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

ABSTRACT

Diseases are hindrance to tomato production in Kirinyaga County, Kenya. However, information on farmer's disease knowledge to warrant pesticide use, disease predisposing factor such as varietal choice and seed source is scanty. 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 method that in cooperated purposive sampling and snowballing approaches were used. 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_1variety 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 trait. Farmers' knowledge of causative agent of early blight, late blight and *Septoria* leaf spot 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

I. INTRODUCTION

Tomato (*Solanum lycopersicum*) is a principle 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 globally [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 effect of drought tomato farmers have adopted new technologies such as use of irrigation and new varieties to enhance productivity [5] [6]. However, use of irrigation may predispose tomatoes to diseases due to changes on relative humidity [7] [8]. Reports illustrates effects of humidity on epical growth and tomato yields that is also dependent on soil characteristics [9] [10] [11]. Studies points at the heterogeneous sources of tomato seeds and seedlings among the farmers and include market, recycling from previous season and agro-vets [12] [6]. Recycling of seeds (Largely uncertified) among farmers have been attributed to higher cost of original hybrid seeds [5]. Uses of uncertified seeds and seedling may be costly as it may be the source of introduction of or persistent of diseases tomato farms.

Diseases such as late blight have potential of causing yield loss exceeding 70% [13] [14], Fusarium wilt with a yield loss of 40 - 80% [15] [16] [17] and bacterial leaf spot with a yield loss of up to 80% [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 include 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] [23] [24] [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 diseased plants serving as inoculum source. Some farmers may be knowledgeable on plant pathogen [28] and deploys indigenous agricultural knowledge such as seed selection and harvest handling in pest management [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 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 farmers' knowledge on fungal diseases in different AEZs in Kirinyaga. The current study on tomato cultivation and farmers' knowledge on selected foliar fungal diseases in agro-ecological zones of Kirinyaga County, Kenya specifically assessed farmers' socio characteristic, varieties grown, seed source and knowledge of selected fungal disease among tomato farmers in AEZs.

II. MATERIALS AND METHOD

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 rains occur 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 AEZ 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), Marginal Cotton Zone in zones LM 3 and LM 4 (Table 1). Soils types differ in agro zone i.e. UM2 and UM3 comprise of volcanic foot ridges soil while LM3 and LM4 comprises majorly of plateau soil [36]. Specifically, the study was conducted in five tomato growing AEZs of Kirinyaga namely LM 3, LM 4, UM 4, UM3 and UM 2 (Figure 1). The five AEZs were selected due to difference in climatic (Table 1) and by virtue of having many farmers who grow tomatoes annually.

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

AEZ	Altitude (m)	Temp (°C)	Subzone	Rainfall (mm)
UM2	1400-1580	19.0-20.1	m/l + m/s	1220-1500
			m + s/m	1200-1250
UM3	1340 - 1400	20.1-20.6	m/s + s	1100 - 1250
UM4	1280 - 1340	20.4-20.9	s/m + s	950 - 1200
			s + s	350 - 960
LM3	1220 - 1280	20.9-21.2	s /m+ s	950 -1200
			s + s	350 -960
LM4	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) Jaetzold *et al.* [36].

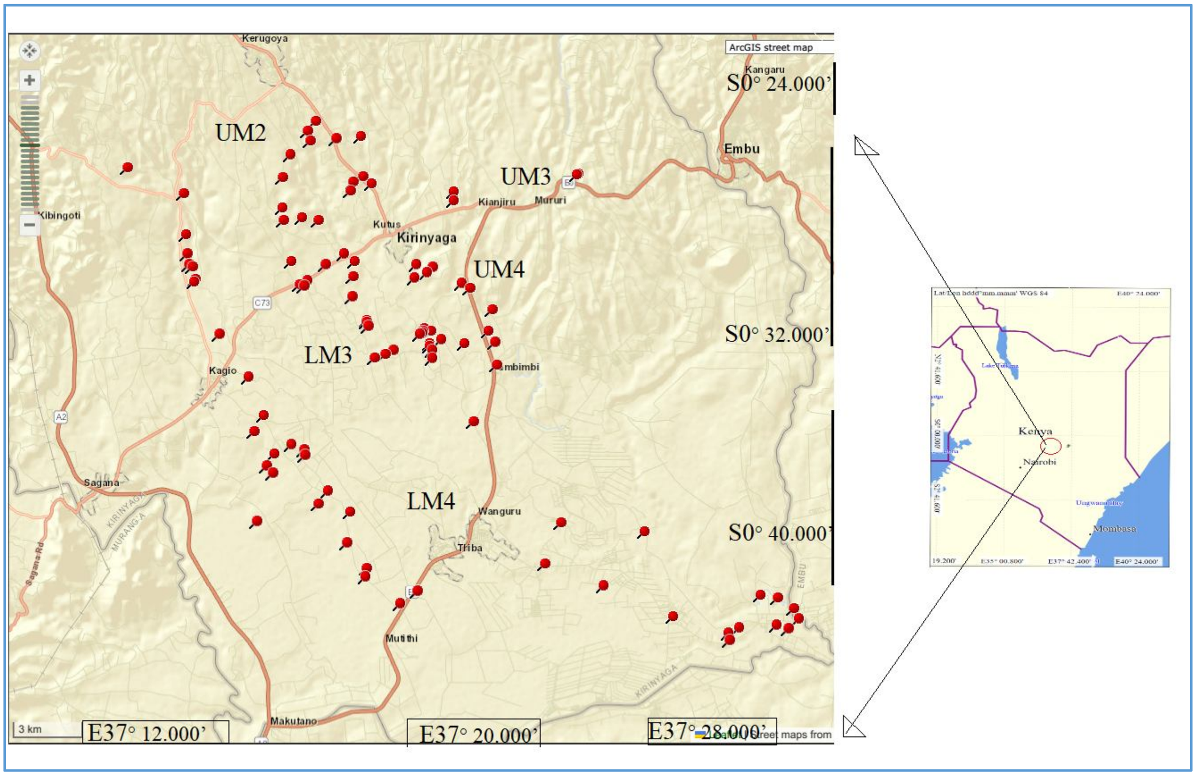

Figure 1: Map of Kirinyaga County showing agro-ecological zones (UM2, UM3, UM4, LM3 and LM4) surveyed for foliar diseases of tomato; where UM = Upper midland (1, 2 and 3), LM = Lower midland (3 and 4).

2.2 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 farther according to villages. Villages and tomato farmers were identified by snowball sampling as was described by Biernacki and Waldorf [38] in which identified farmer introduced the next farmer.

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 (Big fruits, Marketability, Not rot faster, Climate, Tolerant, No reason), other varieties grown alongside the main varieties (Variety that covers less than 30% of tomato planted), source of tomato planting material (Agrovet, 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.

III RESULTS AND DISCUSSION

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

3.1 Gender, Age, Education level and Tomato Farming History

There was no significant association (X^2 (4, 120) = 3.941, p = 0.449) of 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 1). The current results on male domination of tomato farming corresponds to other findings [39] [40] [41] [5]). 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 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 LM4). Basing on these results, it may be concluded that tomato farming in Kirinyaga County is mainly practiced by middle aged individuals. The finding of the 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 that higher numbers of tomato farmers were 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 above 50 years. Lower percentage of youth participating in tomato farming may be attributed to land scarcity and capital as they may not have capital to facilitate farming in addition to not owning land. Further, youths have preference for urban employment as opposed to farming [45] [46] [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 AEZ 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 1). This finding may imply that tomato farming is mainly practiced by people who have not attained postsecondary 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 implementation of tomato production policies and procedures such as fungicide application is achieved in the farm [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 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 1). 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 are in line with the report of Ddamulira [48] where average area of tomato was 0.68. The results uphold the significant role played by small scale farmers in tomato farming due to their dominance in tomato production.

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 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 year ranged from 4.17% in AEZ UM3 and UM2 to 9.17% in AEZ LM4 (Table 2). These finding differ to 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 for year 1-2 and above 10 years as compared to higher number of farmers who have been in tomato farming for only 2-4 points at low entry and slightly higher exit among farmers in tomato farming. Low entry and moderate exit in tomato farming 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, Cal-J and Elgon Kenya. 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 (X^2 (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 prefer tomato variety that is tolerant to pest according to farmers was least preferred 2.5% (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 materials 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 in Malawi. Recycling of seeds encourages use of uncertified seeds which may escalate incidences 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 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 grow by the farmer (%)					
Big fruits	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 do not rot faster	3.33	3.33	0.83	0.83	1.67	10.00
Climate dapted	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
Original regrown	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		
	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 farm was not significantly (X^2 (8, 120) = 10.921, *p* = 0.177) associated with AEZ. Many farmers 70.83% claimed the ability to identify just some of the diseases as compared to 25% who reported 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. Eight point three per cent (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 tomatoes farmers in Sironko district in Uganda had no knowledge of tomato disease (Tospoviruses). Farmers' have been reported to have low awareness of crop diseases and may not consider less conspicuous and highly damaging diseases as crop disease [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 encounter 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 in 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 sources such as 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 (Figure 2).

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

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 (Figure 3).

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

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. 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 (Figure 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.

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

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 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, 0% of farmers reported knowledge of all diseases compared to 5% at age of 31 – 40, 7% at age 41 – 50 and 11.67% 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 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 of train farmers on the diagnosis of tomato diseases to improve which may result in proper crop disease management [58].

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

IV. CONCLUSION AND RECOMMENDATIONS

Tomato farming in Kirinyaga County is a male dominated activity with low involvement of youths. Tomato varieties grown in Kirinyaga County differ from one AEZ to the next and Terminator F1 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. Sources of knowledge of tomato diseases are varied 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. Therefore, measures such coordinated education on crop diseases is necessary to empower farmers on disease causes and identification to enhance disease management and improve tomato yields.

REFERENCES

.

[1] C. A. Njume, C. Ngosong and C. Y. Krah, "Tomato food value chain: managing postharvest losses in Cameroon," *IOP Conference Series: Earth and Environmental Science,* vol. 542 , no. 012021, pp. 1-11, 2020.

[2] S. Savary, S. Bregaglio, L. Willocquet, D. Gustafson, M. D'Croz, A. Sparks and K. Garrett, "Crop health and its global impacts on the components of food security," *Food Security,* vol. 9, p. 311–327, 2017.

[3] S. Panno, S. Davino, A. G. Caruso, S. Bertacca, A. Crnogorac and A. M. S. Mandić, "A Review of the Most Common and Economically Important Diseases That Undermine the Cultivation of Tomato Crop in the Mediterranean Basin," *Agronomy,* vol. 11, no. 11, p. 2188, 2021.

[4] D. Rahut, J. Aryal and P. Marenya, "Ex-ante adaptation strategies for climate challenges in sub-Saharan Africa: macro and micro perspectives," *Journal, Environmental Challenges,* vol. 3, 2021.

[5] W. N. Ochilo, G. N. Nyamasyo, D. Kilalo, W. Otieno, M. Otipa, F. Chege, T. Karanja and E. K. Lingeera, "Characteristics and production constraints of smallholder tomato production in Kenya," *Scientific African,* vol. 2, p. e00014, 2019.

[6] E. P. Nyalugwe, C. Malidadi and H. Kabuli, "An assessment of tomato production practices among rural farmers in major tomato growing districts in Malawi," *African Journal of Agricultural Research,* vol. 8, no. 13, pp. 194-206, 2022.

[7] J. Kalibbala, "The influence of organic manure on tomato growth in Rakai District Uganda," *Bachelor of Science Research Report, Makerere University ,* 2011.

[8] R. Bhandari, N. Neupane and D. P. Adhikari, "Climatic change and its impact on tomato (lycopersicum esculentum l.) production in plain area of Nepal," *Environmental Challenges,* vol. 4, 2021.

[9] B. Acock, D. Charles-Edwards and D. Hand, "An analysis of some effects of humidity on photosynthesis by a tomato canopy under winter light conditions and a range of carbon dioxide concentrations," *Journal of Experimental Botany,* vol. 27, pp. 933-941, 1976.

[10] E. Bradfield and C. Gurrridge, "Effects of night-time humidity and nutrient solution concentration on the calcium content of tomato fruit," *Scientia Horticulturae,* vol. 22, pp. 207-217, 1984.

[11] D. Ehret and L. Ho, "Translocation of calcium in relation to tomato fruit growth," *Annals of Botany,* vol. 58, pp. 679-688, 1986.

[12] I. Gabriel, F. Olajuwon and B. Michael, "Smallholder farmers' perception on tomato (solanum lycopersicum) seedling technologies in the north west zone of Nigeria," *International Journal of Agricultural Extension,* vol. 9, no. 1, pp. 79-89, 2021.

[13] M. R. Foolad, H. L. Merk and H. Ashrafi, "Genetics, genomics and breeding of late blight and early blight resistance in tomato," *Critical Reviews in Plant Sciences,* vol. 27, pp. 75-107, 2008.

[14] M. Nowicki, E. U. Kozik and M. R. Foolad, "Late blight of tomato," in *Translational genomics for crop breeding. Volume I: Biotic stresses*, First Edition ed., K. Rajeev and R. Tuberosa, Eds., Wiley, 2013, p. 241–265.

[15] V. Kesavan and B. Chaudhary, "Screening for resistance to Fusarium wilt of tomato," *SABRO Journals ,* vol. 9, p. 51–65, 1977.

[16] M. P. Sankar, S. Subbiah and S. Ramyabharathi, Fusarium wilt of tomato (Solanum lycopersicum L.), Mauritius: LAP LAMBERT Academic Publishing, 2020.

[17] H. A. Hassan, "Biology and Integrated Control of Tomato Wilt Caused by Fusarium oxysporum lycopersici: A Comprehensive Review under the Light of Recent Advancements," *Journal of Botany Research,* vol. 3, no. 1, pp. 84-99, 2020.

[18] S. Reddy, D. Bagyaraj and R. Kale, "Management of tomato bacterial spot caused by Xanthomonas campestris using vermin compost," *Journal of Biopesticides ,* vol. 5, no. 1, p. 10–13, 2012.

[19] K.-H. Kim, J. Cho, Y. Lee and W. Lee, "Predicting potential epidemics of rice leaf blast and sheath blight in South Korea under the RCP 4.5 and RCP 8.5 climate change scenarios using a rice disease epidemiology model, EPIRICE.," *Agricultural and Forest Meteorology,* vol. 203, p. 191–207, 2015.

[20] D. Bebber, "Range-expanding pests and pathogens in a warming world," *Annual Review of Phytopathology,* vol. 53, p. 335–356, 2015.

[21] C. F. McQuaid, P. Sseruwagi, A. Pariyo and F. van den Bosch, "Cassava brown streak disease and the sustainability of a clean seed system," *Plant pathology,* vol. 65, no. 2, pp. 299-309, 2015.

[22] F. Huapaya, B. Salas and L. Lescano, "“Ethno-phytopathology in Aymara communities of the TiticacaLakeshore,”," *Fitopatologia,* vol. 17, no. 8, 1982.

[23] P. Trutmann, J. Voss and J. Fairhead, "Local knowledge and farmer perceptions of bean diseases in the Central African Highlands," *Agriculture and Human Values,* vol. 13, pp. 64-70, 1996.

[24] J. W. Bentley and G. Thiele, "Bibliography: Farmer knowledge and management of crop diseases," *Agriculture and Human,* vol. 16, p. 75–81, 1999.

[25] M. Mukanga, J. Derera, P. Tongoona and M. Laing, "Farmers’ perceptions and management of maize ear rots and their implications for breeding for resistance," *African Journal of Agricultural Researches,* vol. 6, pp. 4544-4554, 2011.

[26] P. Sillitoe, "“Ethnoscientific observations on entomol-ogy and mycology in the southern Highlands of PapuaNew Guinea,”," *Science in New Guinea,* vol. 21, no. 1, p. 3–26, 1995.

[27] H. Warburton, F. L. Palis and S. Villareal, "“Farmers’perceptions of rice tungro disease in the Philippines”," in *Pest Manage-ment Practices of Rice Farmers in Asia*, K. L. Heong and M. Escalada, Eds., Los Baños,Philippines, IRRI, 1997.

[28] H. D. Thurston, "“Plant disease management practicesof traditional farmers”," *Plant Disease,* vol. 74, no. 2, p. 96–102, 1990.

[29] W. Ngonzi and G. Lubega, "Threats to Indigenous Knowledge in Improving Agricultural Productivity in Crop Production of Kabasekende Sub-County, Kibaale District," *International Journal of Research and Innovation in Social Science,* vol. iv, no. vi, 2020.

[30] F. Y. Anyan, "Farmers Perceptions and Attitudes Towards the Use of Agricultural Indigenous," *Journal of Agriculture and Crops,* vol. 4, no. 6, pp. 63-67, 2018.

[31] K. A. Kumar, "Local Knowledge and Agricultural Sustainability: A Case Study of Pradhan Tribe in Adilabad District," *Working Paper No. 81,* pp. 1-38, 2010.

[32] P. Nyeko, J. G. Edwards, R. Day and T. Raussen, "Farmers' knowledge and perceptions of pests in agroforestry with particular reference to Alnus species in Kabale district, Uganda," *Crop Protection,* vol. 21 , pp. 929-941, 2002.

[33] M. Urge, M. Negeri, T. Selvaraj and G. Demissie, "Farmers’ indigenous knowledge, perception and management practices of American fall army worm (Spodoptera frugiperda J. E. Smith) in maize crop productions in West Hararghe Zone, Ethiopia," *Global Journal of Agricultural Research,* vol. 8, no. 3, pp. 1-19, 2020.

[34] J. K. Paul, "Horticulture Validated Report 2016-2017," Agriculture and Food Authority, Nairobi, 2018.

[35] I. J. Serede, B. M. Mutua and J. M. Raude, "Calibration of Channel Roughness Coefficient for Thiba Main Canal Reach in Mwea Irrigation Scheme, Kenya," *Hydrology,* vol. 3, no. 6, pp. 55-65, 2015.

[36] R. Jaetzold, H. Schmidt, B. Hornetz and C. Shisanya, Farm management handbook of Kenya: part C,

East Kenya, 2nd ed., vol. II, Nairobi: Ministry of Agriculture, 2007.

[37] D. Kaggikah, "Kirinyaga County – 020," Nairobi, 2017.

[38] P. Biernacki and D. Waldorf, "Snowball sampling: Problems and techniques of chain referral sampling," *Sociological Methods & Research,* vol. 198: 10, pp. 141-163, 1981.

[39] B. T. Anang, A. Z. Zulkarnain and S. Yusif, "Production constraints and measures to enhance the competitiveness of tomato industry in Wenchi Municipal District of Ghana," *American journal of Experimental agriculture,* vol. 3, no. 4, pp. 824-838, 2013.

[40] M. W. Mwangi, J. W. Kimenju, R. D. Narla, G. M. Kariuki and W. M. Muiru, "Tomato Management Practices and Diseases Occurrence in Mwea," *Journal of Natural Sciences Research,* vol. 5, no. 20, pp. 119-124, 2015.

[41] A. L. Testen, D. P. Mamiro, J. Nahson, H. D. Mtui, P. A. Paul and S. A. Miller, "Integrating ethnophytopathological knowledge and field surveys to improve tomato disease management in Tanzania," *Canadian Journal of Plant Pathology,* vol. 40, no. 1, pp. 22-33, 2018.

[42] L. Melomey, M. Ayenan, G. Marechera, P. Abu, A. Danquah, D. Tarus and E. Danquah, "Pre- and Post-Harvest Practices and Varietal Preferences of Tomato in Ghana," *Sustainability,* vol. 14, p. 1436, 2022.

[43] V. Clottey, N. Karbo and K. Gyasi, "The tomato industry in northern ghana: Production constraints and strategies to improve competitiveness," *International Journal of Agriculture and Biology,* vol. 9, no. 6, 2009.

[44] M. W. Barasa, R. Kahuthia-Gathu, M. Mwangi and W. Waceke, "Tomato Production Characteristics, Biotic Constraints and their Management Practices by Farmers in Bungoma County, Kenya," *Journal of Natural Sciences Research,* vol. 9, no. 12, pp. 46-55, 2019.

[45] B. Chinsinga and M. Chasukwa, "Youth, agriculture and land grabs in malawi," *IDS Bull.,* vol. 43, no. 6, pp. 67-77, 2012.

[46] B. Naamwintome and E. Bagson, "Youth in agriculture: prospects and challenges in the sissala area of ghana," *Net Journal of Agricultural Science,* vol. 1, no. 2, pp. 60-68, 2013.

[47] S. Bezu and S. Holden, "Are rural youth in ethiopia abandoning agriculture?," *World Dev.,* vol. 64, pp. 259-272, 2014.

[48] G. Ddamulira, O. Isaac, M. Kiryowa, R. Akullo, M. Ajero, M. Logoose, A. Otim, F. Masika, J. Mundingotto, M. Matovu and Ramathani, "Practices and constraints of tomato production among smallholder farmers in Uganda," *African Journal of Food, Agriculture, Nutrition and Development,* vol. 21, no. 2, pp. 17561 - 17580, 2021.

[49] M. Reimers and S. Klasen, " Revisiting the Role of Education for Agricultural Productivity," *Am. J. Agric. Econ.,* vol. 95, p. 131–152, 2013.

[50] F. F. Olayemi, J. A. Adegbola, E. I. Bamishaiye and A. M., "Assessment of post-harvest challenges of small scale farm holders of tomotoes, bell and hot pepper in some local government areas of Kano State, Nigeria," *Bayero Journal of Pure and Applied Sciences,* vol. 3, pp. 39-42, 2011.

[51] M. W. Mwangi, " Interaction Between Fusarium Wilt and Root-knot Nematodes in Tomato and the Potential of Integrated Strategies in Management of the Disease Complex," *Doctoral dissertation, University of Nairobi,* 2018.

[52] H. K. Adu-Dapaah and E. Y. Oppong-Konadu, "Tomato production in four major tomato-growing districts in Ghana: Farming practices and production constraints," *Ghana journal of agricultural science,* vol. 35, no. 1, pp. 11-22, 2002.

[53] L. Guodaar, A. Beni and P. Benebere, "Using a mixed-method approach to explore the spatiality of adaptation practices of tomato farmers to climate variability in the Offinso North District, Ghana," *Cogent Social Sciences,* vol. 3, no. 1, p. 1273747, 2017.

[54] R. Nabuzale, "Effect Of Farmer's Knowledge and Attitudes on Management of the Tomato Spotted Wilt Virus in Sironko District, Uganda," *Msc Thesis, Makerere University,* 2014.

[55] A. Kiros-Meles and M. M. Abang, "Farmers' knowledge of crop diseases and control strategiesin the Regional State of Tigrai, northern Ethiopia: implicationsfor farmer–researcher collaboration in disease management," *Agriculture and Human Values,* vol. 25, no. 3, pp. :433-452, 2007.

[56] P. Schreinemachers, S. Balasubramaniam, N. M. B. Cuong, V. Ha, L. Kenyon, S. Praneetvatakul, A. Sirijinda, N. T. Le, R. Srinivasan and M.-H. Wu, "Farmers' perceptions and management of plant viruses in vegetables and legumes in tropical and subtropical Asia," *Crop Protection,* vol. 75, p. 115e123116, 2015.

[57] A. Palilo, "Prevalence and management of tomato bacterial wilt using selected resistant varieties in Morogoro region, Tanzania," *Msc Thesis, Sokoine University of Agriculture,* 2019.

[58] M. Neindow, E. N. K. Sowely and A. H. Abubakari, "Farmers' knowledge and perceptions of leaf spot disease of groundnut and its management in the Northern Region of Ghana," *Journal of Agricultural Biotechnology and Sustainable Development,* vol. 10, no. 9, pp. 170 - 177, 2018.

[59] E. D. Assefa, "Social-institutional problem dimensions of late blight," *PhD thesis, Wageningen University & Research,* 2020.

[60] A. Quisumbing, L. Brown, H. Feldstein, L. Haddad and C. Peña, "Women: the key to food security," *Food Policy Statement,* vol. 21, 1995.