Tomato Cultivation and Farmers' Knowledge on Selected Foliar Fungal Diseases in Agro- Ecological Zones of Kirinyaga County, Kenya

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Tomato Cultivation and Farmers' Knowledge on Selected Foliar Fungal Diseases in Agro-Ecological Zones of Kirinyaga County, Kenya

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Diseases are hindrance to tomato production in Kirinyaga County, Kenya. However, information on farmer's knowledge about tomato diseases to warrant pesticide usage is scanty. Further, there is information gap on disease predisposing factor such as varietal choice and seed source. This study assessed the tomato farmers' socio characteristic, varieties grown, seed source and knowledge of selected foliar fungal disease among tomato farmers in agro-ecological zones (AEZs) of Kirinyaga County. A cross sectional survey design that in cooperated purposive sampling and snowballing approaches was adopted in the study. Data were collected from 120 tomato farmers using structured questionnaires. A chi square (χ^2) test was used to examine the association between different variables at α= 0.05 using SAS version 9.4. No significant association ($p > 0.05$) was observed between gender of farmers and AEZ. Nonetheless, there were more men (83.33%) than women (16.67%). Terminator F_1 variety was popular among farmers (25%). No significance ($p > 0.05$) association was observed between source of tomato planting material and AEZs. However, Agrovet was a popular seed source among farmers (40%). The reasons for choosing a particular tomato variety was significantly ($p < 0.05$) associated with the AEZ with 40.83% of farmers preferring tomato varieties with good marketability traits such as fruit size. Farmers' knowledge of causative agent of early blight, late blight and *Septoria* leaf spot

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was significantly ($p < 0.05$) associated with AEZs. The source of farmer's knowledge on tomato foliar fungal diseases was not significantly ($p > 0.05$) associated with AEZ. However, farming experiences was a popular source of knowledge (51.67%) among farmers. Inability of some farmers to identify tomato diseases negates the efforts on disease management in tomato production in Kirinyaga County. Therefore, measures such as coordinated education on tomato diseases is necessary to empower farmers on disease causes and identification to enhance disease management and improve tomato yields in Kirinyaga County in Kenya.

Keywords: Tomato varieties; seed source; fungal disease knowledge; agro-ecological-zones

1. INTRODUCTION

Tomato (*Solanum lycopersicum*) is a principal contributor to industrial development, employment and poverty eradication on a global scale [1]. However, tomato production is globally faced with biotic constraints such as diseases which have negative impact on yield [2,3]. In sub-Saharan Africa, variation in climatic conditions such as prolonged droughts, flashfloods and pests' prevalence have negatively impacted on farming particularly where farmers have poor mitigation approach [4]. To cope up with the effect of drought conditions, tomato farmers have adopted new technologies such as use of irrigation (schedule and methods) and cultivation of new varieties to enhance productivity [5,6]. However, use of irrigation particularly those which splash water, may predispose tomatoes to diseases due to changes on relative humidity [7,8]. Reports illustrate effects of humidity on epical growth and tomato yields that is also dependent on soil characteristics [9-11]. Studies points at the heterogeneous sources of tomato seeds and seedlings among the farmers and include commercial nursery practitioners, recycling seeds from previous season and agro-vets [6,12]. Recycling of seeds (Largely uncertified) among farmers have been attributed to higher cost of certified seeds [5]. Uses of uncertified seeds may be costly as it may be the source of introduction of or persistent of diseases in tomato farms.

Diseases such as late blight can cause yield loss exceeding 70% [13,14], Fusarium wilt can cause yield loss of 40 - 80% [15- 17] while bacterial leaf spot may cause up to 80% of tomato yield loss [18]. Persistence of tomato diseases have necessitated over reliant and regular application of fungicides in higher doses to guarantee crop protection [3,8].

Integrated disease management that includes varietal choice may reduce or exacerbate disease impacts [19,20]. However, choice and source of planting material may determine pathogen persistence and prevalence with regard to resistance, susceptibility and contamination levels [21].

Studies on farmers' knowledge and perception on crop disease according to reports [22-25] indicate incorrect identification of diseases due to mixed up of disease symptoms and health factors. For instance, Huapaya et al. [22] observed that farmers believe that causal agents of crop disease were related to halos that forms around the sun, phases of the moon, hail, drought, frosts, thunder, high humidity, dew, mist and use of manure from cow or horses. In Papua New Guinea, farmers were reported to be unaware of the existence of plant pathogen and believed that crop disease occurred due to actions of ancestors' spirits [26]. In Central Africa, farmers related fungal diseases symptoms to rain and soil depletion, while relating virus symptoms to varietal traits [23]. Warburton et al. [27] reported that most farmers were not aware of infected plants serving as inoculum source. Some farmers may be knowledgeable on plant pathogen [28] and employs indigenous agricultural knowledge such as seed selection and good handling practices during harvesting to manage insect pest and disease [25,29,30]. Farmers knowledge may reflect expertise and proper understanding of farmer's environmental accumulated over the years [31]. Thus, studies that create understanding on practices such as seed selection, disease knowledge and control approaches are justified [32,33]. Information on varietal choice and knowledge on disease symptoms and their causative agents creates good understanding on factor that aggravates persistence, spread and severity of plant diseases.

Kirinyaga County is a significant player in tomato production in Kenya, for instance, of the 509,465 metric tons of tomatoes produced in Kenya in 2016-2017, Kirinyaga County accounted for 7%

after Kajiado (14%) and Narok [(11%) [34]]. Nonetheless, there is scarce information on farmers' socio characteristic, variety of tomato grown and knowledge on fungal diseases in different AEZs in Kirinyaga. The current study on tomato cultivation and farmers' knowledge on selected foliar fungal diseases in AEZs specifically assessed farmers' socio characteristic, varieties grown, seed source and knowledge of selected fungal disease among tomato farmers to gather information that will help in designing an integrated diseases management strategy in tomato farms in AEZs of Kirinyaga County, Kenya.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Kirinyaga County which is located in the Southern outskirts of Mt. Kenya and about 100 Km North East of Nairobi [35]. Kirinyaga County lies between latitudes 0° 37'S and 0° 45'S, between longitudes 37° 14'E and 37° 26'E and between 1,100 m and 1,200 m above the sea level. The area receives an average annual rainfall of 940 mm [36]. The long and short rainfalls are from April to May and October to November, respectively. Temperatures in Kirinyaga County range from a minimum of 12°C to a maximum of 26°C with an average of 20°C [37]. The AEZs in Kirinyaga County are grouped from Tea Dairy Zone LH 1 at the base of Mount Kenya National Park, three coffee zones (UM 1, UM 2, UM 3) as well as the Marginal Cotton Zone in zones LM 3 and LM 4 (Table 1). As shown in Table 1, soil types in Kirinyaga County differ within and across AEZs. For instance, whereas AEZ UM2 and UM3 comprises majorly of humic nitosols soil type, LM4 comprises of three soil types i.e. humic nitosols, eutric nitosols and pellic vertisols [36]. Specifically, the study was conducted in five tomato growing AEZs of Kirinyaga namely LM 3, LM 4, UM 4, UM3 and UM 2 (Fig. 1). The five AEZs were selected due to difference in weather conditions (Table 1) and by virtue of having many farmers who grow tomatoes annually.

2.2 Sample Size Determination, Target Population and Sampling Method

A cross sectional survey study was carried out in five different AEZs of Kirinyaga County in February to May 2020. Up to 120 tomato farmers who grow tomatoes in over 0.25 an acre in Kirinyaga County participated in the study (Estimate from Kirinyaga County Agricultural office). Respondents (Farmers) were drawn from different villages in five AEZs. The AEZ LM4 had five villages (Gachogu, Gategi, Kiumbu, Wanguru and Nguka villages), AEZ LM3 had four villages (Kandongo, Kagio, Siranga, and Nyangate villages), AEZ UM4 had three villages (Ndoma, Kianganga, Njiris), AEZ UM3 had two (Gatheri and Kamuthambi villages) and lastly, AEZU M2 had four villages (Kerigo, Karia, Keria and Geotheri villages). Eighteen villages were selected because they have many farmers who grow tomatoes annually. Combination of purposive sampling, stratified sampling and snowball sampling methods were used in the study. Purposive sampling was necessary to exclusively include AEZs with many farmers who grow tomatoes annually. Once the AEZs were identified, tomato farmers were identified and were grouped (Stratification) based on their AEZs and further, according to villages. Villages and tomato farmers were identified by snowball sampling as described by Biernacki and Waldorf [38] in which identified farmer introduced the next farmer.

Table 1. Features of agro-ecological areas of surveyed in Kirinyaga County

AEZs	Soil type	Altitude (m)	Temp (°C)	Subzone	Rainfall (mm)
UM2	Humic Nitosols	1400-1580	19.0-20.1	m/l + m/s m + s/m	1220-1500 1200-1250
UM3	Humic Nitosols	1340 - 1400	20.1-20.6	m/s + s	1100 - 1250
UM4	Humic Nitosols Eutric Nitosols	1280 - 1340	20.4-20.9	s/m + s s + s	950 - 1200 350 - 960
LM3	Humic Nitosols	1220 - 1280	20.9-21.2	s /m+ s s + s	950 -1200 350 -960
LM4	Humic Nitosols, Eutric Nitosols Pellic Vertisols	1090 - 1220	21.2-22.0	s + s/vs	850 - 950

where AEZ = agro-ecological zones, in the subzones, m= medium rainfall, s= short rainfall, l= long rainfall, vs= very short rainfall, UM = Upper midland (1, 2 and 3), LM = Lower midland (3 and 4). Source: Jaetzold et al. *[36].*

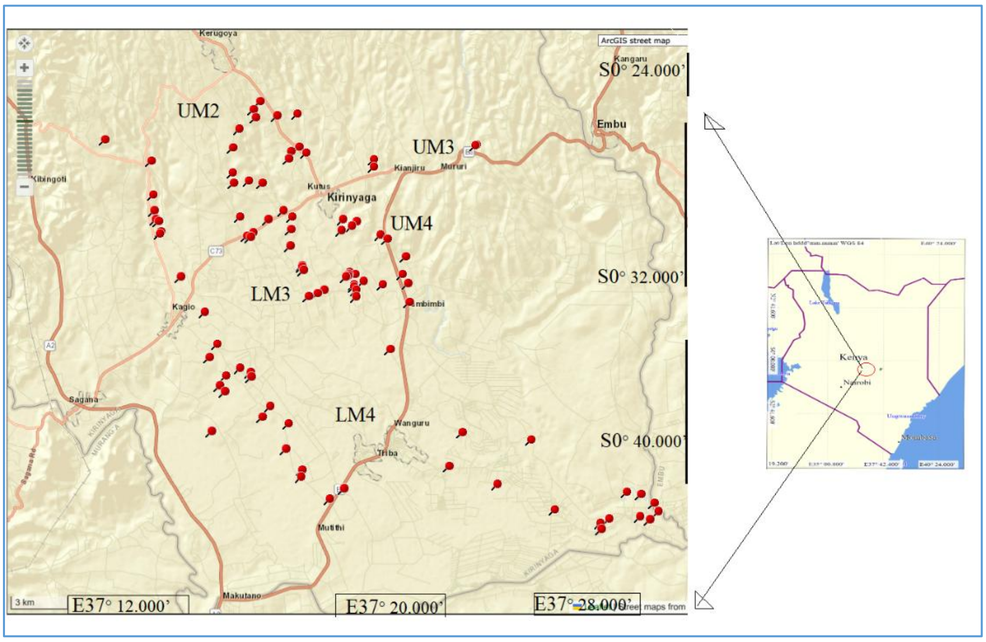

Fig. 1. Map of Kirinyaga County showing agro-ecological zones (UM2, UM3, UM4, LM3 and LM4) surveyed for foliar diseases of tomato; where UM = Upper midland (1, 2 and 3), LM = Lower midland (3 and 4)

2.3 Data Collection

A structured questionnaire was used to gather information from tomato farmers on their gender (Male and Female), age (18-30, 31-40, 41-50, 50 and above), education (Below secondary, Secondary, College and above), history of growing tomatoes (< 1 year, 1-2, 2-4, 4-10, above 10 years), level of farming (Small <2 acres, moderate scale above 2 acres), main varieties of tomatoes grown (Variety that covers over 70% of tomato planted), reason for the main variety in the farm (Fruit size, marketability, rate of rotting, adapted to climate, tolerant to pests, no reason), other varieties grown alongside the main varieties (Variety that covers less than 30% of tomato planted), source of tomato planting material (Agro-vet, recycled seeds, friends, commercial nursery), general knowledge of foliar fungal disease and management. Farmers ability to identify diseases in their farm was assessed (Whether a farmer can identify tomato diseases), source of knowledge (From school, friends, seminars and other training, farming experience), and lastly, knowledge of the causative agents of early blight, late blight and *Septoria* spot.

2.4 Data Analysis

Data collected from tomato farmers using structured questionnaire was analyzed using chi-square (χ^2) test of association in Scientific Analysis System (SAS) Version 9.4 at α= 0.05. In the analysis farmers age, gender, education level and AEZ was treated as independent variables. On the other hand, farming practices such as tomato variety, source of seeds, knowledge of tomato diseases was treated as the dependent variables.

3. RESULTS AND DISCUSSION

3.1 Tomato Farmers' Socio Characteristic, Varieties Grown, Seed Source and Knowledge of Selected Fungal Diseases in Agro-Ecological Zones of Kirinyaga County, Kenya

3.1.1 Gender, age, education level and tomato farming history

There was no significant association (X^2 (4, 120) = 3.941, p = 0.449) between gender of farmers and AEZ. Regarding distribution of farmers based on gender, there were more men than women who practice tomato farming in all the AEZ. Higher percentage of male farmers (24.37%) and female farmer (5.88%) were in AEZ LM4 at 24.37% (Table 2). The current results on male domination of tomato farming corresponds to other findings [5,39-41]. Melomey et al. [42] in Ghana also reported that up to 81%

of tomato farmers were male compared 19% female farmers. Dominance of tomato farming by men as opposed to women farmers may be attributed to high physical and capital requirement [40]. Further, high level of risk associated with tomato farming may explain men dominance of its production [43].

Age of tomato farmers was not significantly (X^2 (12, 120) = 11.940, p = 0.451) associated with the AEZ. Farmers aged 18-30 ranged from 0% in AEZ LM3 to 1.67% in AEZ UM4, AEZ UM3 and AEZ LM4. Farmers aged 31-40 ranged from 2.5% in AEZ UM3 to 9.17% in AEZ LM3. Farmers aged 41-50 ranged from 4.17% in AEZ UM3 to 11.67% in AEZ LM4. Farmers aged over 50 years ranged from 3.33% in AEZ UM3 to 10% in AEZ LM4 (Table 2). Based on these results, it may be concluded that tomato farming in Kirinyaga County is mainly practiced by middle aged individuals. The finding of this study differs with those of Mwangi et al. [40] but agree with those of Testen et al. [41] and Barasa et al. [44] that observed higher numbers of tomato farmers aged between 41-50 years in Tanzania and Mt Elgon in Kenya. However, the results differ with those of Testen et al. [41] on participation of age bracket of 18-30 years who were lower in the current study as compared to those aged above 50 years. Lower percentage of youth participating in tomato farming in Kirinyaga County may be attributed to land scarcity and capital as they may not have capital to facilitate farming in addition to not owning land. Furthermore, many studies have shown that youths have preference for white collar job as opposed to farming [45-47].

Farmers education level was not significantly (χ^2 (8, 120) = 11.1963, p = 0.1908) associated with AEZ. Farmers with secondary education ranged from 7.5% in AEZs UM2 and UM3 to 18.33% in LM4. Farmers who had post-secondary education ranged from 0.83% in AEZ UM4 to 6.67% in the AEZ LM4. Farmers with below secondary education ranged from 3.33% in AEZ UM3 to 9.17% UM4 (Table 2). This finding may imply that tomato farming in Kirinyaga County is mainly practiced by people who have not attained post-secondary education. The finding on the level of education among tomato farmers differs with those reported by Ddamulira [48] in Uganda where majority (52.2%) of tomato farmers had attained secondary education with 29% having attained only primary education level. However, our finding corroborates with those of Melomey et al. [42] where tomato farmers who had primary education were 19% and secondary education were 58%. Education level of farmers may influence how the farmer follows proper agronomic practices of tomato production such as application of fertilizer, insecticide and fungicide [49].

Tomato farming scale was not significantly (χ^2 (4, 120) = 4.1265, p = 0.3892) associated with AEZ. Percentage of small scale farmers ranged from 10.83% in AEZ UM3 to 20.83% in AEZ LM4. Large scale ranged from 1.67% in AEZ UM3 to 9.17% in AEZ LM4 (Table 2). The finding on size of tomato farm agrees with those of Melomey et al. [42] which suggested that tomato farming is done by small holder (89%) in lands less than one acre. Further, this finding is in line with the report of Ddamulira [48] where average area of tomato was 0.68 acre. The results uphold the significant role played by small scale farmers in tomato farming due to their dominance in different areas.

The duration for which a farmer has cultivated tomatoes was not significantly (χ^2 (16, 120) = 17.508, p = 0.354) associated with AEZ. Farmers who have grown tomato for less than one year ranged from 0.83% in AEZ LM3 to 4.17% in AEZ LM4. Farmers who have grown tomato for 1-2 year ranged from 0.83% in AEZ UM3 to 3.33% in AEZ LM4, AEZ LM3 and AEZ UM4. Farmers who have grown tomato for 2-4 years ranged from 4.17% in AEZ UM3 and UM2 to 9.17% in AEZ LM4 (Table 2). These findings differ with those of Nyalugwe et al. [6] in Malawi in which majority of tomato farmers (74.7%) were found to have cultivated tomatoes for 10 years. Low number of farmers who have grown tomato for 1-2 years and above 10 years as compared to higher number of farmers who have been in tomato farming for only 2-4 years indicate that there is low entry and slightly higher exit of farmers in tomato farming. Low entry and moderate exit in tomato farming observed in this study may be attributed to production challenges such as financial and land issues particularly to the youths. According to Olayemi et al. [50], longer stay in tomato farming which is indicated by the higher number of old farmers is likely to be associated with higher interests.

Table 2. Farmers' demographic characteristics in agro-ecological zones of Kirinyaga County

	LM3	LM4	UM2	UM3	UM4	Total	χ^2	N	DF	*p* - value
Gender of tomato farmer (%)										
Male	16.67	24.17	12.50	10.83	19.17	83.33	4.032	120	4	0.402
Female	2.50	5.83	5.00	1.67	1.67	16.67				
Total (%)	19.17	30.00	17.50	12.50	20.83	100				
Age bracket of tomato farmers (%)										
18-30	0.00	1.67	0.83	1.67	1.67	5.83				
31-40	9.17	6.67	3.33	2.50	4.17	25.83	11.940	120	12	0.451
41-50	6.67	11.67	5.00	4.17	7.50	35.00				
50 and above	3.33	10.00	8.33	4.17	7.50	33.33				
Total (%)	19.17	30.00	17.50	12.50	20.83	100				
Farmer's education levels (%)										
Below secondary	5.83	5.00	8.33	3.33	9.17	31.67				
Secondary	11.67	18.33	7.50	7.50	10.83	55.83	11.196	120	8	0.191
Above secondary	1.67	6.67	1.67	1.67	0.83	12.50				
Total (%)	19.17	30.00	17.50	12.50	20.83	100				
Levels of farming (%)										
Small scale	12.5	20.83	15	10.83	15	74.17	4.126	120	4	0.389
Moderate scale	6.67	9.17	2.5	1.67	5.83	25.83				
Total (%)	19.17	30.00	17.50	12.50	20.83	100				
History of growing tomato (%)										
< 1 year	0.83	4.17	0.83	1.67	1.67	9.17				
1-2 years	3.33	3.33	0.83	2.50	3.33	13.33				
2-4 years	8.33	9.17	4.17	5.00	4.17	30.83	17.507	120	16	0.354
4-10 years	5.00	7.50	3.33	1.67	4.17	21.67				
above 10 years	1.67	5.83	8.33	1.67	7.50	25.00				

where , UM = Upper midland, LM = Lower midland, N = Sample size, df = Degree of freedom

3.2 Tomato Varieties Grown, Reason for the Variety Grown and Source of Seeds

The main tomato variety grown were not the same in all the AEZ studied. Higher percentage of farmers (25%) grew Terminator F_1 led by farmers in AEZ LM4 (15.83%). Kilele F_1 was second most cultivated variety (15%) and was more preferred in AEZ UM4 5.83% but least grown in AEZ UM2 at 0.83%. Ansal F_1 was grown mostly in AEZ UM2 (8.33%) and least in AEZ UM4 and LM4 both at 0.83%. Riotinto F_1 was only grown in AEZ UM4 and AEZ UM3 at 5% and 2.5% respectively. Five (5%) of farmers could not tell the variety of tomato growing on their farm during the study (Table 3). Tomato variety reported in this study differs to those reported by Mwangi et al. [40] that reported Safari F_1 (30.35%) and Kilele F_1 (26.6%) as the most popular varieties in Mwea West in Kenya. Our findings further differ with those of Barasa et al. [44] in a study conducted in Mt. Elgon in Kenya where main varieties were found to be Rio-Grande and Cal-J. Varietal differences may be attributed to continuous release of new tomato varieties which seems to be embraced by farmers in addition to regional preferences.

The reasons for which farmers grow a particular tomato variety was significantly (X2 (20, 120) = 36.109, p < 0.0001) associated with the AEZ in Kirinyaga County. Up to 40.83% of farmers prefer tomato varieties with good marketability trait led by AEZ LM4 (15%) while 2.5% of farmers preferred tomato variety that is tolerant to pest (Table 3). These findings on the reason for choice of a variety differ with those of Testen et al. [41] who reported that variety of tomatoes grown were selected based on fruit size at 60%, disease resistance at 25% and insect resistance at 25%. Our findings also differ with those of Ochilo et al. [5*]* who opined that the tomato varieties grown by the farmers was determined by the cost of seeds. Additionally, our findings contradict those of Melomey et al. [42] in Ghana who observed that most farmers choose varieties based on adaptability as opposed to market preference.

The source of tomato planting material was not significantly (χ^2 (8, 120) = 11.028, p-value = 0.5265) associated with AEZ. Sources of seed/ seedling ranged from 5% in AEZ UM3 to 10% in AEZ LM3 and AEZ LM4 for agro-vets, from 5% in AEZ UM3 and UM4 to 13.33% LM4 for commercial nurseries, from 0% in AEZ UM3 to 3.33% in AEZs UM4 and LM4 from friends and from 0.83% in AEZ LM3 to 5% in AEZ UM2 for regrown seeds (Table 3). These results differ with the findings of Mwangi et al. [51] and Barasa et al. [44] that most farmers in Mwea and Mt Elgon respectively prefer raising their own seedlings. Sources of planting material in this study concurs with those of Testen et al. [41]. However, Testen et al. [41] did not report on seedling supplier (Commercial seed nurseries) and friends as source of tomato planting materials. Results showed that 15% recycle seeds (Re-grow) tomato from the original seedlings in the next planting season. This finding corroborates with those of Nyalugwe et al. [6] which reported that up to 17.4% recycled tomato seeds were used in Malawi. Recycling of seeds may escalate incidences of insect pest and diseases in the farm.

Farmers who grow other tomato varieties alongside the main variety in different AEZ were 34.83%. Farmers who grew Prosta F_1 alongside the main variety were high at 8.33% led by AEZ LM3 at 4.17%. Kilele was mostly grown alongside main varieties in AEZ LM4 (4.17%). In AEZ UM2, Venonia F_1 was mostly grown alongside main varieties (3.33%). Ranger F_1 variety was gown alongside the main variety mostly in AEZ UM3 [(1.67%) Table 3]. Cultivation of more than one variety of tomato in the farm may be due to differences in tomato attributes and the desire to serve heterogeneous preferences of customers [52]. It maybe hypothesized that most farmers who grow only one variety of tomato have insufficient funds required to buy different varieties of tomatoes. As hypothesized by Guodaar et al. [53] that financial constraints are the reason why farmers fails to diversify tomato varieties on their farms.

Table 3. Main tomato varieties present in farmer's land across agro-ecological zones of study in Kirinyaga County

	LM3	LM4	UM2	UM3	UM4	Total
Main tomatoes variety grown (%)						
Kilele F_1	4.17	1.67	0.83	2.50	5.83	4.17
Rambo F_1	3.33	2.50	0.00	2.50	1.67	3.33
Terminator F_1	5.00	15.83	0.00	0.00	4.17	5.00
Bawito safa F_1	0.83	2.50	0.00	0.83	1.67	0.83
Ranger F_1	1.67	0.83	0.00	0.00	0.00	1.67
Riotinto F_1	0.00	0.00	5.00	2.50	0.00	0.00
Ansal F_1	1.67	0.83	8.33	2.50	0.83	1.67
Unknown	1.67	1.67	0.00	0.00	2.50	1.67
Others	0.83	4.17	3.33	1.67	4.17	0.83
Total	19.17	30.00	17.50	12.50	20.83	100
Reason for variety grown by the farmer (%)						
Fruit size	7.50	3.33	6.67	0.83	4.17	22.5
Good market	6.67	15.0	3.33	6.67	9.17	40.83
Fruits' long shelf life	3.33	3.33	0.83	0.83	1.67	10.00
Climate adapted	0.83	5.83	6.67	4.17	1.67	19.17
Tolerant to Pest	0.00	1.67	0.00	0.00	0.83	2.50
No reason	0.83	0.83	0.00	0.00	3.33	5.00
	χ^2 (40, 120) = 107.7116				p-value < 0.0001	
Source of tomato seeds variety grown (%)						
Agrovet	10.00	10.00	6.67	5.00	8.33	40.00
From Friend	1.67	3.33	0.83	0.00	3.33	9.17
Recycled seeds	0.83	3.33	5.00	2.50	3.33	15.00
Commercial nursery	6.67	13.33	5.00	5.00	5.83	35.83
	χ^2 (8, 120) = 11.028			p-value = 0.5265		

	LM3	LM4	UM2	UM3	UM4	Total
Farmers growing additional varieties (%)						
Non	11.67	16.67	10.83	9.17	15.83	64.17
TM20 F_1	1.67	0.83	0.00	0.00	0.83	3.33
Kilele F_1	0.00	4.17	0.00	0.83	2.50	7.50
Bawito safa F_1	0.00	0.00	0.00	0.00	0.83	0.83
Nyati F_1	0.83	0.83	0.00	0.00	0.00	1.67
Prosta F_1	4.17	1.67	0.83	0.83	0.83	0.83
Ranger F_1	0.00	0.83	0.83	1.67	0.00	3.33
Zara F_1	0.83	1.67	0.00	0.00	0.00	0.83
Vanora F_1	0.00	1.67	3.33	0.00	0.00	5.00
Vuna F_1	0.00	0.83	0.00	0.00	0.00	2.50
Rambo F_1	0.00	2.83	1.67	0.00	0.00	2.50
Total (%)	19.17	30.00	17.50	12.50	20.83	100

where UM = Upper midland, LM = Lower midland

3.3 Knowledge of Tomato Foliar Fungal Diseases among Farmers Across Agro-ecological Zones of Kirinyaga County

The ability of farmers to identify foliar fungal diseases in their farms was not significantly (X^2 (8, 120) = 10.921, p = 0.177) associated with AEZ. Many farmers (70.83%) claimed the ability to identify a few diseases as compared to 25% who reported having knowledge of all foliar fungal diseases and 4.2% with inability to identify fungal diseases (Table 4). The AEZ LM4 had many farmers (21.67%) who reported knowledge of some fungal diseases of tomato compared to 13.33% in AEZ UM2 and 12.5% in UM4 and LM3. About 8.33% of farmers in AEZ LM4 reported knowledge of all tomato foliar fungal diseases compared to 6.67% in LM3 and 5.83% in UM4 (Table 4). In related studies, Nabuzale [54] reported that most tomato farmers in Sironko district in Uganda had no knowledge of tomato diseases (Tospoviruses). Farmers' have been reported to have low awareness of crop diseases and may not consider less conspicuous and highly damaging diseases as crop diseases [55]. The claimed ability to identify fungal diseases in tomato in the current study, may point on the economically significance of diseases. For instance, it is possible that farmers may have repeatedly encountered these diseases in the farms. However, such claim need verification as cases of misdiagnosis have been reported among farmers [56,41]. Even where farmers seem able of identifying crop diseases, Palilo [57] stressed on the need to equip farmers with technical knowledge about diseases despite claimed knowledge. Providing farmers with technical knowledge on diseases according to Neindow et al. [58] helps reducing misdiagnosis, hence, minimizing disease infections at the farm.

The source of farmer's knowledge on tomato foliar fungal diseases was not significantly (X^2 (16, 120) = 15.145, p = 0.514) associated with AEZ. Friends as source of knowledge ranged from 2.5% in UM3 and UM4 to 8.33% in LM4, seminars as source of knowledge ranged from 0.83% in UM2 to 5% in LM4 while knowledge gained from farming experience ranged from 5.83 in zone UM3 to 15.83% in zone LM4 (Table 4). Variation on the source of knowledge on tomato diseases reported here may be corroborated to the findings of Barasa et al. [44] which suggested that many farmers in Mt. Elgon area obtained agricultural knowledge from other farmers, agro-vet attendants among other sources.

Knowledge on the causative agent of early blight was significantly (X^2 (20, 120) = 57.888, p <.0001) associated with AEZ. Fifty-one per cent (51%) of the respondents gave the correct causative agent of early blight as fungi led by AEZ LM4 (20%) and lower in AEZ UM3 [(3.33%) Table 4]. Knowledge on the causative agent of late blight was significantly (X^2 (20, 120) = 40.936, p = 0.004) associated with AEZ. Forty per cent (40%) of the respondents gave the correct causative agent of late blight as fungi led by AEZ LM4 (19.17%) and was lower in AEZ UM3 [(0.85%) Table 4]. Knowledge on the causative agent of *Septoria* leaf spot in tomatoes was significantly (X^2 (20, 120) = 39.158, p = 0.006) associated with AEZ. Up to 17.5% of the respondents gave the correct causative agent of *Septoria* leaf spot as fungi led by farmers in AEZ UM2 (5.83%) and was lower in AEZ UM3 and ALM3 recording 1.67% each (Table 4).

Table 4. Knowledge of tomato fungal diseases, source of disease knowledge and agro-ecological zones of Kirinyaga County

	LM3	LM4	UM2	UM3	UM4	Total	χ^2	N	df	*p*-value
Knowledge of tomato fungal diseases (%)										
Yes, all	6.67	8.33	3.33	0.83	5.83	25.00	10.921	120	8	0.206
Yes, some	12.50	21.67	13.33	10.83	12.50	70.83				
No	0.00	0.00	0.83	0.83	2.50	4.17				
Source of disease knowledge (%)										
School	0.83	0.00	0.00	0.00	0.83	1.67				
Friends	5.83	8.33	7.50	2.50	2.50	26.67	15.145	120	16	0.514
Seminars	3.33	5.00	0.83	2.50	2.50	14.17				
Farm experience	9.17	15.83	8.33	5.83	12.50	51.67				
Have not learnt	0.00	0.83	0.83	1.67	2.50	5.83				
What causes early blight in tomato (%)										
Bacteria	6.67	8.33	0.00	7.50	5.83	28.33				
Virus	0.00	0.00	3.33	0.83	0.83	5.00				
Fungi	12.50	20.00	10.00	3.33	5.83	51.67	57.888	120	20	<.0001
Insect	0.00	0.00	0.83	0.83	0.00	1.67				
Don’t know	0.001	1.67	3.33	0.00	6.67	11.67				
Bad weather	0.00	0.00	0.00	0.00	1.67	1.67				
What causes late blight in tomato (%)										
Bacteria	3.33	0.83	0.00	0.00	2.50	6.67				
Virus	0.83	0.00	0.00	0.00	0.83	1.67				
Fungi	5.83	19.17	6.67	0.83	7.50	40.00	40.936	120	20	0.004
Insect	1.67	0.00	2.50	0.00	1.67	4.83				
Don’t know	4.17	1.67	3.33	2.50	2.50	14.17				
Bad weather	3.33	8.33	5.00	9.17	5.83	31.67				
What causes *Septoria* spot in tomato (%)										
Bacteria	6.67	0.83	1.67	2.50	4.17	23.33				
Virus	0.00	0.00	0.00	2.50	0.83	3.33				
Fungi	1.67	4.17	5.83	1.67	4.17	17.50	39.158	120	20	0.006
Insect	6.67	10.00	1.67	3.33	3.33	25.00				
Don’t know	4.17	7.50	8.33	2.50	6.67	29.17				
Bad weather	0.00	0.00	0.00	0.00	1.67	1.67				

where UM = Upper midland, LM = Lower midland, N = Sample size, df = Degree of freedom

Farmers claim on disease knowledge was not significantly (χ^2 (10, 120) = 10.7875, p = 0.3743) associated with the knowledge on the causative agent of early blight. Nonetheless, out of the 25% of farmers who claimed the knowledge of all tomato diseases, only 15.83% were able to identify the causative agent of early blight (Fig. 2).

Farmers’ claim on disease knowledge was not significantly (χ^2 (10, 120) = 10.606, p = 0.389) associated with the knowledge of causative agent of early blight. Out of the 25% of farmers who claimed the knowledge of all tomato diseases only 11.67% were able to identify the causative agent of late blight as fungi while 1.67% cited bacteria and 6.67% cited bad weather. Out of 69.17% who reported knowledge of some of the diseases, only 26.67% identified the causative agent of late blight and lastly, out of the 5.85% of farmers who admitted no knowledge of tomatoes, 1.67% identified the causative agent of late blight (Fig. 3).

Farmers claim on disease knowledge was not significantly (χ^2 (10, 120) = 13.76, p = 0.1842) associated with the knowledge of what causes *Septoria* leaf spot. However, out of the 25% of farmers who claimed the knowledge of all tomato diseases, only 3.33% were able to identify the causative agent of *Septoria* leaf spot while 9.17% named bacteria and 6.67% named bad insects.

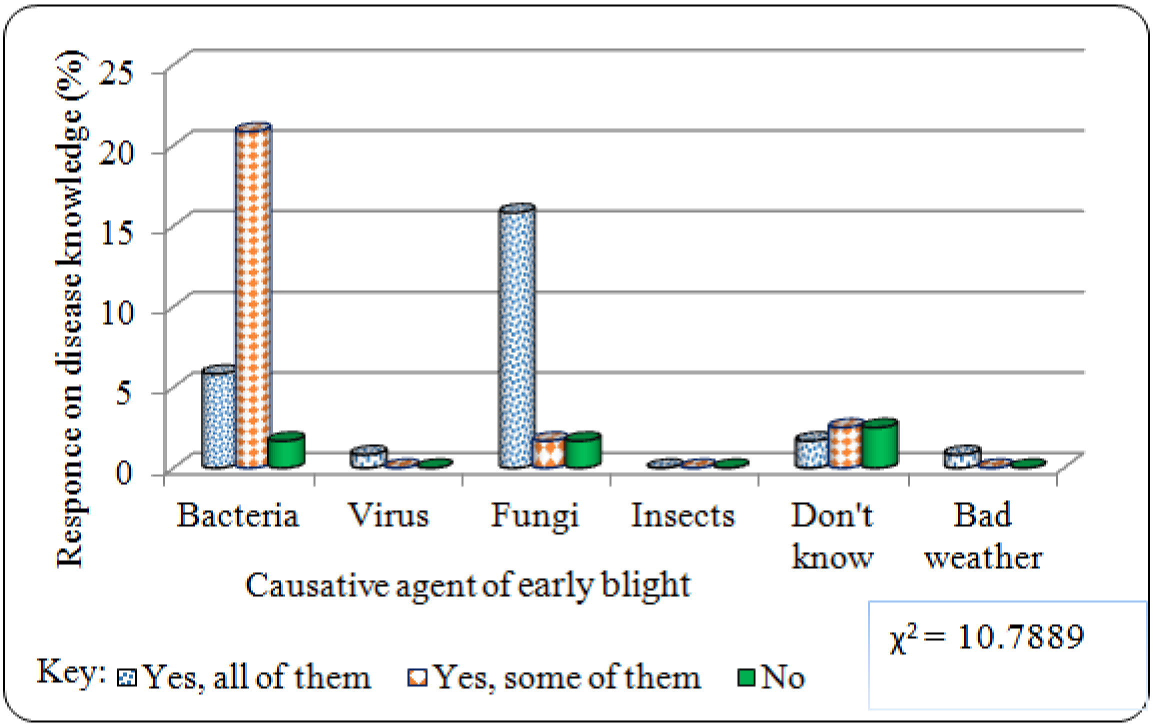

Fig. 2. Percentage of farmers' claim of tomato diseases knowledge and knowledge of causative agent of early blight in Kirinyaga county

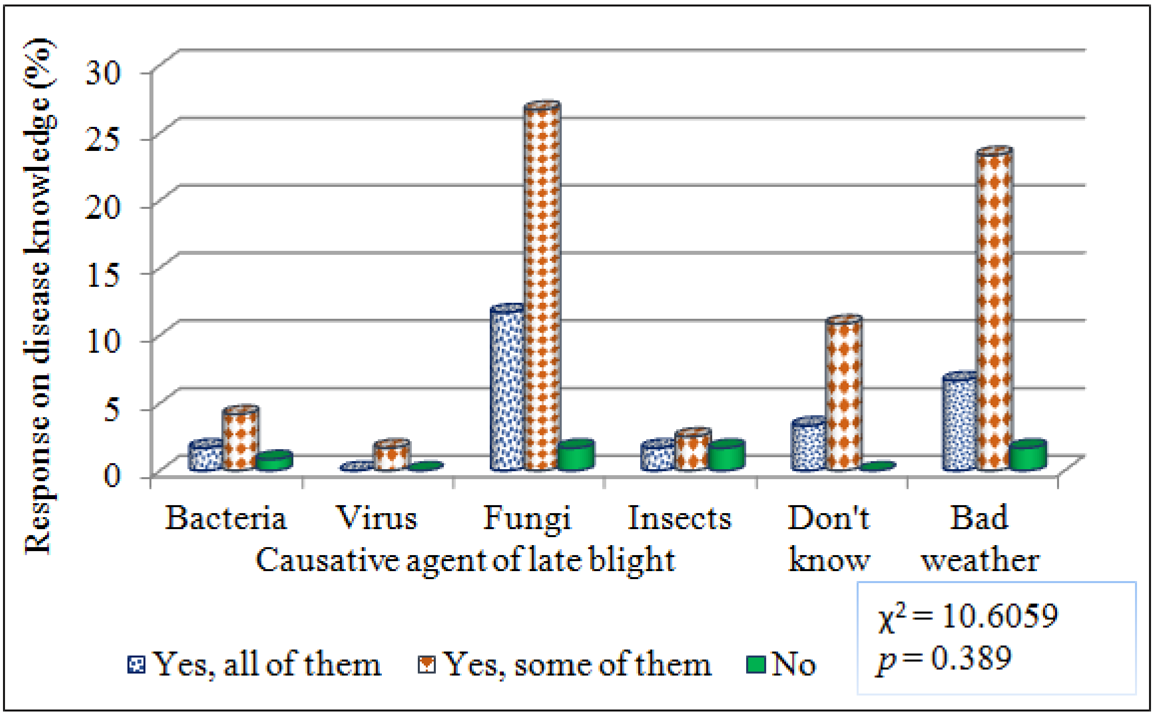

Fig. 3. Percentage of farmers' claim of tomato diseases knowledge and knowledge of causative agent of late blight in Kirinyaga county

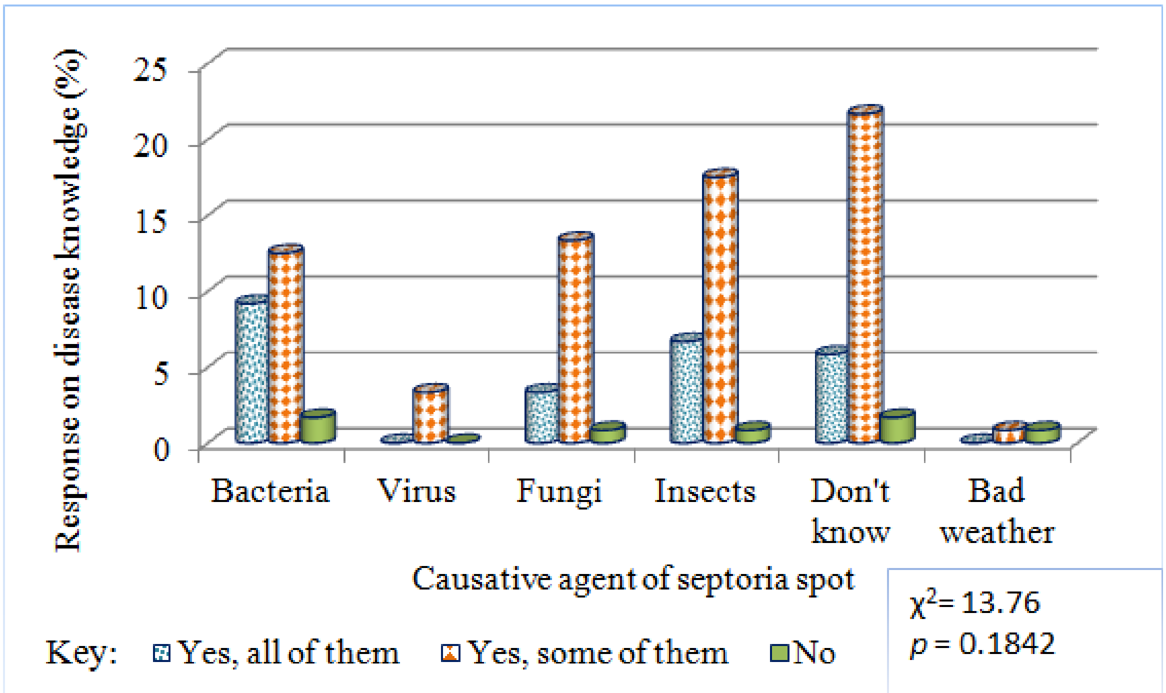

Fig. 4. Percentage of farmers' claim of tomato diseases knowledge and knowledge of causative agent of *Septoria* spot in Kirinyaga county

Out of 69.17% who reported knowledge of some of the diseases, only 13.33% identified the causative agent of *Septoria* spot and lastly, out of the 5.85% of farmers who admitted no knowledge of tomatoes, 0.83% identified the causative agent of *Septoria* spot (Fig. 4). Farmers' inability to link the diseases with their causal agents corroborates with other reports [56,41]. In a related study in USA, Assefa [59] reported that only 3% of farmers identified the causative agent of late blight. Failure to give exact cause of the diseases may be attributed to farmers' diversity of knowledge source. The findings therefore indicate the need to train farmers on phytopathogens to improve their understanding for adequate crop disease management [60].

3.4 Association between Age, Gender, Education level, Farming History and Knowledge of Tomato Fungal Diseases in Kirinyaga County

The association between farmer's gender and category of knowledge of tomato foliar diseases was significant (χ^2 (2, 120) = 8.978, p = 0.011) as shown in Table 5. There were more male who had knowledge of some tomato diseases (58.33%) than those who reported knowledge of all the tomato fungal diseases (23.33%). Likewise, there were more female farmers (12.5%) who reported knowledge of some foliar diseases of tomato than those with knowledge of all diseases [(1.67%) Table 5].

Farmer's age was significantly associated with knowledge of tomato foliar diseases (χ^2 (6, 120) = 16.382, p = 0.012). At the age of 18 – 30, no farmers reported knowledge of all diseases compared to 5% at age of 31 – 40, 7% at age 41 – 50 and 11.67% above age 50 as shown in Table 5. Knowledge of tomato diseases was significantly (χ^2 (4, 120) = 16.592, p = 0.002) associated with education status of tomato farmer. Farmers who claimed the ability to identify all tomato diseases were high (10.83%) among secondary school leavers compared to farmers with primary education (8.33%) and with college education (5.83) as shown in Table 5. Higher number of secondary school leavers with ability to identify tomato diseases may signify the positive value of education in understanding disease concept and ultimate management [49].

Knowledge of tomato diseases was significantly (χ^2 (8, 120) = 18.384, p = 0.019) associated with history of tomato farming. Farmers who claimed the ability to identify all tomato diseases were

Table 5. Association between age, gender, education level, farming history and knowledge of tomato fungal diseases in kirinyaga county

	Yes, all	Yes, some	No	Total	χ^2	N	df	*p* -value
Farmer's gender and disease knowledge (%)								
Male	23.33	58.33	1.67	83.33	8.978	120	2	0.011
Female	1.67%	12.50	2.50	16.67				
Farmer's age and disease knowledge (%)								
18-30	0.00	4.17	1.67	5.83				
31-40	5.83	18.33	1.67	25.83	16.382	120	6	0.012
41-50	7.50	26.67	0.83	35.00				
Above 50	11.67	21.67	0.00	33.33				
Education level and disease knowledge (%)								
Primary	8.33	19.17	4.17	31.67				
Seconday	10.83	45.00	0.00	55.83	16.592	120	4	0.002
College	5.83	6.67	0.00	12.50				
History of farming and disease knowledge (%)								
< 1 year	1.67	6.67	0.83	9.17				
1-2 years	0.83	11.67	0.83	13.33				
2-4 years	5.00	23.33	2.50	30.83	18.384	120	8	0.019
4-10 years	5.00	16.67	0.00	21.67				
Over 10 years	12.50	12.50	0.00	25.00				

where n = Sample size, df = Degree of freedom

high at 12.5% among farmer who have grown tomatoes for over 10 years while those who have grown tomatoes for 1 to 2 years were fewer (0.83%). Farmers who could not identify tomato diseases were high among those who have cultivated tomatoes for 2 to 4 years (Table 5). The findings emphasize on the necessity to train farmers on the diagnosis of tomato diseases to improve their knowledge and result into proper tomato disease management [58].

4. CONCLUSION AND RECOMMENDATIONS

Tomato farming in Kirinyaga County is a male dominated activity. Furthermore, there is lower participation of youths in tomato farming. Government should encourage youths particularly those with good education to participate in tomato farming to offer alternative employment which will also see an improved agronomic practices such as pesticide and fertilizer application for higher yields. Farmers cited commercial nurseries, friends among others as sources of tomato seeds and seedling. Farmers should embrace using tomato seeds or seedlings from certified sources to ensure exclusion of tomato pests. Tomato varieties grown in Kirinyaga County differ from one AEZ to the next and Terminator F_1 appears to be the most dominant variety grown. Farmers gave different reasons for the choose of tomato variety they grow in different AEZ. For instance, marketability of the fruits and fruit sizes were given higher priority by farmers when choosing the type of variety to grow. Sources of knowledge of tomato diseases were varied among farmers and different AEZs and are highly contributed for by friends/ neighboring farmers and history of tomato farming (Experience). Inability of some farmers to identify tomato diseases negates the efforts on disease management in tomato production in Kirinyaga County. Inaccuracies or lack of knowledge of diseases among farmers may arises from heterogeneous knowledge sources which may compromise disease management efforts. Therefore, measures such coordinated training on tomato diseases is needed to empower farmers on knowledge of tomato disease, identification and proper management to improve tomato yields in different AEZs of Kirinyaga County.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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