Farmers' Perspectives on Tomato Leafminer (*Tuta absoluta*) in Tomatoes Production: A Case study of Kathaana Tomato Growers in Machakos County in Kenya

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Abstract

Tomato (*Solanum lycopersicum)* is an important vegetable crop worldwide and locally in Kenya. However, tomato farming is constrained by tomato leafminer (*Tuta absoluta*), an invasive insect pest. The pest cause severe yield losses in tomato production of 80 - 100 % if not controlled. This study determined the knowledge, perceptions and management practices of tomato leafminer. The study targeted Kathaana tomato growers from Machakos County in Kenya. A stratified sampling procedure was employed. Kathaana tomato growers are organized into five blocks. Within each block, farmers were randomly sampled and administered with a semi-structured questionnaire to collect the data. A total of 135 tomato growers were interviewed in this study. Data collected was cleaned and analyzed descriptively using Statistical Packages for Social Scientists (SPSS). From the survey, 99% of the respondents knew *Tuta absoluta* with 52 % of the farmers rating yield losses associated with the pest infection in tomato production to be more than 75 %. About 76 % of the respondents reported the larva stage of the pest as the most destructive stage. Majority of the farmers (97 %) perceived the pest problem to be severe during hot and dry seasons. Farmers knew and employed various methods of controlling the pest including physical and cultural, biological and the use of synthetic insecticides. However, about 99% of farmers majorly used synthetic insecticides, the method they perceived as the most efficient in controlling *Tuta absoluta* with 65 % of farmers reporting a spraying frequency of up to 10 times per growing season. From the study, it is clear that Kathaana tomato growers know *Tuta absoluta* and various management options available for the pest. However, to reduce the amount of synthetic pesticides used in controlling the pest, sensitization on the use of physical, cultural and biological controls before applying synthetic insecticides in managing the pest is important.

Keywords: Farmer perception, integrated pest management, Synthetic insecticides, knowledge, early warnings

Introduction

Tomato (*Solanum lycopersicum*) is an important vegetable crop worldwide and is produced in Kenya mainly for both domestic and export markets. Typically, the crop is highly nutritious and is rich in minerals, antioxidants, and vitamins (Kinyanjui *et al.*, 2021). Besides meeting the nutritional food requirements, tomato production in Kenya serves as a reliable source of employment and income, thereby contributing to improving livelihoods, and economic growth of the country.

The tomato crop is cultivated in all 47 counties of Kenya, with Kajiado, Kirinyaga, Taita Taveta, Narok, and Makueni counties being the leading ones in tomato production in the country (HCDA, 2021). The crop is grown both in open fields and greenhouses under irrigation and rain-fed systems (MoALF, 2015). Over the years, there has been an increment in the area of tomato production and quantity in the country, likely due to an increase in market demands and better crop prices. For instance, in the year 2019 - 2020, tomato was the leading vegetable crops grown in Kenya, accounting for 29.4% of the value of vegetables and 12.7% of the total value of horticultural crops grown in Kenya (HCDA 2021). During the same period, the areas under tomato production increased by 8% in the country from 29,086 ha to 31,486 ha. The production increased from 936,787 tonnes in 2019 to 973,304 tonnes in 2020 accounting for a 4 percent increase (HCDA, 2021). Despite the depicted positive trajectory in tomato production in Kenya, pests and diseases remain a major challenge to tomato farming in the country (HCDA, 2021; Kinyanjui *et al.*, 2021).

Tomato leafminer (*Tuta absoluta**)*** is an important pest affecting tomato production in Kenya and elsewhere. The pest feeds on many species of the Solanaceae plant family including tomato plants, but it also attacks other species outside the Solanaceae plant family, for example, the families of Amaranthaceae, Convolvulaceae, Fabaceae, and Malvaceae (Mutamiswa *et al.*, 2017; Biondi, *et al*., 2018). *Tuta absoluta* was first detected in South America in 2006 (Gharekhani and Salek-Ebrahimi, 2014; Biondi *et al.*, 2018), and today is found in all the major tomato-growing areas of the world including South America, Europe, Africa and Asia (Biondi *et al.*, 2018). In Africa, the pest is reported in 41 of the 54 countries (Mansour *et al.*, 2018). In Kenya, *Tuta absoluta* was first reported in the year 2014 in Mpeketoni and Witu areas in Lamu County. The pest was subsequently reported in other major tomato-growing areas including Isiolo, Kirinyaga, Meru, Nairobi, Nakuru, Kakamega, Kajiado, Rift Valley and Nyanza (KALRO, 2014; Mugo, 2014). From Kenya, the pest further invaded neighbouring countries including Tanzania (2014), Uganda (2015), and other countries in the East African region (Mansour *et al.*, 2018).

Tuta absoluta infestation is reported to cause great losses of up to 80 - 100% (Desneux *et al.*, 2010) in tomato crops when no intervention measures are carried out. This leads to financial losses and a shortage of tomato supply in affected countries (Desneux *et al.*, 2010; Gharekhani and Salek-Ebrahimi, 2014; Biondi *et al.*, 2018). The larvae stage is the most destructive stage of the pest. The larvae attack various parts of the tomato plant including the leaves, buds, stems, flowers, calyces, and fruit. The severely attacked tomato fruits lose their commercial value. Damage to terminal buds reduces plant growth and decreases fruit yield. Both yield and fruit quality are reduced by direct feeding by the larvae, and subsequently by secondary pathogens entering the mines and causing fruit rot (Gharekhani and Salek-Ebrahimi, 2014).

Several management approaches are available for controlling infestations of *Tuta absoluta* in tomatoes, including chemical, biological, cultural, physical methods and breeding programs for tomato resistance (Biondi *et al.*, 2018; Biondi and Desneux, 2019). Chemical control using synthetic insecticides is considered the most effective management option for this pest (Lietti *et al.*, 2005; Silvério *et al.*, 2009; Lebdi-Grissa *et al.*, 2010), but there has been a lot of emphasis in Kenya to promote the use of Integrated Pest Management (IPM) approaches in controlling *Tuta absoluta* (CABI, 2020). The adoption of the IPM approaches by farmers in the country is still limited.

An important part of designing IPM approaches in agriculture is knowledge and perceptions of farmers on the pest. This is

because knowledge and perceptions have implications for management practices. The knowledge, for instance, informs on how farmers understand and appreciate a problem, and how they feel about the cause of the problem, and this information certainly influences the farm management practices they carry out (Lwin *et al.*, 2012; Schreinemachers *et al.*, 2015). However, the understanding of the level of farmers' knowledge, perceptions and management practices for *Tuta absoluta* in tomato production by Kathaana farmers in Machakos County, Kenya, is not documented, which is the objective of this study. The understanding, here documented, is necessary as it will guide the development of appropriate management strategies for *Tuta absoluta* pest in tomato crop production leading to improved yield and income for Kathaana farmers and potentially other tomato farmers elsewhere in the country.

Materials and Methods

Description of the Study site

The study was conducted in Mitaboni ward, Kathiani sub-county in Machakos county, and (Figure 1). The Kathiani sub-county is located between longitudes 37^o 16'30' East and 37^o 19' 0' East and latitudes 1^o 23'0' South and 1^o 20'30' South. The area experiences bimodal rainfall of 500 mm to 1000 mm. The long rains are normally received in March to May whereas the short rains are received in October to December. Temperatures range from 18 to 29° C; July being the coldest month and October and March being the warmest months (CIDP, 2015). The region has sandy clay loams to black cotton soils. The area falls in agroecological zone LM4, suitable for the production of maize, beans, mangoes, cow peas, indigenous chicken, and pigeon peas (Jaetzold *et al*., 2010). Farmers practice mixed cropping of growing of maize, beans and pigeon pea. Irrigation activities are also present in the study area, with farmers relying on the Kathaana river for the production of vegetables, tomatoes and green maize. The study involved the Kathaana tomato Growers, a group of registered farmers under Kenya's Department of Gender and Social Services in Kathiani sub-county.

Sample Size Determination and Sampling Procedure

The Kathaana tomato growers are divided into five blocks with a total number of 200 farmers. A stratified sampling procedure was employed. To calculate the sample size, the formula by Yamane (1967) was used which is as follows $n = \frac{N}{1+Ne^2}$

where n is the sample size, N is the population size, and 'e' is the level of precision (at 5%). The sample size was distributed proportionally to the population of each of the five blocks. Within each block, tomato farmers were randomly sampled and interviewed with the help of an agricultural extension officer.

Data collection

Data were collected using a semi-structured questionnaire administered through face-to-face interviews. The data collected using the questionnaire included socioeconomic characteristics of the farmers, tomato production, farmers' knowledge, perceptions and management practices of the *Tuta absoluta*. Farmers' knowledge was assessed by asking if they were aware of *Tuta absoluta* and its occurrences on their farms. The responses to the knowledge questions were recorded in a series of binary responses (1 for yes and 0 for no) as described by Asudi *et al.* (2015) and Khan *et al.* (2014). A4-size photographs of a tomato crop plant with *Tuta absoluta* infected leaves, stems, petioles and fruits were used to assess farmers' knowledge of the pest. The photos had no text to ensure the identification was based on visual cues by correlating the symptoms in fields with those in the pictures. When needed, the enumerators described the pest infestation symptoms to the farmers. The perception of the disease problem and its rate of spread was captured as a categorical variable using a 4-point Likert scale rating. For this, farmers were asked to rate the disease problem on a scale of 0 to 3, where 0 = no problem, 1 = moderate problem

2 = severe problem, and 3=very severe problem. Interviewed farmers were also asked to name the tomato cultivars they grew, the purposes for which tomatoes were cultivated, the source of planting materials, the cropping system, the seasonal prevalence of the pest on their tomato crops and the control measures they practiced.

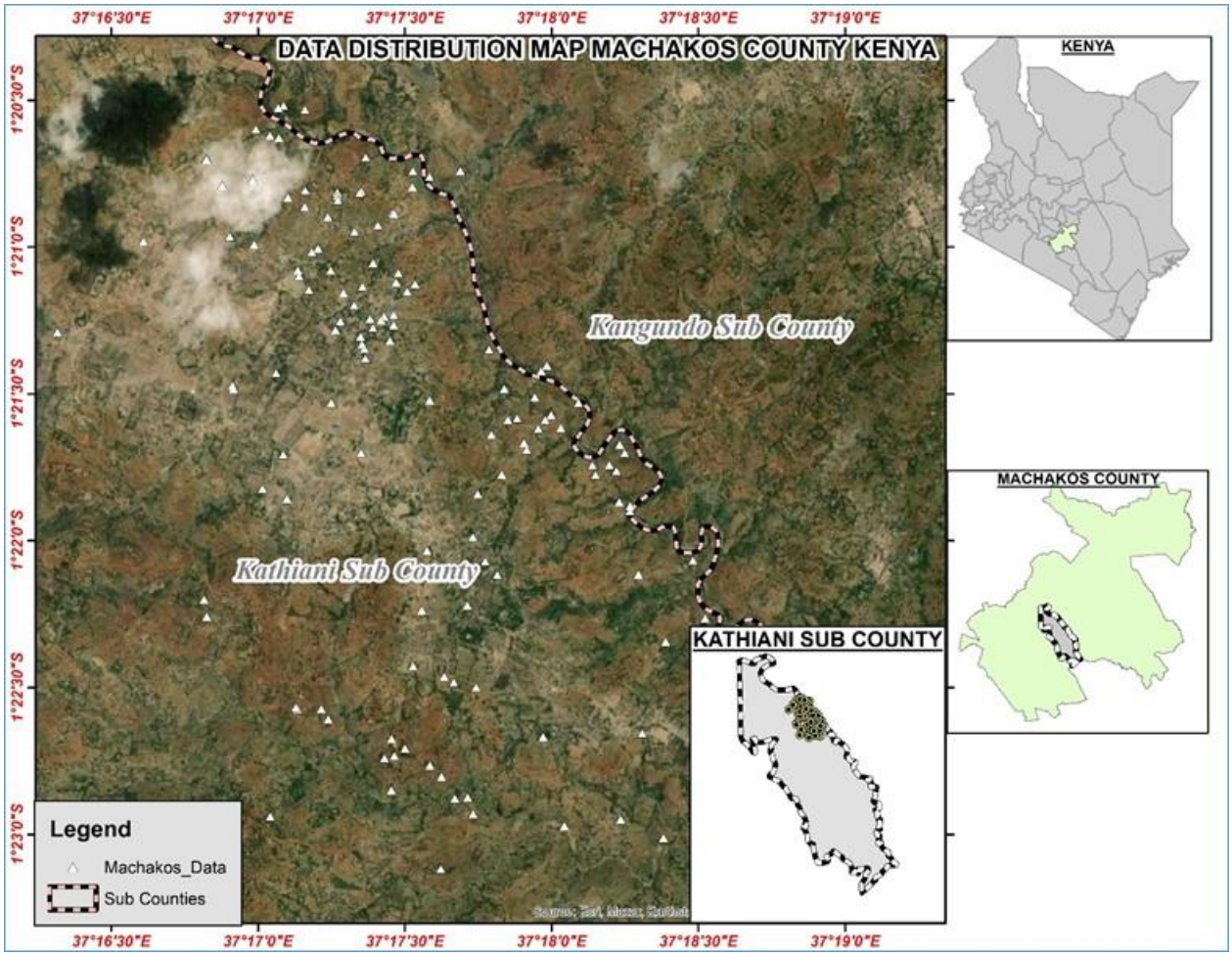

Figure 1: Study site and location of Kathaana tomato growers interviewed knowledge, perceptions and management practices of Tuta absoluta in tomato

Data analysis

Data collected was cleaned and analyzed using Statistical Packages for Social Scientists (SPSS) version 16.0 statistical software (SPSS. Inc. 2008). Data analysis was carried using descriptive statistics such frequency analysis, number and percentage of responses. The analyzed data were summarized and tabulated using tables, bar graphs and bar charts.

Results

A total of 135 farmers were interviewed for the baseline survey in the five blocks (Table 1). The number of farmers per block is given in Table 1. The table also gives the gender, marital status and level of education of the respondents. The majority of the farmers were men (64%), married (93%) and the men were the majority household heads (84%). The age of majority of the respondents was between 35 to 44 and 55 to 64 years old. In terms of education levels, 42 % of the respondents had reached class 8 (School up to 6-9 years (Class 5-8) (Table 1).

In terms of employment majority of the respondents are unemployed in formal occupation. Out of this 51% were trading in livestock and livestock products, on the other hand, 47 % were shopkeepers, firewood traders, and farm produce (Figure 2a). The

monthly household expenditure was highest in paying school fees (Kenya shillings 23,000) followed by farming/buying of livestock inputs (Kenya shillings 19,000; Figure 2b). The majority of the farmers kept farm records (Figure 2c) with sales records being kept by the majority of the respondents followed by production records (Figure 2d).

Table 1: Characteristics of the Kathaana farmers' interviewed for farmers' knowledge perceptions and management practices of *Tuta absoluta* in tomato production

		Block 1 N=26	Block 2 N=30	Block 3 N=22	Block 4 N=42	Block 5 N=15	Total (%)
Gender	Male	18	21	10	30	8	64
	Female	8	9	12	12	7	36
Marital Status	Single	3	2	0	0	0	4
	Married	22	27	21	41	15	93
	Widow/Widower	1	1	1	1	0	3
Age (years)	18-24	1	1	0	1	0	2
	25-34	2	3	3	7	2	13
	35-44	8	7	7	12	3	27
	45-54	5	10	3	6	8	24
	55-64	9	7	8	12	1	27
	>66	1	2	1	4	1	7
Highest educational qualification of the respondent	Illiterate	0	0	1	1	0	1
	Literate but no formal education	0	3	0	0	1	3
	School up to 5 years (class 1-4)	1	0	1	1	1	3
	School up to 6-9 years (Class 5-8)	10	14	10	15	7	42
	Drop out-secondary	3	3	0	2	0	6
	Secondary school	9	5	5	17	4	30
	Artisan training			1			1
	Technical training	3	3	1	5	1	10
	Undergraduate	0	2	3	1	0	4
	Diploma					1	1

About 15 Ha was reported to be the largest farm size owned by the farmers. The reason for growing the tomatoes was reported by 82% of the respondents to be sale and home use (market and subsistence) (Figure 3a). About 93% of the farmers reported having more than two years of experience in growing tomatoes (Figure 3b). About 61% reported growing tomato two times per year per block. Among several varieties of tomatoes grown by Kathaana farmers, the variety ‘Rio grande’ was the most popular (Figure 3c) because of its high-yielding, and tolerance to pests and diseases among other factors (Figure 3d). The seed was mainly sourced from the local agro-dealers.

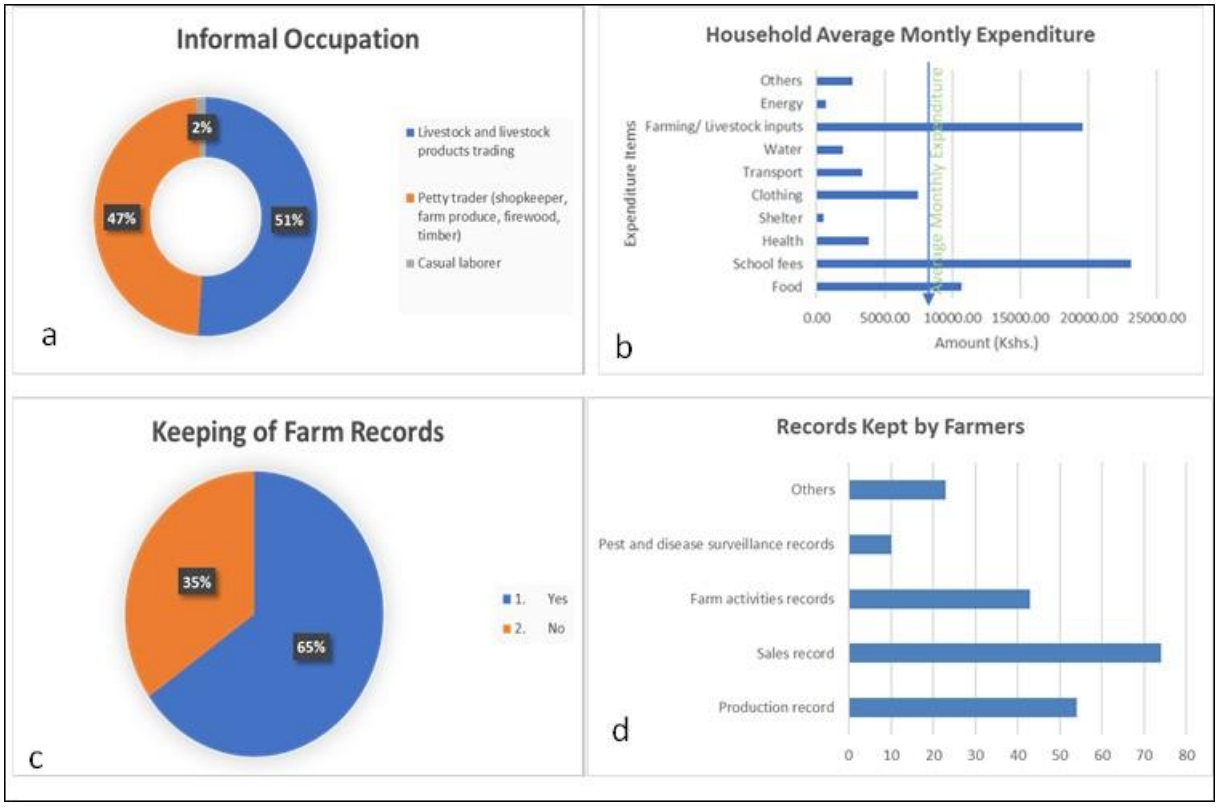

Figure 2: (a) Occupation, (b) monthly expenditure (c) recording keeping and (d) the type of records kept by the Kathaana farmers

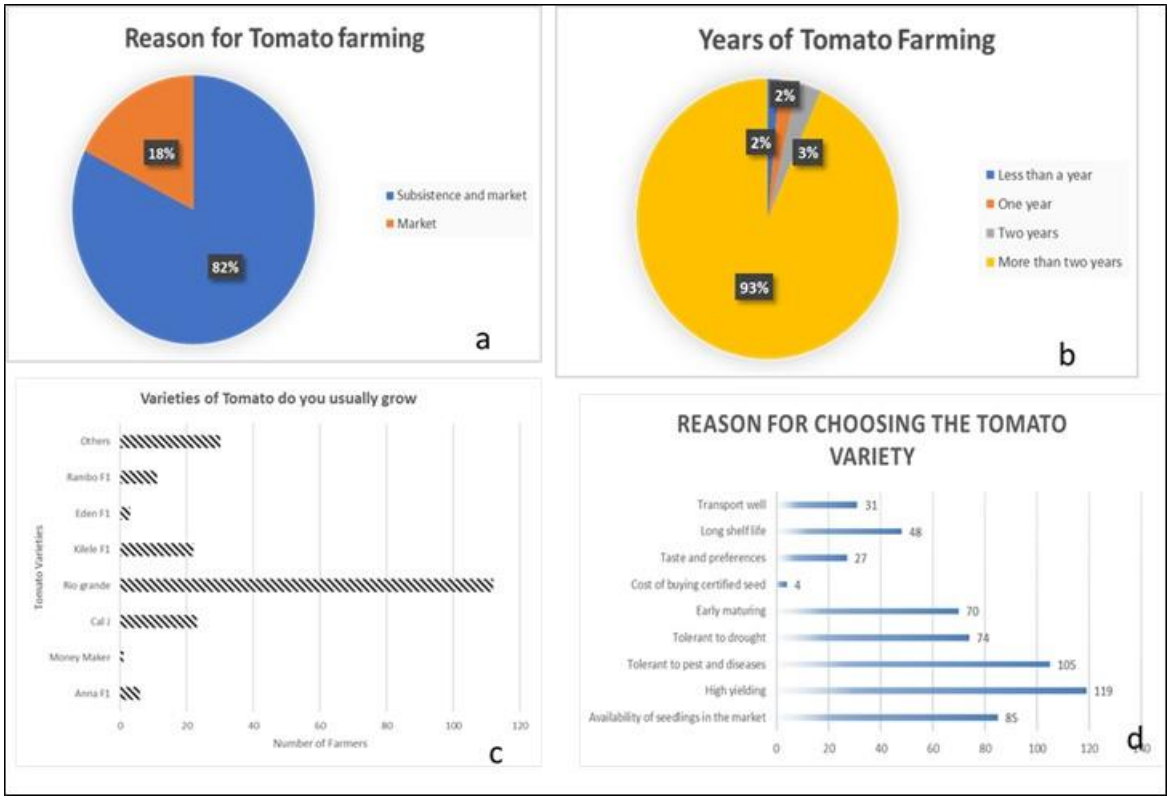

Figure 3: Tomato production by Kathaana farmers. (a): the purpose of tomato cultivation; (b): Number of years of growing tomatoes; (c): varieties grown by the respondents; (d): Reasons for growing the chosen variety.

Kathaana farmers' knowledge of *Tuta absoluta*

As shown in Table 2, 99% of the respondents knew *Tuta absoluta*. The farmers also reported that the most experienced destructive stage of *Tuta absoluta* was the larva (76%). The majority of the farmers were able to recognize symptoms associated with *Tuta absoluta* infection on tomato plants. Some of the symptoms recognized included thin silvery trails (tunnels) on leaves, irregular leaf mines, the larvae itself, black frass inside the tunnels, tiny holes on stems with frass, silky webs folding the leaves, leaf fall, holes in fruit, possibly surrounded by black frass, larvae and galleries inside the fruit, sunscald of fruit due to leaves prematurely falling, fruits rot and presence of adult *Tuta absoluta* in the farm. Symptoms associated with *Tuta absoluta* were reported to be most prevalent during hot and dry seasons (Table 2). The moth infection was reported to be most destructive during the fruiting stage (Table 2). 95% of the farmers rated the problem of *Tuta absoluta* infection as a very severe problem. Of all respondents, 69 farmers rated tomato yield losses associated with *Tuta absoluta* infection at 75% (Table 2).

Table 2: Farmers' Knowledge and Perception of *Tuta absoluta*

		Block 1 N=26	Block 2 N=30	Block 3 N=22	Block 4 N=42	Block 5 N=15	Total (%)
Knowledge of *Tuta absoluta*	Yes	25	29	22	42	15	99
	No	1		1			1
Stage of *Tuta absoluta* is the most destructive	egg						
	Larva	24	22	17	34	5	76
	Pupa	1		1	6	5	9
	Adult	1	7	4	2	5	14
Time/season of the year when damage by *Tuta absoluta* is most severe	Throughout the year		1		1		2
	During the cold and wet season				1		1
	During the hot and dry season	26	29	22	40	15	97
Rating of *Tuta absoluta* problem in Kathaana tomato growers	Not a problem						
	Severe problem	3	0	1	2		4
	Very severe problem	23	29	21	40	15	96
Rating of tomato yield losses associated with *Tuta absoluta* infection	0-5%	2					1
	6-25 %		6	3	1	1	8
	26-50 %		2	1		1	4
	50-75 %	10	12	9	10	6	35
	>75 %	14	10	8	30	7	52

Monitoring and management measures of *Tuta absoluta* outbreak in tomato

The prevention measure for *Tuta Absoluta* infection used by most farmers (27%) was planting clean tomato seedlings free from all stages of the pest. All respondents practiced scouting for *Tuta absoluta* in their farms. About 95% of the farmers looked for black frass on the stem and exit holes on the fruit surface daily as a way of scouting and monitoring the outbreak of *Tuta absoluta*. A success rate of 52% in scouting and monitoring as a prevention measure for *Tuta absoluta* was reported by the respondents. Physical and cultural practices for controlling

the moth were carried out by 85% of the respondents. These practices included destroying infested plants and plant parts, burying (50 - 100 cm) all pest-infested fruits and foliage, removal of alternative reservoir hosts such as nightshades before and during the tomato cropping cycle and crop rotation with non-host crops.

About 86% of the farmers knew biopesticides used them in controlling *Tuta absoluta* such as extracts from neem seeds (Azadirachta indica), or products containing Azadirachtin including Neemroc, Nimbecidine, Neemark EC, Achook 0.15 EC, and Azadirachtin (0.15%). The biopesticides were sourced from local agrochemical shops, with respondents with a 76 % efficacy in controlling the pest. 97% use of the respondents used chemical pesticides to control *Tuta absoluta* (Figure 4a). The majority of the respondents spray chemical pesticides 6-10 times a season (Figure 4b). About 76% of farmers reported that chemical pesticides successfully controlled *Tuta absoluta* (Figure 4c). The average cost for applying chemical pesticides was reported to be Kenya shillings 9,035 (USD 70). Although Kathaana farmers mainly produce tomatoes, the majority of them (61%) reported controlling the outbreak of the moth at different times (Figure 4d). All farmers interviewed were sourcing their pesticides from a local agrochemical shop within their agricultural production area. From the survey, all the farmers (99%) wear protective gear when spraying chemical pesticides (Figure 4e).

Extension services in Kathaana tomato growers

About 67% of the farmers reported having received information on extension services over the past 12 months (Figure 5a). Most of these farmers received information from crop disease management, pest control, and input use (Figure 5b). The farmers' accessed data on agricultural extension service was reported to be through the government of Kenya (GOK) (69 %), radio/ televisions (53 %), private institutions (48%), and between farmers themselves (48 %) (Figure 5c). Although the majority of the farmers were aware of agricultural extension services, they were not willing to pay for the extension services. However, a good percentage was willing to pay and have ever paid for these extension services (Figure 5d).

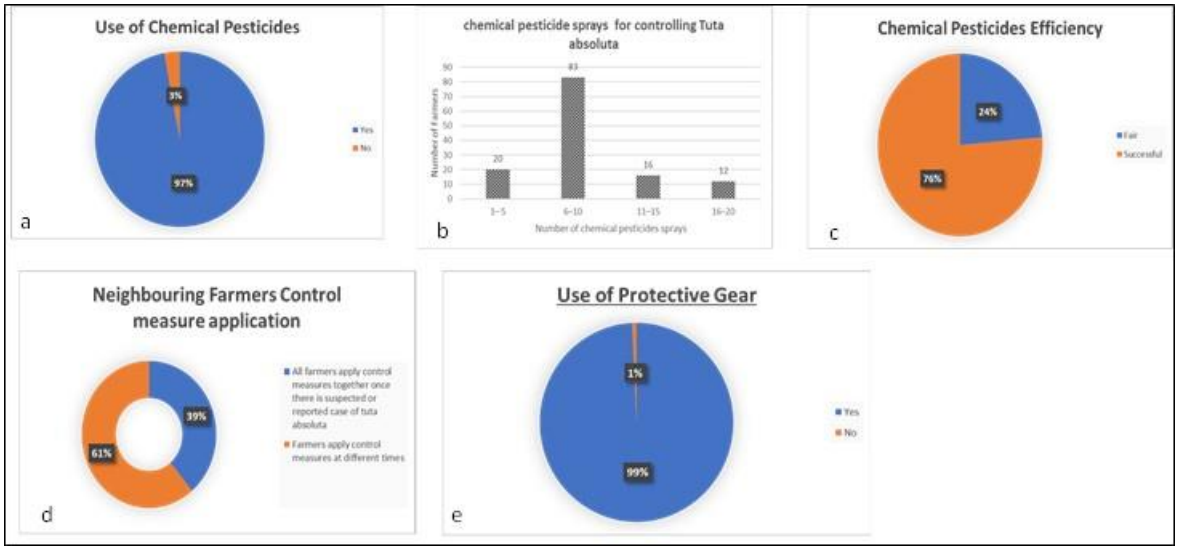

Figure 4: Chemical control of Tuta absoluta (a): Use of chemical pesticides; (b): number of times the chemical is sprayed; (c): Efficiency of the chemicals in controlling the pest; (d): control measures application by neighbours and (e): Use of protective gear when spraying

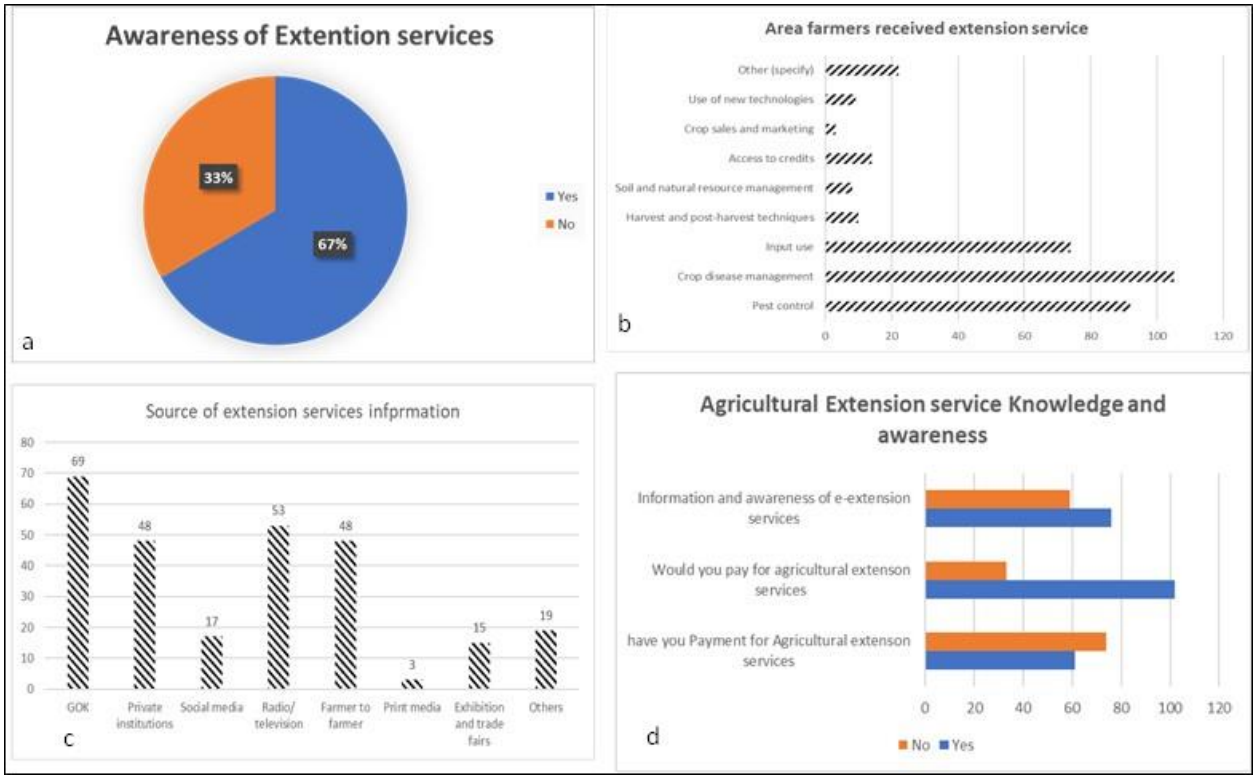

Figure 5: Status of extension services in Kathaana tomato growers. (a): Awareness of extension services; (b): Extension services received; (c): Source of the extension services and (d): Willingness to pay for extension services

Discussion

To implement a successful and sustainable integrated management program for *Tuta absoluta*, adequate knowledge of how farmers perceive the problem, their attitudes, and practices regarding tomato crop protection are required. A survey study was, thus, conducted on Kathaana tomato growers in Machakos County to unravel their pest perspectives. The study showed that almost all Kathaana tomato growers have knowledge of *Tuta absoluta* and had experienced its menace. The pest and its destructive nature have been reported in other parts of Kenya where tomato is produced (Nderitu *et al.,* 2018; Kinyanjui *et al.,* 2021). The destructive nature of the pest poses an important threat to nutrition and food security in Kathaana tomato growers and Kenya. This would probably result in a detrimental socioeconomic impact on the livelihoods of these farmers. The ability of the farmers to recognize symptoms associated with the pest shows the importance of farmers' knowledge in pest management. This is because, once farmers notice the symptoms, they can timely start management interventions to prevent pest spread.

The majority of the farmers rated the problem of *Tuta absoluta* as very severe. This is because the farmers had experienced the damage and yield losses of tomatoes due to the pest infestation. The majority of the farmers reported more than 75 % tomato yield losses as a result of this pest. In other studies, the pest was reported to cause up to 80 – 100% yield losses for greenhouse and open-field tomato production and more so if no intervention measures are taken *(Desneux et al.,* 2010). This agrees with our findings.

Symptoms associated with *Tuta absoluta* were reported to be most prevalent during hot and dry seasons. In Senegal, farmers reported avoiding growing tomatoes during the late dry season since the dry season was reported to be the riskiest period for *Tuta absoluta* infestations (Mansour *et al.,* 2018) which

agrees with our findings. The population growth of *Tuta absoluta* is highly influenced by temperature (Negi *et al.,* 2020). Intrinsic rate of increase, net reproductive rate and finite rate of increase *Tuta absoluta* was reported to be high at 25° and 30°C. This could explain why the *Tuta absoluta* risks are high during the hot and dry season. In Senegal, a field survey of the pest throughout the year showed a severe decline in the pest populations during the rainy season. The decrease in population was primarily attributed to the decrease in resource availability since tomato crops are less planted during the rainy season because of high incidences of foliar diseases (Mansour *et al.,* 2018).

Majority of the Kathaana tomato growers reported to practiced scouting and monitoring for the pest almost daily. Information gathered in the scouting process can be used to determine if pest control measures are warranted. Further, the information helps in selecting appropriate control technologies and time them for maximum effect. From the study, the majority of the farmers grow tomatoes for market and home consumption. In addition, al most all farmers had experienced yield and quality losses in tomatoes as a result of *Tuta absoluta*. Therefore, monitoring and scouting as reported by the majority of the respondents ensured timely interventions to the pest.

Physical and cultural practices of controlling *Tuta absoluta* were reported by the majority of the respondents. For instance, farmers destroyed infected plants during the tomato production cycle. This action may be linked to farmers' knowledge about infected plants being the source of inoculum for further pest spread. Though the practice seemed to bear good results, the level of controlling the pest was reported to be not very effective. The use of pheromone-based traps was minimally applied probably due to a lack of farmers' knowledge. Knowledge and use of biopesticides against *Tuta absoluta* were reported by farmers. The biopesticides are also stocked in the local agrovets showing farmers are using different options for controlling the pest, an important aspect in integrated pest management.

The use of synthetic insecticides is a predominant management option for *Tuta Absoluta* worldwide (Desneux *et al.,* 2011; Biondi *et al.,* 2018). In Kenya tomato farmers have been using synthetic insecticides to control the pest (Kinyanjui *et al.,* 2021; Nderitu *et al.,* 2018). The majority of the farmers in this study sprayed the synthetic insecticides 6-10 times a season, with an average cost for applying them being Kenya shillings of 9,035 (USD 70) per hectare per season. The use of synthetic insecticide management options is costly and could be ineffective and unsustainable, leading to an increase in the number of needed spray applications (Potting *et al.,* 2013). Repeated use of synthetic insecticides reduces the populations of natural enemies of *Tuta absoluta* and increases the development of resistant populations of insect pests (Anastasios *et al.,* 2014; Ajaya *et al.,* 2016). Increasing frequency of insecticide application further leads to reduced efficacy, and possibly more damage to pollinators and other beneficial fauna (Biondi *et al.,* 2018). The overuse of synthetic insecticides could also lead to the fast development of pesticide-resistant strains (Han *et al.,* 2018). Toxic pesticide residues may also persist on harvested fruits, leading to contamination and most notably, food safety concerns for consumers.

Conclusion and recommendations

In conclusion, Kathaana tomato growers know *Tuta absoluta* and employvarious methods to control the same. However, the use of synthetic insecticides is the main method used to control *Tuta absoluta* by the Kathaana tomato growers. The use of synthetic insecticides is however associated with a negative impact on the pests' natural enemies, increase in the cost of production, environmental pollution, and causes chemical residues on tomatoes. Since Kathaana farmers

are aware of the various methods that are used to control the pest, sensitization on the use of environmentally friendly measures in managing the pest is important.

Acknowledgments

The authors wish to thank Artificial Intelligence for Agriculture and Food Systems (AI4AFS) innovation research network for funding this work through the research project 'Pest Occurrence Early Warning System and Diagnostic Tool Development using Geoinformation and Artificial Intelligence: A Case Study of Tomato Leaf Miner (*Tuta Absoluta)*, and in Machakos County, Kenya. We would like to extend sincere gratitude to all respondents who willingly participated in the study.

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