmers in Ruzizi plain in South Kivu. *Cogent Economics & Finance*, *10*(1), 2071386.

Mwangi, M., Ndirangu, N., & Isaboke, N. (2020). Technical efficiency in tomato production among smallholder farmers in Kirinyaga County, Kenya. *African Journal of Agricultural Research*, *16*(5), 667-677.

Mwangi, W., Kimenju, W., Narla, D., Kariuki, M., & Muiru, M. (2015). Tomato management practices and diseases occurrence in Mwea West Sub County. *Journal of Natural Sciences Research, 5*(20), 119-124.

Mwaura, F. (2014). Effect of farmer group membership on agricultural technology adoption and crop productivity in Uganda. *African Crop Science Journal, 22*, 917–927.

Mwenda, E., Muange, N., & Ngigi, W. (2022). Determinants of Adoption of ICT-Based Pest Information Services by Tomato Farmers in the Central Highlands of Kenya. *Journal of African Interdisciplinary Studies, 6*(4), 18-36.

Nakhungu, V., Keraka, N., Abong'o, A., & Warutere, N. (2021). Pesticide Residues on Tomatoes Grown and Consumed in Mwea Irrigation Scheme, Kirinyaga County, Kenya. *Asian Journal of Agricultural and Horticultural Research*, 1-11.

Narita, D., Sato, I., Ogawada, D., & Matsumura, A. (2020). Integrating economic measures of adaptation effectiveness into climate change interventions: A case study of irrigation development in Mwea, Kenya. *PloS one*, *15*(12), e0243779.

Nderitu, P., Jonsson, M., Arunga, E., Otieno, M., Jamleck, J., & Wafula,. O. (2020). Combining host plant resistance, selective insecticides, and biological control agents for integrated management of *Tuta absoluta*. *Advances in Agriculture*.

Nderitu, P., Wafula, O., & Otieno, M. (2019). Tomato leaf miner (*Tuta absoluta*) incidence and severity in Kirinyaga County, Kenya.

Ndiaye, A., Bal, B., Chailleux, A., Garba, M., Brévault, T. & Gauthier, N. (2021). Range-wide mitochondrial genetic homogeneity in the invasive South American tomato pinworm, *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae), with a focus on Africa. *African Entomology*, *29*(1), 42-58.

Nguetti, H., Imungi, K., Okoth, W., Wangâ, J., Mbacham, F., & Mitema, E. (2018). Assessment of the knowledge and use of pesticides by the tomato farmers in Mwea Region, Kenya. *African Journal of Agricultural Research*, *13*(8), 379-388.

Nkadimeng, V., Makombe, G., Mapiye, O., Mapiye, C., Oluwatayo, I., Dzama, K & Mautjana, M. (2021). A gross margin analysis for Nguni cattle farmers in Limpopo Province, South Africa. *Plos one*, *16*(6), e0253657.

Noy, S., & Jabbour, R. (2020). Decision-Making in Local Context: Expertise, Experience, and the Importance of Neighbours in Farmers' Insect Pest Management. *Sociologia Ruralis*, *60*(1), 3-19.

Nuwamanya, A., Runo, S., & Mwangi, M. (2022). In-vitro sensitivity of Alternaria solani isolates to azoxystrobin and difenoconazole fungicides in Kenya and detection of Cyt b mutations associated with azoxystrobin resistance. *Crop Protection*, *158*, 106010

Obeten, O., Ebukiba, S & Otitoju, M. (2021). Factors influencing pest management decisions among maize farming households.

Ochago, R. (2018). Gender and pest management: constraints to integrated pest management uptake among smallholder coffee farmers in Uganda. *Cogent Food & Agriculture*, *4*(1), 1540093.

Ochieng, J., Afari-Sefa, V., Muthoni, F., Kansiime, M., Hoeschle-Zeledon, I., Bekunda, M & Thomas, D. (2021). Adoption of sustainable agricultural technologies for vegetable production in rural Tanzania: trade-offs, complementarities and diffusion. *International Journal of Agricultural Sustainability*, 1-19.

Ogutu, F., Muriithi, W., Mshenga, M., Khamis, M., Mohamed, A., & Ndlela, S. (2022). Agro-Dealers' Knowledge, Perception, and Willingness to Stock a Fungal-Based Biopesticide (ICIPE 20) for Management of *Tuta absoluta* in Kenya. *Agriculture*, *12*(2), 180.

Omotesho, F., Fatodu, A., & Ajibade, B. (2022). Farm record keeping behaviour of rural farming youths in Ekiti State, Nigeria. *Sarhad Journal of Agriculture*, *38*(1), 92-102.

Onyimbo, W., Ayuya, I., Macharia, M. (2021). Contribution of Mango IPM Strategy for Fruit Fly Control on Household Welfare in Kenya.

Osei, M., Ofori, P., Adjebeng-Danquah, J., Nketia, S., Frimpong-Anin, K., Osei-Bonsu, I., & Puozaa, D. (2022). Harnessing Technologies for Vegetable Cultivation: A Panacea for Food and Nutrition Insecurity in Ghana. In *Vegetable Crops-Health Benefits and Cultivation*.

Ozor, N., & Nyambane, A. Policy and Institutional Landscape of Ecological Organic Agriculture in Rwanda.

Paltasingh, R., & Goyari, P. (2018). Impact of farmer education on farm productivity under varying technologies: case of paddy growers in India. *Agricultural and Food Economics*, *6*(1), 1-19.

Pandey, P., & Pandey, M. (2021). Research Methodology Tools and Techniques.

PetrescuMag, M., Banatean-Dunea, I., Vesa, S., Copacinschi, S., & Petrescu, C. (2019). What do Romanian farmers think about the effects of pesticides? Perceptions and willingness to pay for bio-pesticides. *Sustainability*, *11*(13), 3628.

Pfeiffer, G., Muniappan, R., Sall, D., Diatta, P., Diongue, A., & Dieng, O. (2013). First record of *Tuta absoluta* (lepidoptera: Gelechiidae) in Senegal. *Florida Entomologist*, *96*(2), 661-662.

Porras, M., Malacrino, A., An, C., Hian Seng, K., Socheath, O., Norton, G., & O'Rourke, M. (2022). An integrated pest management program outperforms conventional practices for tomato (Solanum lycopersicum L.) in Cambodia. *Plant Health Progress*, PHP-09.

Pratt, F., Constantine, L., & Murphy, T. (2017). Economic impacts of invasive alien species on African smallholder livelihoods. *Global Food Security, 14*, 31–37.

Radcliffe. (2021). *Integrated Pest Management (IPM) Principles*. Retrieved from https://www.epa.gov.

Rani, L., Thapa, K., Kanojia, N., Sharma, N., Singh, S., Grewal, A. S., Srivastav, A. L., & Kaushal, J. (2020). An extensive review on the consequences of chemical pesticides on human health and environment. *Journal of Cleaner Production*, 124657.

Reddy, J. (2018). Tomato Pests and Diseases, Symptoms, Control. Agriculture -farming.

Reddy, P. (2017). Agro-ecological approaches to pest management for sustainable agriculture. Singapore: *Springer Singapore.*

Rickards, A & McConnell, J. (1967). Budgeting, gross margins and programming for farm planning. *Professional farm management Guide Book* No3. Armidale: University of New England; 1967. 2351p.

Ricolfi, L., & Testa, S. (2021). Factorial invariance and orthogonal rotation. *Multivariate Behavioral Research*, *56*(5), 787-804.

Rincon, F., Rivera,T., Mojica-Ramos, L., & Borrero-Echeverry, F. (2021). Sampling plans promoting farmers' memory provide decision support in *Tuta absoluta* management. *Agronomy for Sustainable Development*, *41*(3), 1-12.

Roge, N. (2022) Tomato Leaf Miner, Tuta Absoluta Meyrick: A Menace to Tomato Production in Ethiopia. *Entomology, Ornithology and Herpetology.* Vol.11 Iss.1 No: 1000025.

Roxana, C., & Adriana, R. (2018). First DNA barcodes of *Tuta absoluta* (Meyrick, 1917) (Lepidoptera: Gelechiidae) from Romania. *Journal of Horticulture, Forestry and Biotechnology*, *22*(3), 1-7.

Rwomushana, I., Beale, T., Chipabika, G., Day, R., Gonzalez-Moreno, P., Lamontagne-Godwin, J., & Tambo, J. (2019). Tomato leafminer (*Tuta absoluta*): Impacts and coping strategies for Africa. *CABI (Center for Agriculture and Bioscience International) Working Paper*, *12*.

Sadique, M. (2022). Farmers' perceptions of integrated pest management (IPM) and determinants of adoption in vegetable production in Bangladesh. *International of Pest Management*, *68*(2), 158-166.

Saqib, E., Kuwornu, S., Panezia, S., & Ali, U. (2018). Factors determining subsistence farmers' access to agricultural credit in flood-prone areas of Pakistan. *Kasetsart Journal of Social Sciences*, *39*(2), 262–268.

Sarmento, R & Costa, V. (2019). Confirmatory factor analysis--a case study. *arXiv preprint arXiv:1905.05598*.

Sartipi, F. (2020). Diffusion of Innovation Theory in the Realm of Environmental Construction. *Journal of Construction Materials*, *1*, 4-2.

Savary, S., Willocquet, L., Pethybridge, J., Esker, P., McRoberts, N., & Nelson, A. (2019). The global burden of pathogens and pests on major food crops. *Nature ecology & evolution*, *3*(3), 430-439.

Sawadogo, M, Dabire, R., Ahissou, B., Bonzi, S., Somda, I., Nacro, S., & Verheggen, F (2022). Comparison of life-history traits and oviposition preferences of *Tuta absoluta* for 12 common tomato varieties in Burkina Faso. *Physiological Entomology*, *47*(1), 55-61.

Sayed, A & Behle, W. (2017). Evaluating a dual microbial agent biopesticide with *Bacillus thuringiensis* var. kurstaki and *Beauveria bassiana* blastospores. *Biocontrol Science and Technology*, 27(4), 461-474.

Schreinemachers, P., Chen, H., Nguyen, L., Buntong, B., Bouapao, L., Gautam, S & Srinivasan, R. (2017). Too much to handle? Pesticide dependence of smallholder vegetable farmers in Southeast Asia. *Science of the Total Environment*, 593, 470–477.

Sekyi, S., Domanban, B., & Honya, K. (2019). The impact of informal credit on rural agricultural productivity in the savannah ecological zone of Ghana. *African Journal of Economic and Management Studies*.

Senthoorraja, R., Senthamarai Selvan, P., & Basavarajappa, S. (2022). Eco-Smart Biorational Approaches in Housefly Management. New and Future Development in Biopesticide Research: *Biotechnological Exploration*, 281-303.

Sert, G., Kucukguven, A., Zırh, E. B., Demirtaş, T. T., Çakar, A. N., Gümüşderelioğlu, M., & Calis, M. (2021). Photobiomodulation with polychromatic light (600–1200 nm) improves fat graft survival by increasing adipocyte viability, neovascularization, and reducing inflammation in a rat model. *Lasers in Surgery and Medicine*, 54(2), 268-280.

Shahbaz, M., Nouri-Ganbalani, G., & Naseri, B. (2019). Comparative damage and digestive enzyme activity of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) on 12 tomato cultivars. *Entomological Research*, *49*(9).

Sharifzadeh, S., Abdollahzadeh, G., Damalas, A., & Rezaei, R. (2018). Farmers' criteria for pesticide selection and use in the pest control process. *Agriculture*, *8*(2), 24.

Sharma, U., Singh, K., & Shankar, H. (2018). Effect of Staking Method of Planting on Plant Population, Growth Development and yield of Rainy Season Tomato Crop. *Indian Research Journal of Genetics and Biotechnology*, *10*(04), 32-37.

Shiikaba, P., & Sahinli, M. (2021). Analysis of the efficiency in production of tomatoes among agricultural establishments: data envelopment analysis and stochastic frontier analysis. *Scientific papers-series management economic engineering in agriculture and rural development*.

Shikuku, K. (2019). Information exchange links, knowledge exposure, and adoption of agricultural technologies in northern Uganda. *World Development*, *115*, 94-106.

Sinyolo, S & Mudhara, M. (2018). Farmer groups and inorganic fertiliser use among smallholders in rural South Africa. *South African Journal of Science*, *114* (5/6).

Sosa, A., Diaz, M., Salvatore, A., Bardon, A., Borkosky, S., & Vera, N. (2019). Insecticidal effects of *Vernonanthura nebularum* against two economically important pest insects. *Saudi journal of biological sciences*, *26*(5), 881-889.

Sridhar, J., Kumar, K., Murali-Baskaran, K., Senthil-Nathan, S., Sharma, S., Nagesh, M., Kaushal, P., & Kumar, J. (2020). Impact of Climate Change on Communities, Response and Migration of Insects, Nematodes, Vectors and Natural Enemies in Diverse Ecosystems. *Global Climate Change: Resilient and Smart Agriculture*, 69–93.

Stephenson.,C., Coker, E., Posadas, C., Bachman, R., HarkessL., Adamczyk, J., & Knight, R. (2020). Economic effect of insect pest management strategies on small-scale tomato production in Mississippi. *Horticulture Technology*, *30*(1), 64-75.

Tambe, A., Mbanga, R., Nzefa, L & Nama, G. (2019). Pesticide usage and occupational hazards among farmers working in small-scale tomato farms in Cameroon. *Journal of the Egyptian Public Health Association*, *94*(1).

Tambo, A., Aliamo, C., Davis, T., Mugambi, I., Romney, D., Onyango O & Byantwale, S. (2019). The impact of ICT-enabled extension campaign on farmers' knowledge and management of fall armyworm in Uganda. *Plos one*, *14*(8), e0220844.

Thairu, W. (2020). Effect of strategic planning factors on the non-financial performance of non-governmental organizations in Kenya (*Doctoral dissertation, Strathmore University*).

Tong, R., Wang, Y., Zhu, Y., & Wang, Y. (2022). Does the certification of agriculture products promote the adoption of integrated pest management among apple growers in China? *Environmental Science and Pollution Research*, 1-10.

Tonnang, E., Mohamed, F., Khamis, F., & Ekesi, S. (2015). Identification and risk assessment for worldwide invasion and spread of Tuta absoluta with a focus on Sub-Saharan Africa: implications for phytosanitary measures and management. *PloS one*, *10*(8), e0135283.

Torres, B & Bueno. (2018). Conservation biological control using selective insecticides A valuable tool for IPM. *Biological Control*, *126*, 53–64.

Tropea, G., Siscaro, G., Biondi, A., & Zappalà, L. (2012). *Tuta absoluta*, a South American pest of tomato now in the EPPO region: biology, distribution and damage. *EPPO bulletin*, *42*(2), 205-210.

Ulhaq, I., Pham, N., Le, V., Pham, H., & Le, C. (2022). Factors influencing intention to adopt ICT among intensive shrimp farmers. *Aquaculture*, *547*, 737407.

Urbaneja, A., Vercher, R., Navarro-Llopis, V., Porcuna Coto, J. L., & García-Marí, F. (2007). La polilla del tomate,'*Tuta absoluta*'. *Phytoma Espana: La revista profesional de sanidad vegetal*, (194), 16-23.

Van den Berg, J., Greyvenstein, B., & Du Plessis, H. (2022). Insect resistance management facing African smallholder farmers under climate change. *Current Opinion in Insect Science*, 100894.

Vergani, L., Cuniberti, M., Zanovello, M., Maffei, D., Farooq, A., & Eirale, C. (2022). Return to play in long-standing adductor-related groin pain: a Delphi study among experts. *Sports Medicine-Open*, *8*(1), 1-11.

Wanjiru, J. (2017). Teachers' knowledge on the implementation of inclusive education in early childhood centers in Mwea East Sub-County, Kirinyaga County, Kenya. *Unpublished Masters Dissertation, Kenyatta University, Kenya*.

Woldemichael, A., Salami, A., Mukasa, A., Simpasa, A., & Shimeles, A. (2017). Transforming Africa's agriculture through agro-industrialization. *Africa Economic Brief*, *8*(7), 1-12.

Wyckhuys, A., Bentley, W., Lie, R., Nghiem, P., & Fredrix, M. (2018). Maximizing farm-level uptake and diffusion of biological control innovations in today's digital era. *Biological Control*, *63*(1), 133-148.

Yadav, S., Bhattarai, S., Ghimire, P., & Yadav, B. (2022). A review on ecology, biology, and management of a detrimental pest, *Tuta absoluta* (Lepidoptera: Gelechiidae). *Journal of Agriculture and Applied Biology*, *3*(2), 77-96.

Zappala, L, Biondi, A, Alma, A, Al-Jboory, J, Arno, J, Bayram, A, Guenaoui, Y. (2013). Natural enemies of the South American moth, *Tuta absoluta*, in Europe, North Africa and Middle East, and their potential use in pest control strategies. *Journal of Pest Science*. 86:635-647.

Zekeya, N., Ndakidemi, A., Chacha, M., & Mbega, E. (2017). Tomato Leafminer, *Tuta absoluta* (Meyrick 1917), an emerging agricultural pest in Sub-Saharan Africa*: Current and prospective management strategies.*

Zekeya, N., Peter, H & E. Mbega. 2022. Prospects of Biological Control Agents for Management of Invasive Pest *Tuta Absoluta* (Lepidoptera: Gelechiidae) In Africa. Journal of Animal Sciences and Livestock Productiony. Vol.7 No.1:170.

Zhang, G, Wang, J., Kuang, M., Yang, W., Rao, X., Gao, Y., & Dai, A. (2021). Outbreak of the South American tomato leafminer, *Tuta absoluta*, in the Chinese mainland: *geographic and potential.*

Zheng, R., Zhan, J., Liu, L., Ma, Y., Wang, Z., Xie, L., & He, D. (2019). Factors and minimal subsidy associated with tea farmers' willingness to adopt ecological pest management. *Sustainability*, *11*(22), 6190.

Zhou, X., Zheng, Y., Cai, Z., Wang, X., Liu, Y., Yu, A., Chen, X., Liu, J., Zhang, Y., & Wang, A. (2021). Identification and Functional Analysis of Tomato TPR Gene Family. *International Journal of Molecular Sciences*, *22*(2), 758.

APPENDICES

Appendix I: Questionnaire

PART 1: General information of tomato farmer

A	Serial number	
B	Date of interview	
C	Ward **(CODE A)**	1. Kangai [] 2. Nyangati [ ] 3.Mutithi [ ] 4.Thiba [ ] 5.Murinduko [ ] 6.Gathigiriri[] 7.Wamumu [ ] 8. Tebere[ ]
D	Location	
E.	Name of the respondent	
F.	Gender of the respondent	1= Male [ ] 0= Female [ ]
G	Indicate where tomato is produced (CODE B)	1=Open field / outdoor [ ] 2= Greenhouse [ ] 3=Both [ ]
H	Household contact number (Optional)	

PART 2: Household characteristics

	Code		Code
Who in the household makes farm decisions?	Code C	How many people have lived in your household for at least 6 months during the last 12 months?	
Gender of main decision maker	1.Male 0. Female	Of these people, how many earn an income?	
What is the age of main decision maker?		In your household, how many children are under 18 years?	
Marital status of the household main decision maker?	Code D		
Years of schooling for the main decision maker?		Do you or your household have access to internet enabled devices?	1=Yes 0=No
What is the main decision maker's main occupation in terms of time spent? (hours)	Code E	Do you or your household have access to a steady (cell) phone connection?	1=Yes 0=No
		Do you or your household have access to a steady internet connection?	1=Yes 0=No

CODE C:	CODE D:	CODE E: 1=Agriculture, hunting, forestry, fishing, mining or quarrying 2=Government employment 3=Employed in business 4=Unemployed 5=self-employed 7=Casual labor 8=Other specify
1. Household head 2. Spouse 3. Son/daughter 4. Grandchild 5. Parent 6. Farm manager	1=Married 2=Single 3=Separated 4=Widowed	

PART 3: Farm Characteristics

A. Land allocation

i	Land ownership	A. Owned [ ] B. Rented in/ lease [ ] C. Rented [ ] D. Family [ ] E. Borrowed [ ]
ii	What is the total area of land used for agricultural purposes (in acres)	
iii	How much land did you plant tomato in the last season?	
iv	Estimate the total area or size used for tomato production for the greenhouse tomato production?(M^2)	

B. Land Preparation

(a) How do you prepare land? **(CODE F)**

(b) How much land did you prepare using tractor in the last season?

…………………

(c) What was the cost of the tractor preparation in total? (Kshs)………………….

(d) How much land did you prepare using animal drawn power in the last season? (acres)

(e) What was the cost of the animal drawn preparation in total? (Kshs)………….

(f) How much land did you prepare manually in the last season? (acres)

(g) If manual, how many male did you use in the last season?

(h) How much land did you prepare using chemicals?

(i) What was the total cost of chemicals used in the last season?

(j) Labour distribution for land preparation per acre

Source	Below eighteen males	Below eighteen Females	Above eighteen Males	Above eighteen Females	Total	Days worked per acre	Total labour cost
Family							
Hired							

CODE F: 1= Manually 2=Use Tractor 3=Animal power 4=Other specify

C. **Nursery bed preparation**

i. How do you prepare the nursery bed? **(CODE F)**

ii. What was the size of the nursery bed?

iii. What tomato varieties do plant in your nursery bed **(CODE G)**

(A)Rio grande [ ] (B). Money maker [ ] (C). Cal J [ ] (D). The Elgon [ ] (E) The Star 9068 [ ] (F). Nyota F1 [ ] (G). Marglobe [ ] (H). Ndume [ ] (I). Marmaid [ ] (J). Beauty [ ] (K). M-82 (L). Roma Vf (M). Kilele F1 (N). Zara F1 (O). Prostar F1 (P). Commaando F1 (Q). Victory F1 (R). Anna F1 (S) Ranger F1 (T). Tomato assila F1

D. Do you use certified seeds? 1= yes [ ] 0=N0 [ ]

E. Do use hybrid seeds? 1= yes [ ] 0=N0 [ ]

F. How many grams/ seedlings of certified seed did you plant? ……………….

G. What was the average cost of certified seed per gram/ seedling? ……………………

H. What is the total cost of certified seeds per gram?

I. What is usually the germination rate of certified seed?

J. Labour distribution for nursery bed preparation

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above eighteen Females	Total	Days worked per acre	Total labour cost
Family							
Hired							

F. Water management in tomato production

(i) Water source used? (**CODE J**)

(a) Surface water
(b) Rooftop harvested
(c) Well
(d) River
(e) Borehole
(f) Spring/stream
(g) treated water
(h) water reservoir
(i) no source
(j) rain fed
(k) others, please specify

(ii) What is the distance to the main water point in dry seasons?

(iii) Do you pay for household water uses? 1 = Yes [ ] 0=No [ ]

(iv) How do you pay for irrigation water? **(CODE K)**

(a) Litres
(b) Per 20L jelly can
(c) Cubic metres
(d) Flat rate
(e) others, please specify

(v) What is the cost of water paid?

(vi) In what units do you pay water?

(vii) Source of water for tomato? **(CODE J)**

(viii) Do you use irrigation water?

(ix) What technologies do you use for tomato crop water application? **(CODE K)**

(a) Guttering [ ] (b) Pond [ ] (c) Dam [ ] (d) Tanks (e) Jelicans

(f) Boreholes [ ] (g) Wells [ ] (h) Ground water aquifiers [ ]

(i) others

(x) What is the total cost for irrigation for one acre?

(xi) Labour distribution for watering

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above 18 Female	Total	Days worked per acre	Total labour cost per acre
Family							
Hired							

G. Tomato crop protection

(i)What are some of the pests affecting tomato in your farm? **(CODE H)**

(a) *Tuta absoluta* [ ] (b) Aphids [ ] (c) Blister beetles [ ] (d) Cutworms [ ] (e) Flee beetles [ ] (f) Leaf hoppers [ ] (g) Spider mites (h) Nematodes (i) Slugs and snails [ ]

(ii) What is the damage initiated by *T. absoluta* in percentage in tomato production

(ii) What are some of the pest management practices do you use to control *T. absoluta* (**CODE I)**

(a) Pesticides [ ]
(b) Plant Incorporated Protectants (PIP) [ ]
(c) Intercropping [ ]
(d) Mulching [ ]
(e) Desuckering / pruning [ ]
(f) Uprooting and destruction of crop residue [ ]
(g) Fertilizer application [ ]
(h) Pheromone traps
(i) Predators [ ]
(j) Pathogens
(k) Parasites
(l) Bio-insectides
(m) Weeding
(n) Bio-nematicides
(o) Bio-herbicides

(iii) Labour distribution for tomato protection

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above eighteen Females	Total	Days worked per acre	Total labour cost per acre
Family							
Hired							

H. Chemical control methods (use of chemical pesticides)

i. Did you use pesticide (s)/ agrochemicals in tomato production during the last season? (IF NO skip to question 8)

1= Yes [ ] 0= No [ ]

ii. If yes, what influenced your decision on type of pesticide/ agrochemicasl to apply during tomato production? **(CODE L**)

1. On the first appearance of pests [ ] 2. On calendar basis [ ] 3. Own farming experience [ ] 4. On recommendation by another farmer [ ] 5. On recommendation by pesticide dealer [ ] 6. On first symptom of

crop damage [ ] 7. On recommendation by extension agent [ ] 8. Other, specify

……………………

iii. Who applies the chemicals and agro-chemicals?

(a) Trained household male [ ] (d) untrained household male

(b) Trained household female [ ] (e) untrained household female

(c) Trained hired male [ ] (f) untrained hired female

iv.Total cost for agrochemicals used to control *T.absoluta*?

v. Total labour cost used in agrochemicals applications to control *T. absoluta*?

I. Cultural activities (Non-chemical pest control methods)

(i) Did you use alternative pest control methods in the last tomato production?

1= yes [ ] 0=No [ ]

(ii) Alternative pest methods

	A. Cultural methods	1= Yes 0= No	B. Biological control methods	1= Yes 0= No	C. Bio-chemicals methods	1= Yes 0= N0
1	Weeding		Predators		Bio-insecticides	
2	Crop rotation		Pathogens		Plants incorporated protectants(PIP)	
3	Intercropping		Parasites		Bio-nematicides	
4	Mulching		Others, specify		Bio-herbicides	
5	Pruning				Others, Specify	
6	Uprooting and destruction of crop residue					
7	Fertilizer application					
8	Pheromone traps					
9	Others specify					

J. *Tuta absoluta*

(i) When was *T. absoluta* first encountered in your farm?

(1) This cropping season [ ] (2) the previous cropping season [ ] (3) few cropping seasons ago [ ] (4) Few years ago [ ] please specify

(ii) How does *T. absoluta* spread in your farm?

(a) From neighbouring farm[ ] (c) Infested fruits and packaging [ ] (e) Container

(b) Seeds/ seedlings [ ] (d) crop rotation[ ] (f) other [ ] specify

(iii) What is the proportion of tomato land that was affected by *T. absoluta* in the last cropping season?

(iv) What are the mostly affected tomato parts?

(v) What is the level of damage caused by *T. absoluta* in percentage in tomato production?

(vi) What are some of the pest management practices do you use to control *T. absoluta*

(vii) What are the yield losses as an effect of *T. absoluta* infestation in the last cropping season?

K. Weeding

(i) How many times do you weed for the tomatoes till harvesting?

(ii) Which methods do you use in weeding in tomatoes? **(CODE J)**

(iii)What is the total weeding labour cost per acre/ unit?

(iv)Labour source for weeding

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above eighteen Females	Total
Family					
Hired					

L. Staking

(i) At what stage do you stake your tomatoes?

(ii) What is the cost for stakes in one acre/ greenhouse units?

(iii) Labour distribution for staking

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above eighteen Females	Total
Family					
Hired					

M. Harvesting

(i) How do you harvest**? (CODE)** 1= Manual [ ] 2=Machine [ ] 3= Other, specify

(ii) What is the total yield of tomato harvested in crates? (Gross)…………….

(iii) Total cost of labour for harvesting per acre?

(iv)Labour distribution for harvesting

Source	Below eighteen males	Below eighteen females	Above eighteen Males	Above eighteen Females	Total
Family					
Hired					

N. Postharvest management practices

(i) Where do you store tomatoes immediately after harvesting? ………………..

(ii) How do you grade the products?

(iii)How do you monitor pest in packing and storing areas?

(iv)Do you maintain pest control records? 1=Yes [ ] 0=No [ ]

PART 4: INPUT SOURCING

A. Seed sourcing

(i) Where do you buy tomato seeds/ seedlings for your farm for the last tomato production season?

(a) Agrovets [ ]

(b) Fellow farmers [ ]

(c) Agricultural organizations [ ]

(d) Seeds company [ ]

(e) Others [ ] specify…………..

B. Information access

1. What was the source(s) of information on pest control methods to control *T. absoluta* 1=Colleague farmers [ ] 2=Family/Relatives [ ] 3=Marketers [ ] 4=Ministry of Agriculture [ ] 5=Radio/TV [ ] 6= others [ ] (Specify……………………………………………………
2. Do you have a mobile Phone? 1. Yes [ ] 2 No [ ]
3. What kind of mobile phone? …………………………………………
4. Do you receive tomato production information from your phone? 1. Yes [ ] 2 No [ ]
5. If yes above, what kind of tomato production information?
   A. Tomato production information [ ]
   B. General farm production information [ ]
   C. Advertisement of farm inputs [ ]
   D. Pest control information
   E. Others [ ] specify………………………………………………………

C. Extension services

I	Have you accessed any training related to tomato production in the last two years	1 =Yes [ ] 2= No [ ]
Ii	If yes how many trainings	
Iv	If yes above, what aspects of tomato production were you trained on?	
v	When in need, where do you access extension services?	
Vi	Do you pay for extension services	1 =Yes [ ] 2= No [ ]
vii	In the last and current tomato production season, how many contacts with the extension officer had you had related tomato?	
viii	What support mechanism do you need to support tomato production?	
Ix	How do you mitigate the risk associated with growing tomato crop?	

D. Credit Access for tomato production

i.	Have you ever accessed a credit facility/ loan for the last tomato production season?	1= Yes [ ] 0 = No [ ]
ii.	If yes, what is the total amount of credit (Ksh.) received in the last season?	
iii	What are the common financial needs for the farmer in regards to farm activities?	
iv	Do you or any other member of your household get income from other activities than crop farming?	1 =Yes [ ] 2= No [ ]
v.	What other sources of income did you and other members of your household have?	Remittances [ ] Pension [ ] Own-business[ ] farm paid labour[ ] Crop Farming[ ] Livestock[ ] Farming[ ] Other [ ], specify

E. Organizational or Group Membership

(i) Is the household head a member of a tomato farmer's organization? 1.Yes [ ] 0.No[]

(ii) What was the reason for joining the tomato farmer's organization?

1= Access to input [ ] 2 = Access to output market [ ] 3= Extension/training services [ ] 4= Finances [ ] 5= others [ ] Specify…………………………….

(iii)What are the benefits derived from being a member of that group as regarding choice of pest management?

(a)Get higher prices (b) reduced inputs (c) collective selling (d) lobbying (e) bargaining power (f) access credit/loans (g) pool resources for various reasons

(h) Reduced inputs cost (i) other, please specify ……………

(iv) What is your contribution to the farmer's organization? …………………………

1= Finances [ ]

2= Training [ ]

3= in kind contribution

4= time contribution

5= any other specify………………………………………………………………

(v) Are you or household head a member of other groups other than the farmers' group?

1 = Yes [ ]   2= No [ ]

(vi) To what other type of organization did you or household head belong?

1 = Community/family group [ ]   2 = Saving/credit group [ ]   3 = Labour union [ ]

4 = Women's group [ ]   5 = Men's group [ ]   6 = Youth group [ ]

7 = Church Group [ ]   8 = Sport and leisure group [ ]   9= other, please specify…………..

PART 5: RISK PERCEPTION ON PEST MANAGEMENT METHODS

A. How important are these management methods in your farm in controlling *Tuta absoluta*?

	Choice of management method	1=not very importa nt	2=Sligh tly im-portant	3=Moderat ely important	4=Neutral	5= Very im-portant
1	Pesticides					
2	Weeding					
3	Crop rotation					
4	Intercropping					
5	Mulching					
6	Pruning/ Desuckering					
7	Uprooting and destruction of crop residue					
8	Fertilizer application					
9	Pheromone traps					
10	Predators					
11	Pathogens					
12	Parasites					
13	Bio-insecticides					
14	PIP					
15	Bio-herbicides					
16	Bio-nematicides					
17	Others, specify					

B. Risk perception of pest management methods in relation to health **(Tick where appropriate)**

	With respect to the pest control method used, tick where appropriate	1=strongly disagree	2=disagree	3=uncertain	4=agree	5=strongly agree
1	use is harmful to household health					
2	Use is harmful to the hired/ users health.					
4	Inappropriate use causes chronic illness					
5	Improper use causes acute illnesses.					

C. Farmer's knowledge and awareness of choice of management methods efficiency effect on *T. absoluta.* **(Tick where appropriate)**

	With respect to the pest control method used, tick where appropraite	1=strongly disagree	2=disagree	3=uncertain	4=agree	5=strongly agree
1	Have knowledge on…..					
2	The farmer is believes that the pest control method used is effective in controlling *T.absoluta*					
3	the farmer believes the pest control method used completely eliminates *T.absoluta*					

D. Risk perception on pest management methods use in relation to environment and food safety.

	With respect to the pest control method used, tick where appropriate	1=strongly disagree	2=disagree	3=uncertain	4=agree	5=strongly agree
1	Improper use affects food safety					
2	Use affects air quality (negatively).					
3	Use affects water quality(negatively)					
4	Improper use affects biodiversity negatively					
5	Inappropriate use leads to soil contamination					

E. What is your opinion on the choice of *T. absoluta* management methods in your farm? **(Tick where appropriate)**

	Opinion on choice of *T. absoluta* management method	1=Strongly Disagree	2=Disagree	3=Neutral	4=Agree	5=Strongly agree
1	high Performance and effectiveness					
2	Highly aware and have more information					
3	The management choice is highly technical					
4	Highly aware of the environmental effects					

5	Cheap as compared to other methods					

F. How do you perceive risk on each choice of management *T. absoluta* methods in your farm for general value chain players? **(Tick where appropriate)**

	Choice of Management	1= Not risky	2=slightly risky	3=moderately risky	4=very risky	5=extremely risky
1	Chemical control (pesticides use)					
2	Biological control					
3	Mechanical control					
4	Cultural control (Improved seeds varieties, irrigation, rotation)					
5	IPM techniques					

God bless you for responding.

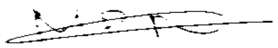
Appendix II: Introduction letter

Dear Sir/ Madam

My name is Poline Wawira Mwaniki, a student at Chuka University, Pursuing a Master's Degree in Agricultural Economics. I am conducting an academic study on **"Effects of Tomato Farmers' Gross Margin, Perception and Socio-Economic Characteristics on Choice of *Tuta absoluta* Management Methods in Mwea, Kirinyaga County."** This study's main objective is to fulfill the academic requirement for a Master's Degree in Agricultural Economics award. I, at this moment, request your honesty when answering the following questions. All responses will be handled with discretion, and data obtained will aid to meeting the study intents no names nor will personal information be published.

Thank you for participating in this study.

Yours Faithfully,



Poline Wawira Mwaniki.

Appendix III : Chuka University Ethics Approval Letter

CHUKA UNIVERSITY

Knowledge is Wealth *(Sapientia divitia est)* Akili ni Mali

CHUKA UNIVERSITY INSTITUTION ETHICS COMMITTEE

Telephones: 0612304004 P.O. Box 109 - 60400

Fax line: 020 2310302 Chuka

1st MARCH 2022

REF: **CUIERC/ NACOSTI 219**

TO: **Poline Wawira Mwaniki**

Dear Sir/madam

<u>RE:</u> Effect of Tomato Farmers' Gross Margin , Perception and Socio;Economic Characteristics on Choice of Tuta Absoluta Management Methods in Mwea , Kirinyaga County

This is to inform you that *Chuka University IERC* has reviewed and approved your above research proposal. Your application approval number is *NACOSTI/NBC/AC-0812* **.**The approval period is1st March 2022 to 1st March 2023

This approval is subject to compliance with the following requirements;

i. Only approved documents including (informed consents, study instruments, MTA) will be used

ii. All changes including (amendments, deviations, and violations) are submitted for review and approval by *Chuka University IERC*..

iii. Death and life threatening problems and serious adverse events or unexpected adverse events whether related or unrelated to the study must be reported to *Chuka University IERC* within 72 hours of notification

iv. Any changes, anticipated or otherwise that may increase the risks or affected safety or welfare of study participants and others or affect the integrity of the research must be reported to to *Chuka University IERC* within 72 hours

v. Clearance for export of biological specimens must be obtained from relevant institutions.

vi. Submission of a request for renewal of approval at least 60 days prior to expiry of the approval period. Attach a comprehensive progress report to support the renewal.

vii. Submission of an executive summary report within 90 days upon completion of the study to *Chuka University IERC*.

Prior to commencing your study, you will be expected to obtain a research license from National Commission for Science, Technology and Innovation (NACOSTI) https://research-portal.nacosti.go.ke and also obtain other clearances needed.

Yours sincerely

Dr.Benjamin Kanga

SECRETARY CHUKA UNIVERSITY

Appendix IV: Kirinyaga County Authority

MINISTRY OF EDUCATION
STATE DEPARTMENT OF EARLY LEARNING & BASIC EDUCATION

Telephone: 060-21835/0202641217
Email kirinyagacde1@gmail.com
When replying please quote
Ref. No. and date

COUNTY DIRECTOR OF EDUCATION
KIRINYAGA COUNTY
P. O. BOX 96
KERUGOYA

REF.NO.MOE/CDE/KRG/GEN/09/85/79

22ND MARCH, 2022

Ms. PAULINE WAWIRA MWANIKI

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effects of Tomato Farmers Gross margin, Perception and Social-Economic Characteristics on choice of Tuta absoluta management methods in Mwea Kirinyaga County,Kenya"***

I am pleased to inform you that you have been authorized to undertake research in Kirinyaga County for a period ending **18th March 2023**

The County Commissioner and Deputy County Commissioner Kirinyaga County is requested to accord you necessary action.

SAMUEL GICHONI

FOR: COUNTY DIRECTOR OF EDUCATION

KIRINYAGA

CC.

1. **County Commissioner**
   Kirinyaga County
2. **Deputy County Commisioner**
   Kirinyaga County
3. **SCDE – Mwea East**
4. **SCDE – Mwea West**

Appendix V: NACOSTI Research License

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: 501386

Date of Issue: 18/March/2022

RESEARCH LICENSE

This is to Certify that Ms.. PAULINE WAWIRA MWANIKI of Chuka University, has been licensed to conduct research in Kirinyaga on the topic: EFFECTS OF TOMATO FARMERS' GROSS MARGIN, PERCEPTION AND SOCIO-ECONOMIC CHARACTERISTICS ON CHOICE OF TUTA ABSOLUTA MANAGEMENT METHODS IN MWEA, KIRINYAGA COUNTY for the period ending : 18/March/2023.

License No: **NACOSTI/P/22/16358**

501386

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.