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Tomato Production Characteristics, Biotic Constraints and their Management Practices by Farmers in Bungoma County, Kenya

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Abstract

Tomato (*Solanum lycopersicum* L.) is an important crop in Bungoma County, Kenya. Its production is constrained by arthropod pests and diseases which make farmers rely heavily on synthetic chemicals to control them. To support the development of effective integrated pest and disease management strategies on tomato, a survey was carried out in Sirisia, Bumula and Mt. Elgon sub-counties. A total of 90 randomly selected farmers in the region were interviewed using a structured questionnaire. Data collected included demographic characteristics of farmers, tomato varieties, farm size, prevalence of pests, diseases and their management practices. Majority of the respondents were male with 89.7% in Mt. Elgon. Most of the respondents had primary education. The varieties of tomato grown were Rio-grande, Kilele, Carl-J, Money-maker, Safari and Onyx. The average farm size ranged from 0.25 to 1.0 hectare with 80.4% in Sirisia. Most prevalent pests affecting tomato were *Frankliniella occidentalis* (58.6%) and *Bemisia tabaci* (35%) while the most reported disease was *Ralstonia solanacearum* (75%). The chemicals used against pests included Imidacloprid (24.4%), Alpha-Cypermethrin (20.7%) and Lambda-cyhalothrin (20%). Farmers controlled diseases using Metalaxyl-M, Mancozeb, Propineb and Carbendazim. Out of the total ninety respondents in the region, only 2.4% in Sirisia used bio-pesticides. At least 60%, 22% and 20.7% of respondents in Bumula, Sirisia and Mt. Elgon, respectively used more than one chemical. About 10% of respondents in Bumula and 6.9% in Mt. Elgon applied chemicals twice a week. In Sirisia, about 53.6% reported that the chemicals used effectively controlled the pests and diseases compared to Bumula (61%) and Mt. Elgon (58.6%) who reported that they were ineffective. The main source of advice on crop protection was Agrovet shops. The findings revealed that pest and diseases limited tomato production in the region. The study therefore recommends increased awareness on proper use of chemicals and use of safer alternatives such as bio-pesticides to reduce on pesticide residues and the production cost. Future studies on the level of synthetic chemical residues in tomatoes produced in the region should be conducted.

Keywords: Bio-pesticides, chemicals, diseases, pests, tomato.

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1. **Introduction**

Tomato (*Solanum lycopersicum* L.), is among the most valuable crops grown by small scale farmers in Kenya (FAOSTAT, 2018). Tomatoes are the most locally marketable vegetable and accounts for about 20% of the total vegetable production in Kenya (HCDA, 2017). It also contributes 137,000 US dollars annually to the Kenyan economy and is a source of income and employment opportunities to small scale farmers (HCDA, 2017). Tomato production is estimated at an average of 410,033 tons per annum (Factfish website, 2018). The production of the crop is impeded by a myriad of biotic and abiotic factors. Biotic constraints such as arthropod pests, fungal, bacterial and viral diseases are among the most important draw backs (HCDA, 2017; Willis *et al*., 2018).

The most important arthropod pests infesting tomato crop are the leaf miner moth (*Tuta absoluta*) (Meyrick), whiteflies (*Bemisia tabaci*) Gennadius, thrips (*Frankiliniella occidentalis*) Pergade, African bollworm (*Helicoverpa armigera*) (Hubner), aphids (*Myzus persicae*) and mites *Tetranychus* spp. (Infonet-Biovision, 2018; Wakil *et al*., 2018). The crop also affected by diseases including early blight (*Alternaria solani*), bacterial wilt (*Ralstonia solanacearum*), late blight (*Phytophthora infestans),* Fusarium wilt (*Fusarium oxysporum),* powdery mildew (*Oidium neolycopersici*), tomato spotted wilt, chlorotic spot disease and tomato yellow leaf curl virus (Kubienova *et al*., 2013; Akrami and Yousefi, 2015).

In an effort to control tomato pests and diseases, small scale farmers rely heavily on synthetic chemicals (Nashwa and Abo-Elyousr, 2012; Asante *et al*., 2013). However, concerns have been raised regarding contamination of the produce and pollution of the environment by the pesticides, health hazards to producers and consumers and the risk of elimination of non-target beneficial organisms from the ecosystems (Business Daily, 2015; Ndakidemi *et al*., 2016; Mustapha *et al*., 2017; Victoria *et al*., 2017). In export markets, misuse of synthetic chemicals poses problems with market access due to high residue levels (Muthomi *et al*., 2016). This study was therefore conducted to investigate farmers' knowledge on tomato production, pests and disease constraints and the methods used to control them.

2. Materials and methods

A survey was conducted in June, 2017 in Bungoma County situated in Western Kenya. Farming is the main economic activity in the County with farmers engaged in cultivation of crops and livestock keeping. Crops grown include maize, beans, finger millet, potatoes and vegetables such as tomatoes, kales and cabbages. The County is among the key tomato producing regions in Kenya dominated by small-scale farmers (NAFIS, 2018). Three tomato producing sub-counties were surveyed. These were Mt. Elgon, Sirisia and Bumula. The sub-counties were selected based on their prominence in producing significant tomato in the County and represented different production agro-ecological zones. Mt. Elgon lies between 1°10´12´´N and 34°19´48´´E with altitude ranging from 1,547 to 1,856m above sea level (ASL) on lower highland agro ecological zone. Bumula sub-county is found on lower midland zone 4 (LM4) between 0°37´12´´N and 34°27´36´´E within 1,301-1,467m ASL. Sirisia is within the lower midland zone 2 (LM2) located between 0°45´0´´N and 34°30´36´´E under lower midland zone 2 (LM2) with an altitude ranging from 1,354 to 1,508m ASL. The areas have varying soil types, with inherently fertile deep rich Andosols, Acrisols and Nitisols in Sirisia, Bumula and Mt. Elgon, respectively (Jaetzold *et al.,* 2012). These areas experience average annual temperatures between 15° to 23°C (Jaetzold *et al*., 2012). The sub-counties are characterized by a bimodal rainfall pattern amounting to 950 mm-1,500 mm per annum. The long rainfall season is experienced from March to July while short rain season from August to October (Bungoma CIDP 2013-2018).

Purposive random sampling technique based on Nassiuma (2000) formula for determining the sample size: $n = NC^2 / C^2 + (N-1)\ e^2$ where, n =Sample size, N= Size of the target population which was 900 tomato farmers, C= Coefficient of variation (0.5) and e= Margin of error (0.05) was used to select tomato fields. Substituting the values in the above equation, estimated sample size was: $n = 900\ (0.5)^2/0.5^2 + (900-1)\ 0.05^2$

n=90 respondents.

Following all roads, fields were selected 3 to 5 Km apart. Forty one farmers' managed fields from Sirisia, 29 from Bumula and 20 from Mt. Elgon sub-County were selected for data collection. A Global Positioning System (GPS) unit was used to get the coordinates of the farmers' fields. A structured questionnaire was administered to tomato farmers to gather information on demographic characteristics such as age, gender and education level. Other data included sources of seedlings, tomato varieties grown, farm sizes, prevalence of pests, diseases, their management practices and sources of information on tomato production. Photo-cards of pests and symptoms of diseases were used to assist the farmers in identification.

Pest and disease prevalence was determined visually as described by NICRA *et al*. (2012). Twenty tomato plants at vegetative, flowering and fruiting stages were randomly selected from each field and physically checked for presence of individual pests, diseased plants and their damage symptoms. The immature and adult stages of the pests detected on the tomatoes were collected by carefully detaching the infested plant parts, placed in labeled plastic vials, stored in a cool box and taken to Kenyatta University laboratory for adult emergence and identification based on morphological features (Moritz *et al*., 2013). Samples of diseased tomatoes from farmers' fields were also collected, taken to the laboratory for isolation of the pathogens for further confirmation.

2.1 Statistical analysis

Data on age, gender, education level, farm sizes, sources of seedlings, varieties of tomatoes grown, incidence of pests and diseases, management practices and source of agricultural information was reviewed, cleaned, summarized, organized in Microsoft Excel, coded and analyzed using Statistical Programmes for Social Sciences (SPSS) (IBM Statistics 20). Descriptive statistics was carried out to generate frequencies and percentages of the variables studied.

3. Results

3.1 Demographic characteristics of respondents

The study indicated that male were more involved in tomato production compared to female across the sub-counties with Mt. Elgon having 89.7 % of growers being male. Majority of the farmers were between 41-45years; (37.9% in Mt. Elgon, 25% in Bumula and 22% in Sirisia sub-county). Most of respondents had attained primary level of education, with Bumula and Mt. Elgon having over 45% with at least secondary education (Table 1).

Table 1: Percent (%) gender, age and education level of respondents in the sub-counties

Variable		Sirisia	Bumula	Mt. Elgon
Gender	Male	85.4	80	89.7
	Female	14.6	20	10.3
Age in years	<25	-	5	-
	26-30	4.9	-	3.4
	31-35	22	15	17.2
	36-40	9.8	20	34.5
	41-45	22	25	37.9
	46-50	14.6	5	6.9
	51-55	14.6	15	-
	>55	12.2	15	-
Education level	None	2.4	-	-
	Primary	75.6	50	55.2
	Secondary	19.5	45	41.4
	College	2.4	5	3.4

3.2 Sources of seedlings and varieties of tomato grown by farmers

The outcomes of this study revealed that all farmers raised their own seedlings in the homesteads for use in the field. It was observed that Rio-Grande was the most popular variety grown in all the sub-counties with 44.8% cultivated in Mt. Elgon, 41.5% in Sirisia and 35.0% in Bumula Sub-county. Other varieties included Kilele, Carl-J, Ana F1, money maker, Safari, Elgon Kenya and Onyx (Figure 1).

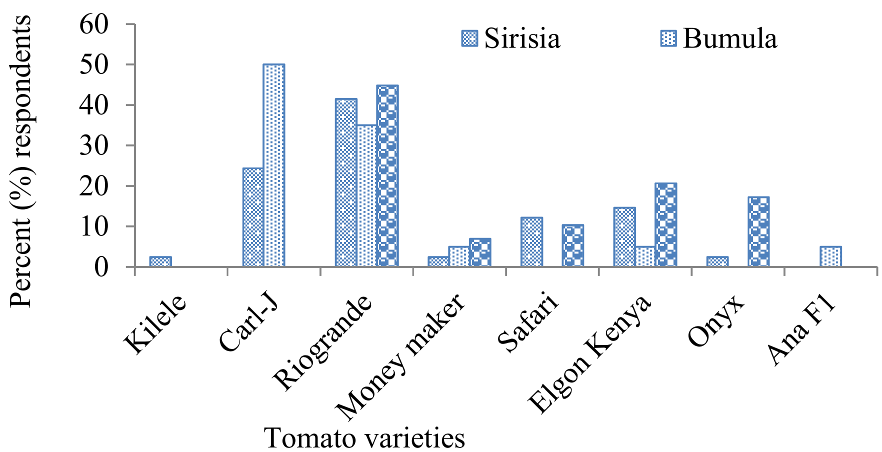

Figure 1: Tomato varieties grown by respondents in Bungoma County

3.3 Farm size used by farmers for tomato production

The study indicated that total farm sizes in all the sub-counties ranged from 0.25 to 2.0 hectares. Majority of the respondents had farm sizes ranging from 0.25 to 1.0 hectares with 80.4% in Sirisia sub-county. About 2.3 % of the respondents in Sirisia sub-county had above 2 hectares of land (Figure 2).

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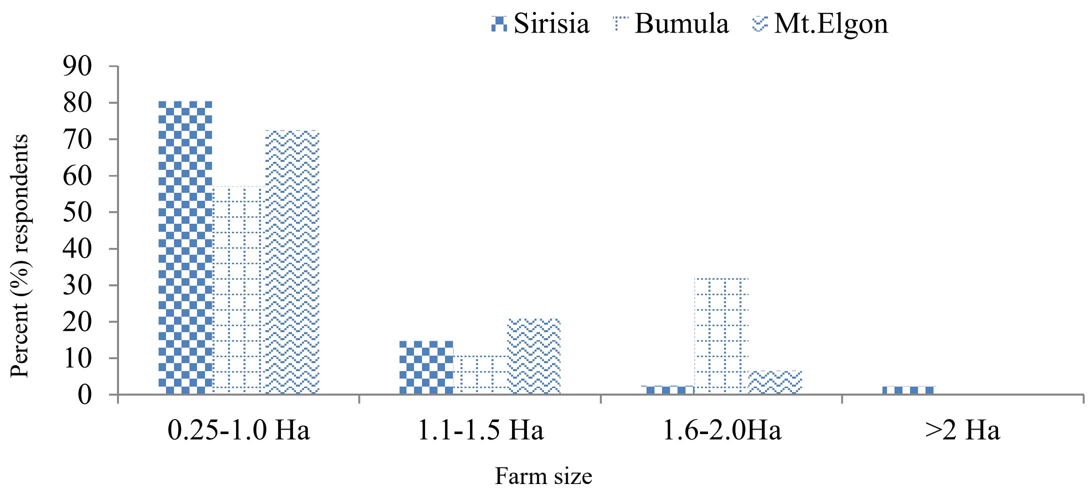

Figure 2: Land under tomato cultivation

3.4 Pests and diseases affecting tomato production

Six arthropod pests including *F. occidentals*, *T. absoluta*, *B. tabaci, H. armigera*, *Tetranychus* sp., and *M. persicae* were identified as main pests affecting tomato crop in Bungoma County. *Tuta absoluta* was abundant in Sirisia followed by Mt. Elgon and least in Bumula Sub-county accounting for 29.3%, 27.65 and 5%, respectively. *Frankliniella occidentalis* was most prevalent in Mt. Elgon sub-county with 58.6% followed by 31.7% in Sirisia and 30% in Bumula. About 35%, 17.1% and 10.3% of *B. tabaci* were reported in Bumula, Sirisia and Mt. Elgon, respectively. *Helicoverpa armigera* accounted for 30%, 14.6% and 3.4% in Bumula, Sirisia and Mt. Elgon. *Tetranychus* sp. and *M. persicae* were only reported in Sirisia sub-County accounting for 4.9% and 2.4 %, respectively (Figure 3). It was observed that *Ralstonia solanacearum* was the major disease limiting tomato production across the three sub-counties accounting for 75% in Bumula. The highest incidence of *P. infestans* (24.1%) and *Fusarium oxysporum* (17.1%) was recorded in Mt. Elgon and Bumula respectively (Figure 4).

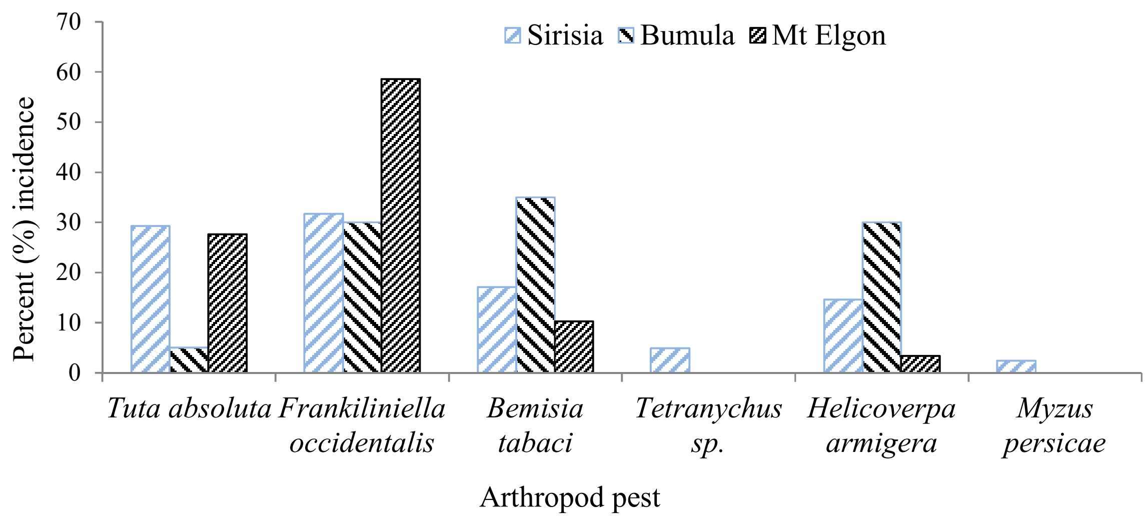

Figure 3: Arthropod pests of tomato reported in Bungoma County, Kenya

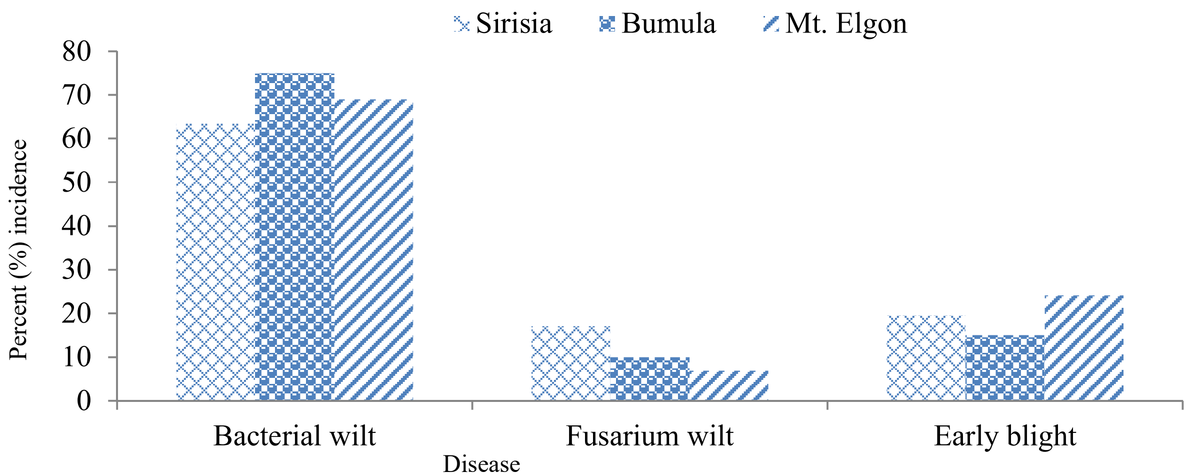

Figure 4: Diseases reported on tomato in the study areas

3.5 Pest and disease management practices on tomato production

All farmers used chemicals in management of pests and diseases. They relied on either single or a combination of chemicals. The pesticides used by farmers included Lambda-cyhalothrin, Imidacloprid, Acephate, Alpha-Cypermethrin, Mancozeb and Flubendiamide. Imidacloprid, Lambda-cyhalothrin and Alpha-Cypermethrin were the most common pesticides used accounting for 24.4% in Sirisia, 30% in Bumula and 20.7% in Mt. Elgon respectively (Table 2). The fungicides used to control diseases included Metalaxyl-M, Propineb+Cymoxanil, Mancozeb, Propineb and Carbendazim. Results of this study found that the highest percentage of farmers (60%) in Bumula combined chemicals followed by 22% in Sirisia and 20.7 in Mt. Elgon (Table 3).

Table 2: Pesticides used on tomato production in management of arthropod pests

		Percent (%) use per sub-County		
Chemical active ingredient	Group	Sirisia	Bumula	Mt. Elgon
Lambda-Cyhalothrin	Pyrethroid	19.5	30	6.9
Imidacloprid	Nicotinoid	24.4	20	-
Acephate	Organophosphate	2.4	5	-
Alpha-Cypermethrin	Pyrethroid	4.9	5	20.7
Flubendiamide	Ryonoid	2.4	-	-
Cypermethrin	Pyrethroid	7.3	5.0	37.9
Other chemicals				
Mancozeb, Lambda-cyhalothrin		7.3	-	10.3
Imidacloprid, Mancozeb		2.4	5	13.8
Lambda-cyhalothrin, Imidacloprid		17.1	5	3.4

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Table 3: Chemicals used by farmers in the control of diseases on tomato

		Percent (%) use per sub-County		
Active ingredient	Group	Sirisia	Bumula	Mt. Elgon
Metalaxyl-M	Anilide	9.8	10	3.4
Propineb+Cymoxanil	Dithiocarbamate	17.1	-	-
Mancozeb	Dithiocarbamate	4.9	10	17.2
Propineb	Dithiocarbamate	4.9		3.4
Carbendazim	Carbamate	2.4	-	-
Other chemicals				
Metalaxyl-M, Propineb+Cymoxanil		22	60	3.4
Metalaxyl-M, Cypermethrin		17.1	5	20.7
Propineb+Cymoxanil, Cypermethrin		14.7	10	13.8

3.6 Chemical use practices on tomato production in Bungoma County

In Sirisia sub-county, all respondents used pesticides once on weekly basis. About 10% and 6.9% respondents in Bumula and Mt. Elgon Sub-county respectively applied chemicals twice a week. Approximately, 53.6% of the respondents in Sirisia cited that the chemicals were effective while 61% of the respondents in Bumula and 58.6% in Mt. Elgon reported that they were ineffective. Almost 97.6% of the respondents were unaware of safer alternatives to synthetic chemicals such as biological control strategy in integrated pest management (IPM). Only 2.4% of respondents in Sirisia sub-county had knowledge on biological control strategy (Table 3).

Table 3: Chemical application frequencies and effectiveness on management of tomato pests and diseases in Bungoma County, Kenya

		Percent per sub-County		
Variable		Sirisia	Bumula	Mt. Elgon
Spray frequency	Weekly	100	90	93.1
	Twice a week	-	10	6.9
Effectiveness of the chemical	Effective	53.6	39	41.4
	Not effective	46.4	61	58.6
Awareness on the use of biological control	Yes	2.4	-	-
	No	97.6	100	100

3.7 Sources of agricultural information on tomato pests and disease management measures

Farmers relied on different sources for knowledge on use of chemicals in tomato production. About 41.5% of the respondents in Sirisia sub-county relied on other farmers while 65% and 62% of respondents in Bumula and Mt. Elgon, respectively relied mainly on Agro-vet operators (Table 4).

Table 4: Most available sources of agricultural information

	Sub-County		
Source	Sirisia	Bumula	Mt. Elgon
Agricultural extension officer	2.4	-	-
Agrovet-shops	34.1	65	62.1
Trainings by agricultural specialists	4.9	-	-
Other farmers	41.5	30	24.1
Mass media	7.3	-	-
Own experience	9.8	5	13.8

4. Discussion

The results revealed male dominance in tomato production across the three sub-counties. Possibly due to the fact that tomato production is capital intensive and men control most of productive resources such as land in addition to the capital. Angelina, (2014) reported similar outcomes of males' majority in tomato production in Musoma Municipality, Tanzania. Our findings are also consistent with the study conducted by Margaret *et al.* (2015) and Nguetti *et al*. (2018) in Mwea West sub-county Kirinyaga County, Kenya.

Majority of the respondents were aged 41-45 years accounting for 37.9% in Mt. Elgon followed by 25% in Bumula and 22% in Sirisia. This revealed that the middle age people who probably had much responsibility for their families were the ones more involved in the production of tomato as it seemed to be a feasible activity in Bungoma County. Having low number of the youth engaged in tomato production could be due to several factors such as limited access to land since majority of the youth do not have their own land to cultivate, lack of adequate capital and extension support due to unemployment (Willis *et al*., 2018). These results concurs with the previous studies in Tanzania by Angelina (2014) and in Mwea Region, Kenya by Nguetti *et al*. (2018) who found that majority of the tomato growers were between 42 to 52 years. These results differ from those reported by Anang *et al*. (2013) in Wenchi Municipal District of Ghana and Margaret *et al*. (2015) in Mwea West, Kenya which showed that about 80% of the farmers were between 21-40 years.

Most of the farmers had reached primary level of education with only 2.4% who had not attended any formal education. This shows that majority of primary school leavers who could not continue with further education, could have joined farming as a source for their livelihood (URT, 2014). However, in Bumula and Mt. Elgon, over 45% of farmers had secondary education. This is vital in understanding many management practices, pests and diseases that affect tomatoes. Farmers in the area may easily adopt improved farming practices as they can fully comprehend the implications of such practices. Literacy is an important characteristic that influence production (Awan *et al.,* 2012).

It was observed that all farmers in the three sub-counties obtained tomato seedlings from their own nurseries since it was appropriate to have seedlings readily accessible and also to avoid spread of pests, diseases from other nurseries. The results showed that Rio-Grande, Cal-J and Elgon Kenya were the popular tomato cultivars produced by farmers in the region. Farmers cited that these tomato varieties were preferred by customers due to their longer shelf life. The farmers were also embracing new cultivars of tomatoes such as Kilele, Safari and Ana F1 which are documented as high yielding and resistant to diseases (Monsanto, 2017). Thus choosing these varieties could increase tomato production. Margaret *et al*. (2015) reported similar findings in Mwea West Sub-County where farmers grew a wide variety of tomatoes with varied preferred attributes such as high yielding, resistance to pests, diseases and longer harvesting period.

The findings showed that the respondents had farm size ranging from 0.25 to 2.0 ha. The highest percentage of respondents cited that they owned between 0.25 and 1.0 ha. The small pieces of land could limit tomato production and yields in the region since land is a major factor of production (Willis *et al*., 2018). This is in line with several small scale growers across the African continent who own related land sizes (Karuku *et al*., 2016). Also, in a similar study in Fufore Local government area of Adamawa state Nigeria, Usman and Bakari (2013) analysed the profitability of dry season tomato production by small holder farmers and reported that about 63.8% of the farmers had less than 2.0 ha of land.

Frankliniella occidentals and *B. tabaci* were the most dominant pests affecting tomato production across the three sub-Counties in the region. This could have been contributed by the favorable ecological conditions coupled with wider host range and their ability to migrate and colonize new habitats (Bidhan, 2017; Infonet-biovision, 2018). In addition, these pests have also been reported to be resistant to commonly used synthetic chemicals such as imidacloprid making it difficult to effectively manage them (Olivier *et al*., 2013; Yu *et al*., 2019). Further, the prevalence of *F. occidentallis* and *B. tabaci* indicated that the pests also affected tomato production through transmission of viral diseases such as tomato chlorotic spot virus (TCSV) tomato spotted wilt virus (TSWV) and tomato yellow leaf curl virus vectored by *F. occidentalis* and *B. tabaci*, respectively (Macharia *et al*., 2015; Marabi *et al*., 2017; Stephanie *et al*., 2017). These findings are in agreement with a study by Juma (2015) in Kirinyaga County, Kenya and Infonet-Biovision (2018) who reported thrips and whiteflies as key pests affecting tomato production. The high incidence of *Ralstonia solanacearum* disease across the three sub-counties implied that the disease was widespread and challenging to control. These results collaborate with earlier research that have reported the long term persistence of the disease in the soil and wide spread in many infested tomato fields (Margaret *et al*., 2015; Kanyua *et al*., 2018).

It was noted that the farmers applied a range of chemical groups such as organophosphates, neonicotinoids, pyrethroids, carbamates and dithiocarbamates based synthetic chemicals to manage tomato pests and diseases. However, these chemicals have been reported to be toxic to non-target beneficial organisms such as bees, fish and natural enemies of arthropod pests (Mollah *et al*., 2013; Ndakidemi *et al*., 2016). All respondents in Sirisia applied chemicals once on weekly basis. This frequent use of pesticides could lead to development of pesticide resistance as well as increased cost of production (Asif *et al*., 2014). These results are in line with the findings of earlier study by Mutuku *et al*. (2014) and Nguetti *et al.* (2018) who found that 86.1% and 93.9% of the respondents sprayed chemicals on weekly basis, respectively.

There was variation in the responses on the effectiveness of the chemicals applied by the farmers in tomato production. This could be due to difference in the frequency of chemical application, mode of action and their target pathogens (Tarla *et al*. 2015). This was evident as some farmers interviewed could not distinguish symptoms of early blight disease from that of *T. absoluta* pest and this could result to application of wrong chemicals. Majority of the respondents were unfamiliar with the use of biological control strategies in integrated pest management (IPM) on tomato production. This could be due to lack of information on alternatives to chemical pesticides as majority of respondents sourced advice on pest and diseases control from pesticide sellers such as agrovet shop operators who may be interested in making more profits through sell of synthetic chemicals as opposed to biological control products. The results in the present study support the previous report which illustrated that in several developing countries, the type of chemicals used in crop protection by the farmers is highly influenced by the distributors (Asif *et al*., 2014).

Majority of the respondents in Sirisia relied on the advice from other farmers. It was also observed that most of the respondents in Bumula and Mt. Elgon received advice from pesticide sellers such as Agrovet-shop operators as they were permanently located in the study areas and may have showed the effectiveness of the chemicals used in crop protection. These results could also implied lack of adequate agricultural extension services in the region. These findings are consistent with the previous report in Vietnam by Huynh (2014) who found that 72.5% of the tomato farmers obtained information on chemical use from pesticide retailers. However, these findings differ from those reported by Margaret *et al*. (2015) in Mwea West sub-County, Kenya who found that majority of the farmers (40.4%) sourced information on tomato production from the agricultural extension officers.

5. Conclusion and recommendations

The findings demonstrated that tomato farmers in the study area have in depth knowledge of tomato production. However, pests and diseases were the major limitations to tomato production in the region. There are still major gaps in knowledge concerning the use of chemicals on tomato production and awareness on safer alternatives to synthetic chemicals such as use of bio-pesticides. Therefore, the study recommends for increased awareness on the judicious use of chemicals, frequency of application and risks associated with synthetic chemicals on tomato production. Future studies on the level of synthetic chemical residues on tomatoes produced in region and their health impact on the farmers should be conducted.

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