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Research Article

Effects of Socio-Economic Characteristics on Choice of *Tuta Absoluta* Management Methods in Tomato Production in Mwea, Kirinyaga County

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Abstract

The study assessed the effect of socio-economic characteristics on the management methods of *T. absoluta* in Mwea, Kirinyaga County. The target population was 2300 open fields and 20 green-house tomato farmers in Mwea. A descriptive research design was used in the study, and a multistage sampling procedure was used to get a sample of 303 respondents. Through a survey, 283 open-field tomato small-scale farmers were randomly interviewed using semi-structured questionnaires. Socio-economic and crop protection data were analyzed using descriptive statistics and econometric modeling. The multivariate probit model estimates showed that gender, education, age, land size, household income, and extension significantly affected farmers' choice of pest control methods to manage *T. absoluta*. The negative coefficients showed that an increase in either one of the socio-economic factors would help increase tomato yields reduced by *T. absoluta*. The study results encourage small-scale tomato farmers to use other pest management methods, such as crop rotation and weeding, so as not to rely on chemical pesticides alone to control *T. absoluta*. To learn more about tomato pest management practices, Tomato small-scale farmers should join farmers' groups and organizations. National and County policymakers should adopt policies to encourage integrated pest management methods to avoid excess chemical pesticides in tomato production.

Keywords

Tomato Production, Choice of Management, *Tuta Absoluta*, Selected Socio-Economic Characteristics, Small-Scale Farmers, Multivariate Probit

1. Introduction

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,

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Kajiado, Makueni and Nakuru counties among others. According to previous research, for instance [52], tomato farming is severely hampered by diseases and insect infestations which are as a result of abiotic and abiotic stresses limitations. 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 [27] the adoption of these pest control methods in the management of *T. absoluta* is hindered by farmers' experience and credit access.

This study objective was to determe the effect of farmers' 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. The study was guided by the research question (How does the farmers' socio-economic characteristics affect the choice of management of *T. absoluta* in tomato production in Mwea, Kirinyaga County?)

2. Background Information

Tomato (*Solanum Lycopersicum* L.) originated in the Andean region of South America, which includes Chile, Bolivia, Ecuador, Colombia, and Peru [23]. The actual site of the origin is unknown, but it has been hypothesized to be Peru or Mexico [47]. The five largest tomato producers worldwide are China, India, the United States of America, Turkey, and Egypt [10]. Tomato is one of the most economically valued vegetables in the world, with a projected yearly production of 182 million tonnes value of US$ 87.9 billion [36]. The tomato crop is used for commercial purposes, nutritional value, prevalent production, and as a model plant for research [13, 23]. Tomato is rich in vitamins (A and C), minerals (iron, phosphorus, lycopene, beta-carotene), and water. They can be used fresh or processed into a range of products such as juice, sauce, and puree [19].

Tomato production plays a vital role in Africa because it provides employment opportunities for women, who make up more than 60% of the labor force [45]; important vegetable for nutrition value and a source of income for smallholder farmers. After potato, tomato is the second most valuable and produced vegetable in Kenya. Tomato accounts for 14% of total vegetables produced in Kenya and is grown in greenhouse technology and open fields [27]. Kirinyaga, Kajiado, and Taita Taveta are Kenya's primary tomato-producing counties [28]. Tomato production is done in Mwea East and Kirinyaga West, Kirinyaga Central sub-Counties, in Kirinyaga County.

Tomato production in the world is severely hampered by biotic and abiotic constraints such as diseases and insect pests [48]. Higher numbers of pests affect tomato production economically, among them being *T. absoluta. T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) and it is considered one of the most devastating pests affecting tomatoes and has invaded several tomato-producing regions worldwide [7]. *Tuta absoluta* as an agricultural pest is a global concern and has spread widely across continents resulting in substantial economic damages; in tomato cultivation and Africa, the problem is much more severe to the extent that farmers are abandoning the crop [46]. This migratory pest was initially recorded in Eastern Spain in late 2006 [44] and has since expanded across Europe, the Mid East, Parts of northern America, and Sub-Saharan Africa. *T. absoluta* was initially documented in Algeria, Morocco Africa in 2008 and 2009 [14], then expanded to Egypt in 2010 [25], and Sudan and South Sudan in 2011 [4, 34]. The pest arrived in Ethiopia and Kenya in 2012, Sudan or Yemen [11] *T. absoluta* had first been discovered in Kenya in 2014 from 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] [17].

Tuta absoluta has been reported whenever temperatures rises, occasioned by various inter-related processes, including amplified rates of population growth, development and migration [15]. Further, the 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, especially true for migrant predatory insects like *T. absoluta* [22]. *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 [7]. Further, it is tough to manage *T. absoluta* because of its varied hostage range. Some of the host plants include pepper (*Capsicum annuum* L.), long-spined thorn apple (*Daturaferox Kunth*) [46], Devil's trumpet (*Datura stramonium*), tobacco (*Nicotiana tabacum* L.) and the American nightshade (*Solanum americanum* Miller). Although *T. absoluta* prefer tomato over other solanaceous crops, it was encountered on beans (*Phaseolus vulgaris*) in Italy which acted as an alternative host, *Lycium* sp. *Malva* sp [46].

Tuta absoluta in tomato and other Solanaceae family crops is spreads through seedlings, diseased tomato f tainers. 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 [8, 18]. It can damage all plant sections, including the leaves, leaf veins, stems margins, sepals, and green and white flowers. 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 and yield losses of up to 100% [8]. 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* [33].

Farmers in Mwea use various management methods to control *T. absoluta*, affecting tomato production [8]. These methods include use of agrochemicals, use of certified seedlings, crop rotation, staking, intercropping, desuckering, uprooting and destruction of residues [6]. However, the choice of management method is affected by various factors, and farmers consider several aspects before choosing the method to use to control *T. absoluta*. For instance, the availability of choice, modern technology, farmers' socio-economic characteristics, and attitudes affect the choice of management methods [1]. Farmers also consider the cost of management methods, the effect on the farmers, customers, and the environmental effect, among others [20, 39].

The use of chemical control can have a positive and negative impact on human well-being and the environment [40]. Bio-pesticides that use beneficial microbial agents could reduce reliance on pesticides and chemical pesticides in managing *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 [38].

Tomato farmers in Mwea East and West, Kirinyaga County, use biological mechanism choices such as the use of predators and natural enemies as some of the methods to reduce tomato destruction by *T. absoluta* [49]. In their study, [21] 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 the use of cultural control methods whereby they use methods such as crop rotation, use of improved seed varieties, and irrigation. Further, integrated pest management programs like selective host plants, selected insecticides, and pesticides help control *T. absoluta*.

Tuta absoluta characteristics on pesticide resistance, a leaf-mining behavior and an increased survival rate have made it difficult to control using pesticides alone. The use of resistant varieties combined with insecticides has been proven effective, and it lessens the use of insecticides in the management of *T. absoluta* in tomatoes [31, 37]. Farmers in Mwea East and Mwea West Sub-Counties have also been using parasites such as parasitic wasps to control *T. absoluta* [2]. 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. This study, therefore, looked at some of the socio-economic factors affecting the choice of each management method used by tomato farmers in managing *T. absoluta* in Mwea East and West Sub-Counties, Kirinyaga County.

3. Materials and Methods

3.1. Study Area

The study was conducted in Kirinyaga County between March and April 2022. Kirinyaga County has 5 Sub-Counties: Kirinyaga Central, Kirinyaga West, Kirinyaga East, Mwea East, and West. Tomato production is done in all the five sub-Counties, but majorly in Mwea East and West Sub-Counties commonly known as Mwea. Mwea has a population of 237,382 and is located about 100km Northeast of Nairobi (Latitude 041’ S and Longitude 3720’ E) at an elevation of 1160 m above sea level [16]. Mwea has eight wards, namely Murinduko, Tebere, Gathigiriri and Nyangati, Kangai, Mutithi, Thiba, and Wamumu, producing tomato. The area has two rainy seasons that is long rains (March-May) and short rains (October- November). Mwea receives an average annual rainfall amount of about 930 mm, and the temperatures lie between (14°C- 31°C) with humidity ranging from 55% to 70% [3]. Thiba and Nyamidi rivers provide water for irrigation throughout the year [30]. The soils are deep, medium-textured loamy soils that are productive and well drained with a pH between 6.0 and 7.0, which favors tomato production. Some of the agricultural practices in the area include crop and vegetable production as well as livestock and fisheries farming [29]. The region's climatic data favor vegetable production, especially tomato production; hence it is a suitable area for the survey. During the first stage, Mwea East and West Sub-Counties were purposefully selected because they are the leading tomato production areas in Kirinyaga County. They have reported *T. absoluta* as a challenge in tomato production.

3.2. Sampling and Data

The survey employed a multistage sampling procedure. A sampling frame from the list of small scale farmers 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 were sampled. The third stage involved random sampling of small-scale tomato farmers from the sample wards, and the respondents were randomly 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 obtained and the farmers were interviewed. The data obtained was cleaned and Data analysis was done using SPSS and Stata.

3.3. Econometric Analysis

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 [5]. 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 [12]

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 [5].

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 [28].

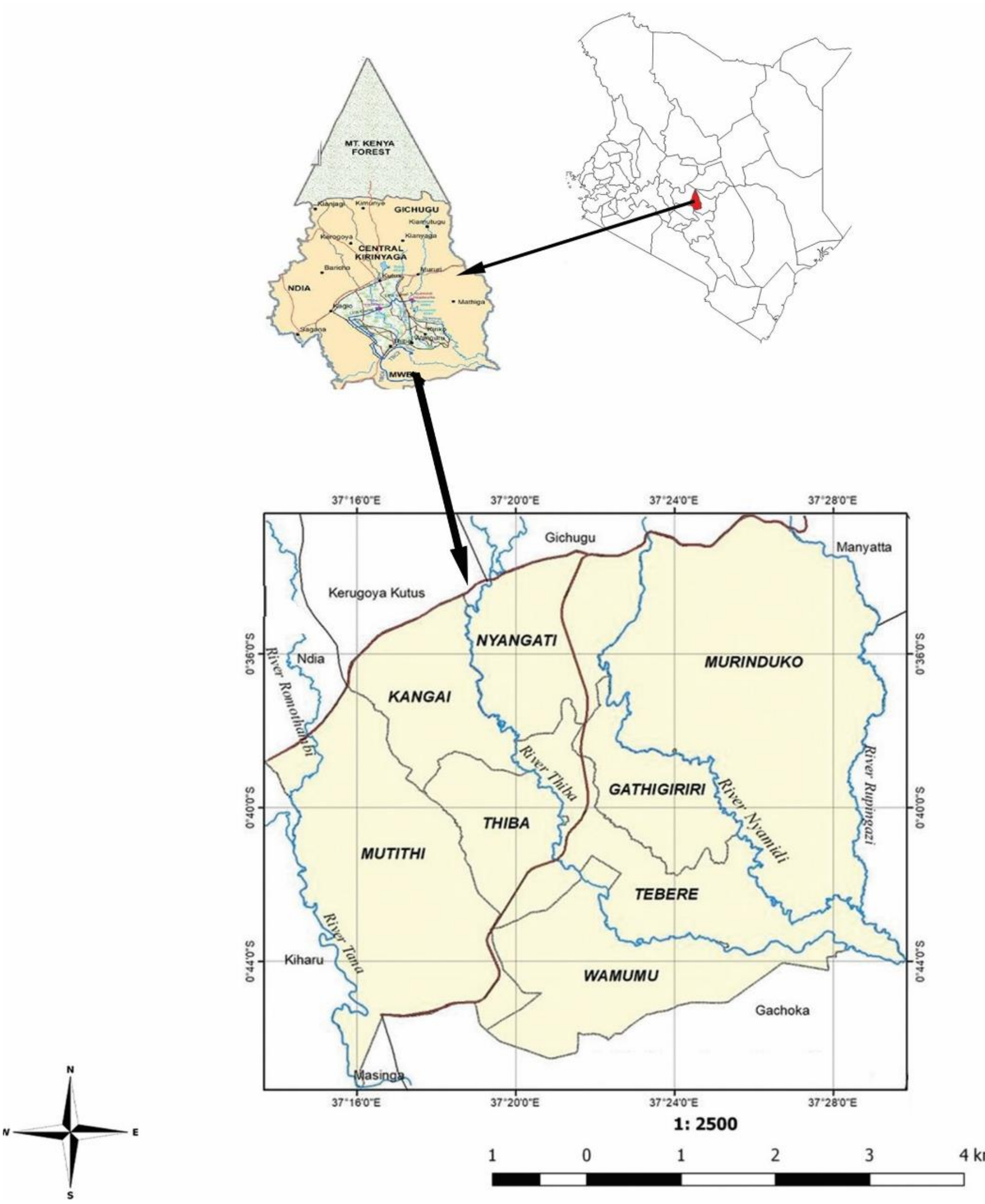

Figure 1. *Map of Mwea from Map of Kenya showing Mwea East and Mwea West Sub-Counties.*

4. Results and Discussions

Table 1 shows a summary of decision makers' years of schooling, age of the decision maker, household size, income of dependent, children under 18 years and years of experience in tomato farming.

Table 1. *A Summary of Household Characteristics.*

Variable	Observations	Mean	SD	Min	Max
Decision maker years of schooling	283	10.57	2.91	5	18
Age of Decision maker	283	39.73	7.03	23	57
Household size	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

It was 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.

When studying the age, it was observed that tomato small scale farmers' mean age was approximately 39.73 years (Table 1). The study findings are in line with [44] survey findings which recorded that majority of farmers were between the ages of 31 and 40, with 86.50 % being male.

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. These findings showed that most of the respondent's at least acquired secondary education which is very important in decision making in the farm. [35] 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. The respondents had a mean of at least 5.23 years of experience.

During the study, it was observed that several factors influenced tomato small-scale farmers' decisions to use a particular choice of management to control *T. absoluta*. A multivariate probit model was used to evaluate the effect of socio-economic characteristics on the choice of management of *T. absoluta*. MVP model contained six dependent variables and eight independent variables. The likelihood ratio test of x^2 (positive, Likelihood ratio test of rho=0) rejects 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 2).

The study findings showed that the respondent gender variable had a significant (P-value=10%) positive relationship with small-scale tomato farmers' choice 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 had a significant (P-value=5%) positive relationship with crop rotation and staking as methods that the respondents used to control *T. absoluta* (Table 2). The study observed that women were more inclined to the pesticide management techniques, and these required less attention than other IPM strategies. The survey findings are in line with [25] study, which observed that gender had a positive and significant (P-value at 5%) association with the adoption of various technologies used to control pests. [33] study results also reported that chemical control outcome category, the variable 'Gender' had a negative and significant effect, indicating that male compared to female farmers have a lower liking for farming relative to the use of pesticides management strategies in pest management as well as the tactics are used.

The study results further observed that the education variable described the number of years of schooling for the decision maker on the farm. The findings showed that education had a significant (P-value= 5%) and a positive relationship with chemical pesticides but failed to explain *T. absoluta*'s management choice of intercropping, desuckering, fertilizer application, crop rotation, as well as stakes. The study results showed that an additional year of schooling improves the respondent's awareness of the use of chemical pesticides. Education was not significant in other pest management choices. The findings are in line with those of [10] study, which reported that higher education status created more awareness for the farmers to adopt the use of various practices on 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 the use of chemical pesticides. The results showed that age also had a significant (P-value=5%) positive relationship with desuckering pest management choice. An increase in the 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 compared to using chemicals. Age did not explain other choices: intercropping, fertilizer application, crop rotation, and staking. These survey results showed that young people used more chemicals than the elderly. The findings are consistent with [33] study, which reported that as age increases, the preference for the farmer to use IPM techniques is relative among maize framers in Abuja.

Further, the survey investigated the influence of farmers' experience on the choice of pest management methods to control *T. absoluta*. The study observed that experience had a significant (P-value=5%) positive relationship with intercropping, fertilizer application, and staking management methods. Years of experience had no relationship with chemical pesticide use, desuckering, and crop rotation. This can be explained by the fact that the more experienced the small-scale tomato farmers were, the more they knew about using various cultural methods to control *T. absoluta*. The study results contradicted those of [37], who reported that the more experienced the farmers, the less they adopted IPM techniques in China.

The study also investigated the effect of income on *T. absoluta* management methods. The study results observed that income significantly negatively correlated with intercropping, desuckering, and staking. It was also observed that household income was significant (P-Value at 1%) and had a negative relationship with intercropping and desuckering, while Staking was significant at (P-value 5%).

The study observed that farmers used income from multiple choices to purchase chemical pesticides, which they explained was much more effective than cultural and biological control methods. The findings were consistent with [45] study, which observed that income was significant to integrated pest management methods.

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 had an antagonistic relationship. This showed that reduction in extensional training and accessibility led to less use of intercropping pest management methods to control *T. absoluta* due to lack of knowledge. The study results were consistent with [37] study, which reported that farmers had less accessibility to extension services, and the government promoted it among tomato farmers in China.

Table 2. *Multivariate Probit Results.*

Variable	Chemical pesticides	Intercropping	Desuckering	Fertilizer application	Crop rotation	Staking
	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Respondent gender	-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)
Age of Decision maker	-0.158(0.064)**	-0.033(0.031)	0.057(.021)**	-0.039(0.026)	-0.008(0.016)	0.026(.031)
Years of 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.
Source: Authors analysis using primary data.

5. Conclusion

The effects of socio-economic characteristics on choice of *tuta absoluta* management methods in tomato production in mwea were assessed and the marginal effects were analysed using Multivariate probit model. The likelihood ratio test of independence of error terms was rejected in all MVPs, which justified the choice of the MVP over a single equation-probit model to capture the interaction of the choices of pest management used.

The effect of gender, education, age, experience, land size, loan accessibility, household revenue, and extensional services have a significant positive or negative relationship with the use of chemical pesticides, intercropping, desuckering, fertilizer application, crop rotation and staking methods used to control *T. absoluta*. 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*. 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. 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. 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.

Abbreviations

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
NPPO	National Plant Protection Organization
SPSS	Statistical Package for Social Sciences
STATA	Statistics and Data Analysis Tool

Author Contributions

Mwaniki Poline Wawira: Formal Analysis, Methodology, Resources, Writing - original draft, Writing - review & editing

Gathungu Geofrey Kingori: Conceptualization, Formal Analysis, Methodology, Resources, Supervision, Validation, Writing - original draft, Writing - review & editing

Njogu Martin Kagiki: Data curation, Formal Analysis, Methodology, Resources, Supervision, Validation, Writing - original draft, Writing - review & editing

Ireri Dave Mwangi: Conceptualization, Resources, Data curation, Formal Analysis, Supervision, Validation, Investigation, Writing - original draft, Methodology, Writing - review & editing

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Data Availability Statement

Data used for analysis can be shared with the authors' authorization.

Conflicts of Interest

The authors declare no conflicts of interest.

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