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ASSESSMENT OF TOMATO FARMING STRATEGIES, DISEASES KNOWLEDGE AND MANAGEMENT PRACTICES AMONG FARMERS' IN KIRINYAGA COUNTY, KENYA

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ABSTRACT
Diseases are hindrance to tomato production in Kirinyaga, Kenya. However, information on farmer's disease knowledge to warrant pesticide use, disease predisposing factor such as varietal choice, seed source and irrigation system is scanty. This study assessed the association between tomato varieties grown, farming strategies, farmers' socio characteristic, disease knowledge, diseases management practices, legal status and sources of pesticides used in tomato farming, knowledge of biological control agents with the agroecological zones in Kirinyaga. A cross sectional survey method was used. Data was collected from 120 tomato farmers using structured questionnaires. A chi square test was used to determine association between different variables using SAS version 9.4. There was no significant (p>0.05) association between source of tomato planting material and agroecological zones. There was significant (p<0.05) association between tomato varieties and the reasons for choice. Irrigation system used in tomato farms was significantly (p<0.05) associated with agroecological zones. Farmers' knowledge of causative agent of early blight, late blight and septoria leaf spot was significantly (p<0.05) associated with agroecological zones. Farmers able of identifying causative agent of early blight, later blight and septoria spot were 51.7%, 40%and 17%, respectively. Up to 55% of farmers gained knowledge of tomato diseases through farming experience. Observation of the chemical withdrawal period in tomatoes was not significantly (p>0.05) associated with the level of pesticide dose applied. Over 46% farmers use wrong pesticide doses and only 48.33% of farmers use legal pesticides. The knowledge of use of biological control agents among farmers was not significantly (p>0.05)associated with agro ecological zones. Inability of some farmers to identify tomato diseases, use of illegal pesticides and use of improper doses of pesticides are challenges in tomato production in Kirinyaga. Therefore, measures such coordinated education on crop diseases, proper use of pesticide and surveillance to limit access to illegal pesticides should be considered.
Keywords: Tomato varieties, Pesticide, Agro-Ecological Zones, Kirinyaga County

INTRODUCTION
Tomato (*Solanum lycopersicum*) is a principle contributor to industrial development, employment and poverty eradication on a global scale (Njume *et al*., 2020). Tomato production is faced by biotic constraints such as diseases which negatively impact on yield (Savary *et al.*, 2017). Diseases which infect tomatoes include late blight which have been reported to causes yield loss of up to 70% (Foolad *et al*., 2008; Nowicki *et al.*, 2012), *Fusarium* wilt witha yield loss of 40 - 80% (Kesavan and Chaudhary, 1977; Sankar *et al.*, 2020; Hassan, 2020) and bacterial leaf spot with a yield loss of up to 80% (Reddy *et al*., 2012). Ambient environment partly contributed for by global climate change has impacted on plant disease dynamics, such as biology and ecology that govern pathogen's population and distribution (Pangga *et al.*, 2011; Juroszek and von Tiedemann, 2013; Barioni *et al*., 2019). Integrated disease management and modified farm conditions due to irrigation may reduce or exacerbate disease impacts (Bebber, 2015; Kim, 2015). Choice and source of planting material may determine pathogen persistence and prevalence regarding their resistance, susceptibility and contamination (McQuaid *et al.*, 2015).

Use of pesticide has remained the first choice among farmers in managing crop diseases due to their effectiveness (Hossain *et al*., 2013; Food-print, 2021a; Assefa, 2020). Due to pest pressure in crop production, importations of pesticides have risen to 15000 tonnes and use of illegal pesticides has risen to 18% in Kenya (Xinhua, 2019; Swagata *et al*., 2021). Access and use of illegal pesticides has escalated due to laxity of the government to control cross-border and local trade of illegal pesticides (Swagata *et al.*, 2021). If used inappropriately, pesticides may causeprofound environmental effect such as pollution and emergence of resistance pathogen strains (FAO, 2020). Sustainable agriculture advocates for farming practices with minimizes harm to animals, people and the environment(Food-print, 2021b). It involves evaluation of on-farm practices (Crop choice, sources of planting materials, disease management, irrigation methods) and farmers' indigenous disease knowledge and perception.

Studies on farmers' knowledge and perception on crop disease according to reports (Huapaya *et al.*, 1982; Trutmann *et al.* 1996; Bentley and Thiele 1999; Mukanga *et al.*, 2011) indicate incorrect identification of diseases due to mixed up of disease symptoms and health factors. For instance, Huapaya *et al*. (1982) 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. Thus, diseases control strategy that included application of wood ashes soaked in fish water on crops among other practices could be applied during specific periods. In New Guinea, farmers were reported to be unaware of the existence of plant pathogen microorganisms and believed that crop disease occurred due to actions of ancestors' spirits (Sillitoe, 1995). In Central Africa, farmers related fungal diseases symptoms to rain and soil depletion, while relating virus symptomsto varietal traits (Trutmann *et al.*, 1996). Warburton *et al.* (1997) reported that most farmers were not aware of diseased plants serving as inoculum source. Some farmers may be knowledgeable on plant pathogen (Thurston1990) and deploys indigenous agricultural knowledge such as seed selection and harvest handling in pest management (Mukanga *et al.* 2011; Anyan, 2018; Ngonzi and Lubega, 2020). However, some of practices may be ineffective in diseases management and calls for evaluated to ascertain their sustainability and effectiveness (Thurston, 1990; Lwoga *et al.*, 2010; Mukanga *et al.*, 2011; Ngonzi and Lubega, 2020). Verified beneficial practices should be intergrated in pest and diseases management approaches since such knowledge may reflect expertise in and proper understanding of farmer's environmental accumulated over the years (Kumar 2010). Thus, studies that create understanding on farmers' indigenous knowledge and practices such as pest control approachesare justified (Nyeko *et al.*, 2002; Urge *et al*., 2020). Studies on farmers' perceptions and knowledge regarding farm practices such as plant diseases management creates good understanding on factor that aggravates persistence, spread and severity of plant diseases. Though Kirinyaga County is a significant player in tomato production in Kenya, there is scarce information on farmers' indigenous knowledge, perception and practices towards tomato diseases in the area. Thus, this study evaluated farmers' knowledge, perception and disease management practices intomato farms in different agro ecological zones of Kirinyaga County, Kenya.

METHODOLOGY

Study Area

The study was carried out in Kirinyaga County (Figure 1). Kirinyaga County is located in the Southern outskirts of Mt. Kenya and about 100 km North East of Nairobi (Serede *et al.*, 2015). Kirinyaga County was suitable for this study since it is one of the leading tomato production Counties in Kenya (Ref). Geographically, Kirinyaga County lies between latitudes 0° 37'S and 0° 45'S and between longitudes 37° 14'E and 37° 26'E, and about 1,100 m to 1,200 m above sea level. The area receives an average annual rainfall of 940 mm (Jaetzold *et al*., 2007). The long and short rains occur between April to May and October to November, respectively. The temperature ranges from a minimum of 12°C to a maximum of 26°C with an average of 20°C (Kaggikah, 2017). Kirinyaga County has ten agro-ecological zones that include LH 1 (Tea Dairy Zone), TA I+II Tropical, Alpine Zone, UH 0, LH 0, LH 1, UM1, UM 2, UM 3 (three coffee zones), LM 3 and LM 4 (Marginal Cotton Zone). The study was specifically done in zone UM2, UM3, UM4, LM3 and LM4 with the agro-ecological conditions described in .

Table 19: Characteristics of surveyed agro ecological zones, Kirinyaga County, Kenya.

Table 19.

Table 19: Characteristics of surveyed agro ecological zones, Kirinyaga County, Kenya

Agro-ecological zone	Altitude (m)	Temp (°C)	Subzone	Rainfall (mm)	Soil type
UM2	1400-1580	20.1-19.0	m/l i m/s	1220-1500	Volcanic foot ridges soil
			m + s/m	1200-1250	
UM3	1340 - 1400	20.6-20.1	m/s + s	1100 - 1250	volcanic foot ridges soil
UM4	1280 - 1340	20.9-20.4	s/m + s	950 - 1200	Plateau soil
LM3	1220 - 1280	21.2 - 20.9	s + s	350 - 960	Plateau soil
			s /m+ s	950 -1200	
LM4	1090 - 1220	22.0 - 21.2	s + s	350 -960	Plateau soil and upland soils
			s + s/vs	850 - 950	

m = medium, s = short, vs= very short, l = long

Tomato is grown in coffee zones, tea zones and in some areas in cotton zone through irrigation. This study was conducted in five tomato growing agro- ecological zones of Kirinyaga namely LM 3, LM 4, UM 3 and UM 3 (.

Table 19 and Figure 9).

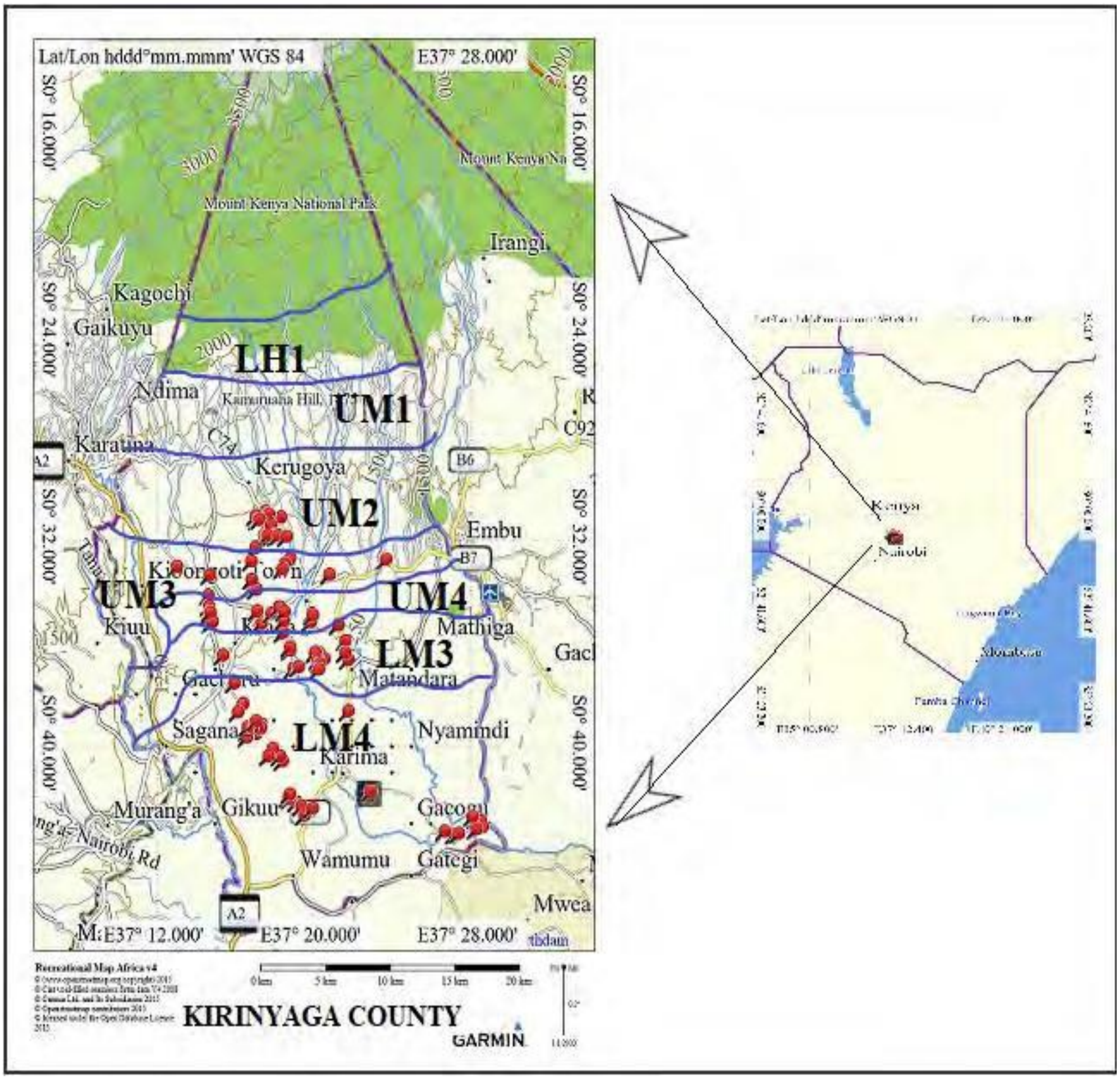

Figure 9: Study locations surveyed (red whiskers) in agroecological zones of Kirinyaga County

Villages in different agroecolocal zones were involved in the study. In agro-ecological zone LM4 (Gachogu, Gategi, Kiumbu, Wanguru and Nguka villages), LM3 (Kandongo, Kagio, Siranga, and Nyangate villages), UM4 (Ndoma, Kianganga, Njiris), UM3 (Gatheri and Kamuthambi villages) and UM2 (Kerigo, Karia, Keria and Geotheri villages). Eighteen villages were selected because they have many farmers who grow tomatoes annually.

Data Collection

A cross sectional survey study was carried out in five different agro ecological zones of Kirinyaga County between the months of February to May 2020. Villages for the survey were identified in the month of February before the actual study began. In Kirinyaga, tomatoes are planted in different seasons through irrigation systems. The sample size of 120 farmers was drawn using, Cochran (1963) formula from 1000 tomatoes farmers grow tomatoes over ¼ an acres in Kirinyaga County based on preliminary study done in February 2020.

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, large 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), disease knowledge and on disease management. Description of irrigation system in the farm and frequency of irrigation was categorized (Low pressure flowing piped water, Medium pressure flowing piped water and High pressure flowing piped water).

Frequency of irrigation was classified (Once a week, twice a week, after two weeks). Enquiry on disease occurrences on tomato farm was made. Farmers ability to identify diseases in their farm was assessed, i.e. (whethera farmer can identify tomato diseases), source of knowledge (From school, friends, seminars and other training, farming experience), knowledge of the causative agents of early blight, late blight and septoria spot; disease management strategy; the point at which fungicides are applied and dose level used in tomato farm, frequency at which spraying is done in their farm, whether the farmer allowed chemical withdrawal period prior to harvesting. Farmers were also asked on legality of the pesticides used in the farm, reason for using illegal pesticides and sourcesof illegal pesticides. Lastly, the questionnaire sort to know whether a farmer has used and or heard of biological control agents (BCAs). The questionnaire was administered on a one on one basis with either the farmer or permitted farm attendant. Data was evaluated in percentage and using chi-square (χ^2) test of association in ScientificAnalysis System (SAS) Version 9.4.

RESULTS

Tomato varieties grown by farmers and farming strategies Kirinyaga County

The main tomato varieties grown were not the same in all the agroecological zones studied. In agroecological zone LM3, the percentages of farmers growing Terminator F1 variety were higher at 26%. In agro ecological zone LM4, the percentage of farmers growing terminator variety were high at 52.77%. In agroecological zone UM2, Ansal F1was highly grown by farmers at 42.22. In zone UM3, higher percentage of farmers at 47.63% reported to grow Ansal F1 variety. In zone UM4 higher percentage of farmers at 27.98% reported to grow Kilele F1 variety (

Table **20**).

The source of tomato planting material was not significantly (χ^2 (8, 120) = 9.8227, p-value = 0.6315) associated with agro ecological zones. The highest percentage of farmers (53.33%) obtained tomato seeds from the agrovets while only 10% obtained seeds or seedlings from friends (Table 21).

Table 20: Main tomato varieties present in farmer's land across agroecological zones of study in Kirinyaga

Main tomatoes variety grown	Respondents in agro ecological zones (%)				
	LM3	LM4	UM2	UM3	UM4
Kilele f1	21.75	5.57	4.75	4.75	27.98
Rambo f1	17.37	8.33	0.00	0.00	8.01
Terminator f1	26.08	52.77	0.00	0.00	20.01
Bawito safa F1	4.33	8.33	5.41	0.00	8.01
Ranger f1	8.71	2.77	0.00	0.00	0.00
Rio Tinto F1	0.00	0.00	28.59	28.59	0.00
Ansal F1	8.71	2.77	42.22	47.63	3.98
Unknown	8.71	5.57	0.00	0.00	12.00
Others	4.33	13.90	19.04	19.04	20.01
%Total	100.00	100.00	100.00	100.00	100.00

Table 21: Sources of tomato planting material in different agro ecological zones, Kirinyaga County

Source of tomato seeds	Agro ecological zones (%)					Total
	LM3	LM4	UM2	UM3	UM4	
Agrovet	12.5	15	7.5	6.67	11.67	53.33
From Friend	2.5	3.33	0.83	0	3.33	10

Original regrown	0.83	5	5	2.5	3.33	16.67
Commercial nursery	3.33	6.67	4.17	3.33	2.5	20
Total	19.17	30	17.5	12.5	20.83	100
	Chi- value =9.8227			*p*-value =0.6315		

There was significant ($\chi^2(40, 120) = 107.7116$, $p < .0001$) association between tomato varieties grown and the reasons for its choice by the farmer. Marketability of tomatoes had a significantly higher percentage of 38.33%, followed by big fruit size at 27.5%. Tolerance to pests and diseases had lower percentage of 2.5%. Terminator F1 scored higher percentage of 12.5% for its good marketability followed by Kilele F1 at 9.17% while ranger scored 0%. Ansol F1 variety had higher percentage of 8.33% for its bigger fruits and was followed by terminator with 5% with Rio tinto F1 scoring 0%. Rio tinto F1 scored 5.83% for its adaptation to climate (Cold area) and was followed by Terminator F1 (5%) which was reported to tolerate slightly dry hot area ().

Table 22).

Table 22: Relationship between main varieties grown and reasons for its choice

Reason for variety grow	Main tomato variety currently grown (%) K_F1	R_F1	T_F1	BS_F1	Rr_F1	Rio_f1	An_f1	Unk	Others	Total
Big fruits	3.33	0.83	5.00	2.50	2.50	0.00	8.33	1.67	3.33	27.50
Marketability	9.17	4.17	12.50	1.67	0.00	1.67	3.33	0.83	5.00	38.33
Not rot faster	1.67	1.67	1.67	0.83	0.00	0.00	1.67	0.00	3.33	10.83
Climate	0.00	2.50	5.00	0.00	0.00	5.83	0.83	0.00	1.67	15.83
Tolerant	0.00	0.83	0.83	0.00	0.00	0.00	0.00	0.00	0.83	2.50
No reason	0.83	0.00	0.00	0.83	0.00	0.00	0.00	3.33	0.00	5.00
Total	15.0	10.0	25.0	5.83	2.50	7.5	14.17	5.83	14.17	100.0
	Chi- value = 93.1029, *p*-value <.0001									

Where K_FI= Kilele F1, R_F1= Rambo F1, T_F1= Terminator f1, BS_F1= Bawito safa F1, Rr_F1= Ranger, Rio_F1= Rio tinto f1, An_F1= Ansol F1, Unk= Unknown

Percentages of farmers who grew other tomato varieties alongside the main variety were different in agro ecological zones. Farmers who grew Prosta F1 alongside the main variety were high at 21.75% in agro ecological zone LM3. In agro ecological zone LM4, high percentages of farmers grew Kilele alongside the main variety. In agro ecological zone UM2 high percentage of farmers (19.04%) grew Venonia F1 alongside the main variety. In agro ecological zone UM3, high percentage (13.36%) of farmers grew Ranger F1 variety (**Error! Reference source not found.**).

Table 23: Tomato varieties grown alongside the main varieties in agroecological zones in Kirinyaga

	Responses Agro ecological zone (%)				
Other tomato variety	LM3	LM4	UM2	UM3	UM4
Non	60.88	55.57	61.92	73.36	76.03
TM20 F1	8.71	2.77	0.00	0.00	3.99
Kilele F1	0.00	13.90	0.00	6.64	12.01
Bawito safa F1	0.00	0.00	0.00	0.00	3.99
Nyati F1	4.33	2.77	0.00	0.00	0.00
Prosta F1	21.75	5.57	4.75	6.64	3.99
Ranger F1	0.00	2.77	4.75	13.36	0.00
Zara f1	4.33	5.57	0.00	0.00	0.00
Vanora F1	0.00	5.57	19.04	0.00	0.00
Vuna F1	0.00	2.77	0.00	0.00	0.00
Rambo F1	0.00	2.77	9.55	0.00	0.00
Total	100	100	100	100	100

Irrigation in tomato farms in agro ecological zones of Kirinyaga County

The irrigation system used by farmers in tomato farms was significantly (χ^2 (8, 120) = 79.9843, $p < .0001$) associated with agro ecological zones. High percentage of farmers uses 'high pressure flowing piped water' (40.0%) while

‘Low pressure flowing Piped water’ recorded low percentage of 24.17%. Use of high pressure flowing piped water was high in zone LM4 (24.17%) and low in zone UM3 with 0.83%. Use of medium pressure flowing piped water was high in zone UM4 (15%) and lower in zone UM3 (2.5%). ‘use of low pressure flowing piped water’ was high inzone UM2 (10%) and low in zone LM4 and LM3 both recording 0.83%). The frequency at which tomato farms get irrigated by farmers was significantly (χ^2 (8, 120) = 56.4345, p <.0001) associated with agro ecological zones. High percentage of farmers irrigate tomato farm once a week (40%) while low percentage irrigate after every two weeks (Table 25).

Farmers’ demographic characteristics and knowledge of tomato diseases in Kirinyaga County

The ages of tomato farmers interviewed were not significantly associated (χ2 (8, 120) = 11.9402, p = 0.4505) with agro ecological zones. However, farmers at the age of 41-50 had slightly higher percentage mean of 35% while farmers at age 18-30 years were lower at 5.83% (Table 8). Farmers education level was not significantly (χ^2 (8, 120) = 11.1963, p = 0.1908) associated with agro ecological zones. However, high percentages of tomato farmers have secondary education level at 55.83% while the percentages of those who have post-secondary education level were low at 12.5%. Level of farming based on farm size was not significantly (χ^2 (4, 120) = 4.1265, p = 0.3892) associated with agro ecological zones. High percentage of farmers reported being small scale farmers at 74.17% while large scale farmers were only 25.83% (

Table **27**). The duration for which a farmer has been growing tomatoes in Kirinyaga County was not significantly (χ^2 (16, 120) = 17.5077, p = 0.3535) associated with agro ecological zones. Farmers who have grown tomato for a period of below 2-4 years were higher at 30.83% while those who have grown tomatoes for less than one year were few at 9.17% (

Farmers’ **age and knowledge of tomato diseases in Kirinyaga County**

The age of tomato farmers was significantly (χ^2 (6, 30) = 16.191, p = 0.0128) associated with ability to identify tomato diseases. Percentage of farmers who are able to identify all tomato diseases was high at 11.67% at the age of 50 years and above with 0% at 18 to 30 years. Farmers who could only identify some diseases were high in age 41- 50 years (21.67%) and low at 18-30 with 4.17%. Finally, percentage of farmers with no ability to identify tomato diseases were 3.38% at 31 to 40 years and low was 0% at 50 years and above (Table 30). Knowledge of tomato diseases was significantly (χ^2 (8, 120) = 43.8836, p = 0.0072) associated with number of years of tomato farming. Farmers who claimed the ability to identify all tomato diseases were high at 12.5% for those who have grown tomatoes for over 10 years while those who have grown tomatoes for 1 to 2 years were less at 0.083%. farmers who could not identify tomato diseases was high among those who have cultivated tomatoes for 2 to 4 years (bacteria while 5% cited viruses.

Farmers knowledge of causative agent of late blight differed was significantly (χ^2 (20, 120) = 40.9362, p = 0.0038) associated with the agro ecological zones. Only 40% of farmers gave the correct causative agent as fungi. Most of the farmers who gave the correct causative agent for late blight were from zone LM4 (19.17%) followed by zone UM4 (7.5%) while only 0.83% in zone UM3 got it correctly (

Table **33**)

Table 31).

Table 28). The duration for which a farmer has been growing tomatoes was significantly (χ^2 (12, 120) = 43.884, p-value <.0001) associated with the age of farmer. Farmers who have grown tomatoes for 2 to 4 years were high at 30.83 % while those who have grown tomatoes for less than 1 year were less at 9.17% (Table 29).

Table 24: Farmers using different irrigation system in tomato farm in in agro ecological zones of Kirinyaga

	Agro ecological zone (%)					
Irrigation system used in tomato farm	LM3	LM4	UM2	UM3	UM4	Total
Low pressure flowing piped water	0.83	0.83	10.0	9.17	3.33	24.17
Medium pressure flowing piped water	7.50	5.0	5.83	2.50	15.0	35.83
High pressure flowing piped water	10.83	24.17	1.67	0.83	2.5	40.0
	Chi Square value =79.9843				*p* value <.0001	

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Table 24: Farmers using different irrigation system in tomato farm in in agro ecological zones of Kirinyaga

	Agro ecological zone (%)					
Irrigation system used in tomato farm	LM3	LM4	UM2	UM3	UM4	Total
Low pressure flowing piped water	0.83	0.83	10.0	9.17	3.33	24.17
Medium pressure flowing piped water	7.50	5.0	5.83	2.50	15.0	35.83
High pressure flowing piped water	10.83	24.17	1.67	0.83	2.5	40.0
	Chi Square value =79.9843				*p* value <.0001	

Table 25: Percentage of farmers irrigating tomato farms in agro ecological zones of Kirinyaga

	Agro ecological zone (%)					
Irrigation frequency	LM3	LM4	UM2	UM3	UM4	Total
Twice a week	6.67	16.67	1.67	1.67	7.50	34.17
Once a week	10.00	12.50	2.50	3.33	11.67	40.00
After two weeks	2.50	0.83	13.33	7.50	1.67	25.83
			Chi Square =56.434!	*p* value <.0001		

Table 8: Ages of tomato farmers in agro ecological zones of Kirinyaga County

Respondent Age	Agro ecological zone (%) LM3	LM4	UM2	UM3	UM4	Total	*Chi* Square	*p* -value
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	11.9402	0.4505
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		

Table 26: Percentages of tomato farmers Education levels in agro ecological zones of Kirinyaga

Farmer's Education level	Agro ecological zone (%) LM3	LM4	UM2	UM3	UM4	Total	*Chi* Square	*p* value
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	11.1963	0.1908
College and above	1.67	6.67	1.67	1.67	0.83	12.50		

Table 27: Percentage of farmers practicing tomato farming in agro ecological zones

Farming level	Agro ecological zone (%) LM3	LM4	UM2	UM3	UM4	Total
Small <2 acres	12.5	20.83	15	10.83	15	74.17
large scale above 2 acres	6.67	9.17	2.5	1.67	5.83	25.83
Total	19.17	30	17.5	12.5	20.83	100
	Chi Square= 4.1265			*p* value= 0.3892		

Farmers' age and knowledge of tomato diseases in Kirinyaga County

The age of tomato farmers was significantly (χ^2 (6, 30) = 16.191, p = 0.0128) associated with ability to identify tomato diseases. Percentage of farmers who are able to identify all tomato diseases was high at 11.67% at the age of 50 years and above with 0% at 18 to 30 years. Farmers who could only identify some diseases were high in age 41- 50 years (21.67%) and low at 18-30 with 4.17%. Finally, percentage of farmers with no ability to identify tomato diseases were 3.38% at 31 to 40 years and low was 0% at 50 years and above (Table 30). Knowledge of tomato diseases was significantly (χ^2 (8, 120) = 43.8836, p = 0.0072) associated with number of years of tomato farming. Farmers who claimed the ability to identify all tomato diseases were high at 12.5% for those who have grown tomatoes for over 10 years while those who have grown tomatoes for 1 to 2 years were less at 0.083%. farmers who could not identify tomato diseases was high among those who have cultivated tomatoes for 2 to 4 years (bacteria while 5% cited viruses.

Farmers knowledge of causative agent of late blight differed was significantly (χ^2 (20, 120) = 40.9362, p = 0.0038) associated with the agro ecological zones. Only 40% of farmers gave the correct causative agent as fungi. Most of the farmers who gave the correct causative agent for late blight were from zone LM4 (19.17%) followed by zone UM4 (7.5%) while only 0.83% in zone UM3 got it correctly (
Table **33**)

Table 31).

Table 28: Farmers' History of Growing Tomato Based on Agro ecological Zones

Tomato farming history	Agro ecological zone (%) LM3	LM4	UM2	UM3	UM4	Total
< 1 year	0.83	4.17	0.83	1.67	1.67	9.17
1-2 years	3.33	3.33	0.83	2.5	3.33	13.33
2-4 years	8.33	9.17	4.17	5	4.17	30.83
4-10 years	5	7.5	3.33	1.67	4.17	21.67
above 10 years	1.67	5.83	8.33	1.67	7.5	25
Total	19.17	30	17.5	12.5	20.83	100
	Chi square= 17.5077		*p*-value= 0.3535			

Table 29: Percentages of farmers age bracket and history of growing tomatoes in Kirinyaga County

	History of growing tomato (%)					
Age bracket	Less than one year	1-2 years	2-4 years	4-10 years	above 10 years	Total
18-30	0.83	1.67	3.33	0.00	0	5.83
31-40	2.5	3.33	12.5	5.83	1.67	25.83
41-50	4.17	7.5	10	9.17	4.17	35
50 and above	1.67	0.83	5	6.67	19.17	33.33
Total	9.17	13.33	30.83	21.67	25	100
	Cl i- value = 43.8836		*p*-value < 0.0001			

Table 30: Percentage of farmers age and knowledge of tomato diseases in Kirinyaga County

	Age (%)						
Diseases Knowledge	18-30	31-40	41-50	50 and above	Total	Chi value	*p*-value
Yes, all of them	0.0	5.83	7.5	11.67	25.0		
Yes, some of them	4.17	16.67	26.67	21.67	69.17	16.191	0.0128
No	1.67	3.33	0.83	0.0	5.83		
Total	5.83	25.83	35.0	33.33	100.0		

Knowledge of causative agent of early blight, late blight and septoria spot in tomato in Kirinyaga

Farmers knowledge of causative agent of early blight was significantly (χ^2 (20, 120) = 57.8876, p <.0001) associated with agro ecological zones. Up to 51.67% of farmers gave the correct causative agent as fungi with high percentage from zone LM4 (20%) and was low 3.33% in agro ecological zone UM3

	History of tomato farming					
Diseases Knowledge	< 1 year	1-2 years	2-4 years	4-10 years	> 10 years	Total
Yes, all of them	1.67	0.83	5	5	12.5	25
Yes, some of them	6.67	11.67	21.67	16.67	12.5	69.17
No	0.83	0.83	4.17	0	0	5.83
Total	9.17	13.33	30.83	21.67	25.0	100
	Chi square value = 20.9715				*p*-value =0.0072	

Table 32). Eleven (11.67%) of the farmers had no knowledge of the causative agent of early blight while 36.67% were wrong with 1.67% citing bad weather and viruses, 28.33% cited bacteria while 5% cited viruses.

Farmers knowledge of causative agent of late blight differed was significantly (χ^2 (20, 120) = 40.9362, p = 0.0038) associated with the agro ecological zones. Only 40% of farmers gave the correct causative agent as fungi. Most of the farmers who gave the correct causative agent for late blight were from zone LM4 (19.17%) followed by zone UM4 (7.5%) while only 0.83% in zone UM3 got it correctly (
Table **33**)

Table 31: Percentage of farmer's history of growing tomato and knowledge of diseases in Kirinyaga

	History of tomato farming					
Diseases Knowledge	< 1 year	1-2 years	2-4 years	4-10 years	> 10 years	Total
Yes, all of them	1.67	0.83	5	5	12.5	25
Yes, some of them	6.67	11.67	21.67	16.67	12.5	69.17
No	0.83	0.83	4.17	0	0	5.83
Total	9.17	13.33	30.83	21.67	25.0	100
	Chi square value = 20.9715				*p*-value =0.0072	

Table 32: Percentage of farmer's knowledge on causative agent of early blight in tomato farms in agro ecological zones of Kirinyaga County

Couse of ELB	Agro ecological zone						*Chi* Square	*p* -value
	LM3	LM4	UM2	UM3	UM4	Total		
Bacteria	6.67	8.33	0.0	7.50	5.83	28.33		

Couse of ELB	Agro ecological zone						Chi Square	p -value
	LM3	LM4	UM2	UM3	UM4	Total		
Virus	0.0	0.0	3.33	0.83	0.83	5.0		
Fungi	12.5	20.0	10.0	3.33	5.83	51.67	57.888	<.0001
Insects	0.0	0.0	0.83	0.83	0.0	1.67		
Don't know	0.0	1.67	3.33	0.0	6.67	11.67		
Bad weather	0.0	0.0	0.0	0.0	1.67	1.67		

Table 33: Percentage of farmer's knowledge causative agent of late blight in tomato farms in agro ecological zones of Kirinyaga County

Couse of LBT	Agro ecological zone						Chi Square	p -value
	LM3	LM4	UM2	UM3	UM4	Total		
Bacteria	3.33	0.83	0.0	0.0	2.5	6.67		
Virus	0.83	0.0	0.0	0.0	0.83	1.67		
Fungi	5.83	19.17	6.67	0.83	7.5	40.0	40.9362	0.0038
Insects	1.67	0.0	2.5	0.0	1.67	5.83		
Don't know	4.17	1.67	3.33	2.5	2.5	14.17		
Bad weather	3.33	8.33	5.0	9.17	5.83	31.67		

Where LBT = Late Blight

Farmers' knowledge of causative agent of septoria leaf spot of tomato was significantly (χ^2 (20, 120) = 39.158, p = 0.0064) associated with ecological zones. Only 17% of farmers cited correct causative agent as fungi with high percentage from zone UM2 (5.83%) and low percentage from zone UM3 and LM3 both with 1.67%. Farmers 29.17% had no knowledge of septoria leaf spot causative agent (

Table **34**).

Farmers claim on disease knowledge was not significantly (χ^2 (10, 120) = 10.7875, p = 0.3743) 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 15.83% were able to identify the causative agent of early blight (
Figure 10).

Table 34: Percentage of farmers' knowledge on causative agent of septoria leaf spot in tomato farms in agro ecological zones of Kirinyaga County

	Agro ecological zone						Chi Square	p -value
Couse of Septoria	LM3	LM4	UM2	UM3	UM4	Total		
Bacteria	6.67	8.33	1.67	2.5	4.17	23.33		
Virus	0.0	0.0	0.0	2.5	0.83	3.33		
Fungi	1.67	4.17	5.83	1.67	4.17	17.5	39.158	0.0064
Insects	6.67	10.0	1.67	3.33	3.33	25.0		
Don't know	4.17	7.5	8.33	2.5	6.67	29.17		
Bad weather	0.0	0.0	0.0	0.0	1.67	1.67		

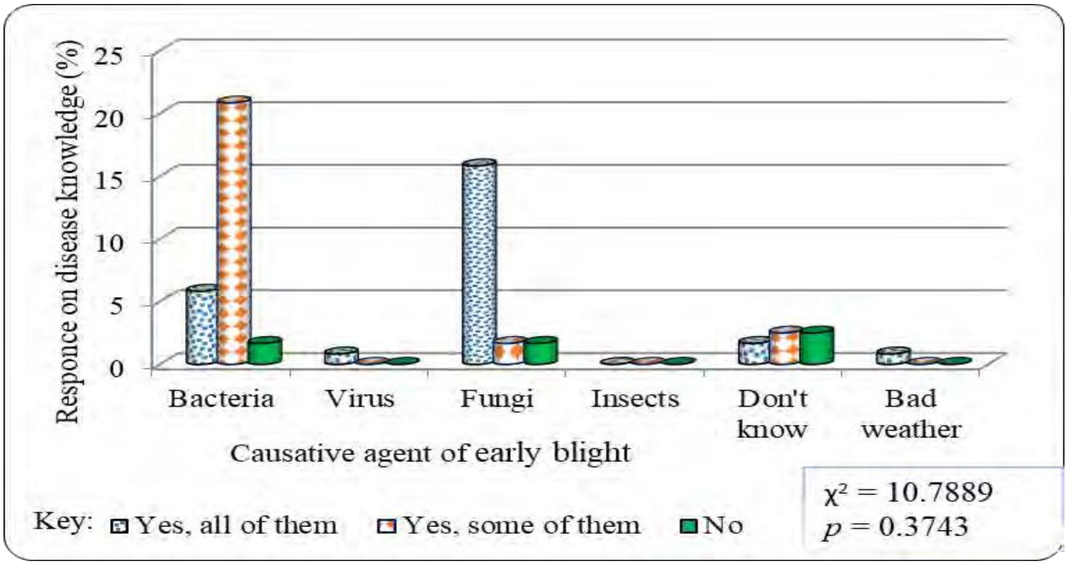

Figure 10: Percentage of Farmers' claim of tomato diseases knowledge and knowledge of causative agent of early blight in Kirinyaga county

Farmers' knowledge was not significantly (χ^2 (10, 120) = 10.6059, 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 had no knowledge of tomatoes, 1.67% identified the causative agent of late blight (Figure 11).

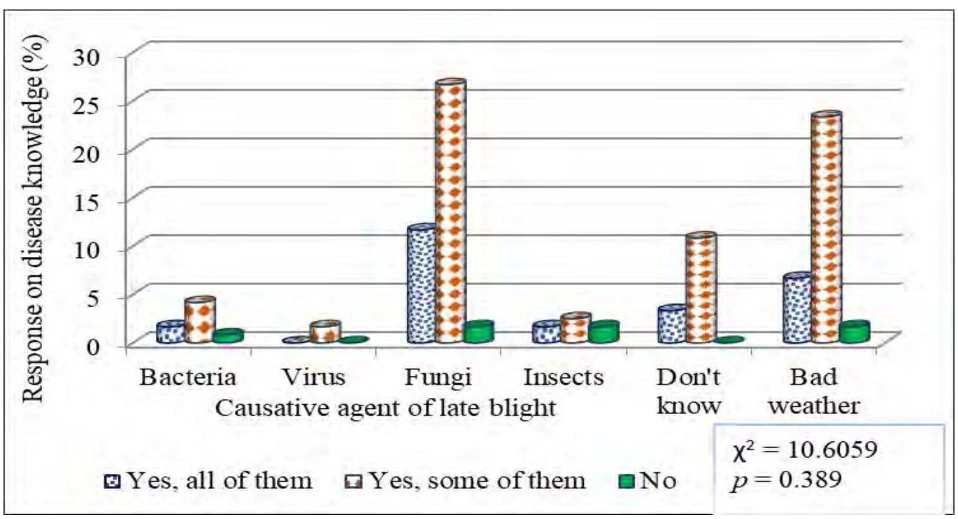

Figure 11: Percentage of farmers' claim of tomato diseases knowledge and knowledge of causative agent of late blight in Kirinyaga county

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. 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% cited bacteria and 6.67 cited 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 12).

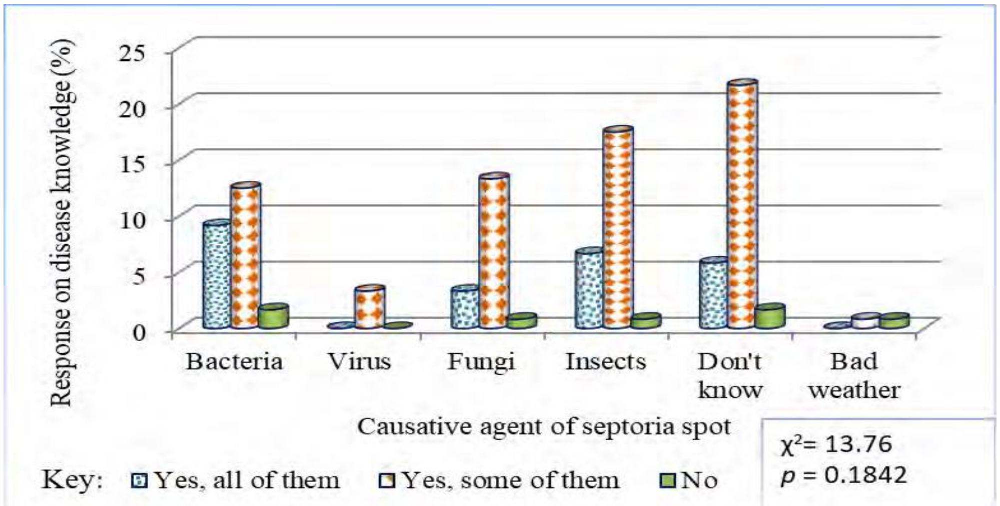

Figure 12: Percentage of farmers' claim of tomato diseases knowledge and knowledge of causative agent of septoria spot in Kirinyaga county

Sources of knowledge of tomato diseases among farmers in Kirinyaga County

Source of knowledge of diseases among tomato farmers was not significantly (χ^2 (16, 120) = 13.448, p = 0.6398) associated with the agro ecological zones. However, higher number of farmers pointed out farming experience (55%) as the source of knowledge while school was least cited 1.67% (
Table **35**).

Table 35: Farmers' with different categories of knowledge of tomato disease in Kirinyaga

Knowledge Source	Agro ecological zone						*Chi* Square	*p* -value
	LM3	LM4	UM2	UM3	UM4	Total		
From school	0.83	0.00	0.00	0.00	0.83	1.67		
from friends	5.83	8.33	4.17	2.50	2.50	23.33	13.448	0.6398
Seminars and other training	3.33	5.00	0.83	2.50	2.50	14.17		
Farming experienced	9.17	15.83	11.67	5.83	12.50	55.00		
Have not learnt	0.00	0.83	0.83	1.67	2.50	5.83		
Total	19.17	30.00	17.50	12.50	20.83	100.0		

Relationship between farmer's age, history and knowledge of tomato diseases in Kirinyaga County

Farmers' age was significantly (χ^2 (12, 120) = 23.255, p = 0.0256) associated with source of knowledge of tomato diseases. Farming experience was mostly stated as the knowledge source (55%) while school (1.67%) was least reported as knowledge source. Farming experience was high at 25.17% in aged 50 years and above was lower at 31-40 year with 1.67% (Table 36).

Table 36: Farmer age associated with different sources of knowledge of tomato diseases in Kirinyaga

Knowledge source	Farmer's Age bracket (%)				Total
	18-30	31-40	41-50	50 and above	
From school	0.00	0.83	0.83	0.00	1.67
from friends/Neighbors	0.00	7.50	10.83	5.00	23.33
Seminars and other training	2.50	3.33	4.17	4.17	14.17
Farming experienced	1.67	11.67	17.50	24.17	55.00
Have not learnt	1.67	2.50	1.67	0.00	5.83
Total	5.83	25.83	35.00	33.33	100.00
	Chi Square = 23.255			*p* –value = 0.0256	

Table 37: Percentage of farmers with different history of growing tomatoes and source of knowledge of tomato diseases

History of tomato farming	School	Friends/ Neighbors	Knowledge Source: Seminars and other training	Farming experienced	Have not learnt	Total
< 1 year	0	2.5	2.5	2.5	1.67	9.17
1-2 years	0	6.67	2.5	3.33	0.83	13.33
2-4 years	0.83	7.5	4.17	15	3.33	30.83
4-10 years	0	5	3.33	13.33	0	21.67
> 10 years	0.83	1.67	1.67	20.83	0	25
Total	1.67	23.33	14.17	55	5.83	100
	Chi Square = 29.6856			*p* –value = 0.0197		

The history of growing tomatoes was significantly (χ^2 (16, 120) = 29.6856, p = 0.0197) associated with knowledge source. Farmers who have grown tomatoes for less than one year acquired knowledge of diseases from friends, farm experience and seminars each at 2.5% each. Farmers who have done farming for 1-2 years mainly get knowledge from friends (6.67%). High percentage of farmers who have done farming for 2-4 and over 10 years acquired knowledge through farm experience at 15% and 20.83% respectively. Low percentages of farmers acquire knowledge of tomato diseases from school (
Table **37**).

Pesticide application time, criteria frequency and legality in tomato farms in Kirinyaga County

The phase (Time) at which pesticide are applied by the farmers in their tomato plantation was significantly (χ^2 (8, 120) = 23.408, p = 0.0029) associated with agro ecological zone. High percentage of farmers 69.17% apply pesticideprior to the occurrence of disease symptoms and were high in zone LM4 21.67% in zone LM3 9.17% in zone UM4. Percentage of farmers who apply pesticide only on the appearance of disease symptom was high in zone UM4 with 5.83% and lower 2.5% in zone UM2. Percentages of farmers who apply pesticide throughout tomato growing period were only in zone LM3 with 6.67% and LM4 with 3.33% ().

Table 38).

Table 38: Percentage of farmers applying fungicides at different diseases phases in agro ecological zones of Kirinyaga County

Pesticide Application time	Agro ecological zone (%): LM3	LM4	UM2	UM3	UM4	Total	*Chi* Square	*p* value
Before diseases occur	9.17	21.67	13.33	10.0	15.0	69.17		
when symptoms occurs	3.33	5.00	4.17	2.5	5.83	20.83	23.408	0.0029
Throughout growth period	6.67	3.33	0.00	0.00	0.00	10.00		

There was no significant (χ^2 (8, 120) = 6.504, p = 0.1645) association on how fungicides are applied in tomato farm and agro ecological zone. Farmers who apply fungicides as a mixture were slightly higher in all agro ecological zones except for zone UM2. Agro ecological zone LM2 had higher percentage of farmers mixing up pesticides with 20.83% while zone UM3 was lower with 7.5% (Figure 13).

The frequency of pesticide application in tomato farm was not significantly (χ^2 (8, 120) = 9.0232, p = 0.3403) associated with agro ecological zones. However, the percentage of farmers who apply pesticide in tomato after every two weeks were slightly high in zone LM4 at 15.83% and was lower in zone LM3 at 9.17% (Figure 14). Pesticides doses levels used by the farmers were not significantly (χ^2 (8, 120) = 7.192, p = 0.5161) associated with agro ecological zones. However, farmers who apply pesticide at the recommended dose were slightly higher in agro ecological zone LM4 (15%) and lower in zone UM3 with 6.67%. Farmers who apply pesticide doses above the recommended level were slightly high in zone LM4 at 9.17% and lower in zones UM2, UM3 and UM4 all having 5%. Farmers who apply pesticide below the recommended dose were slightly higher in zone LM4 5.83%, and low inzone LM3 0.83% (

Table **39**).

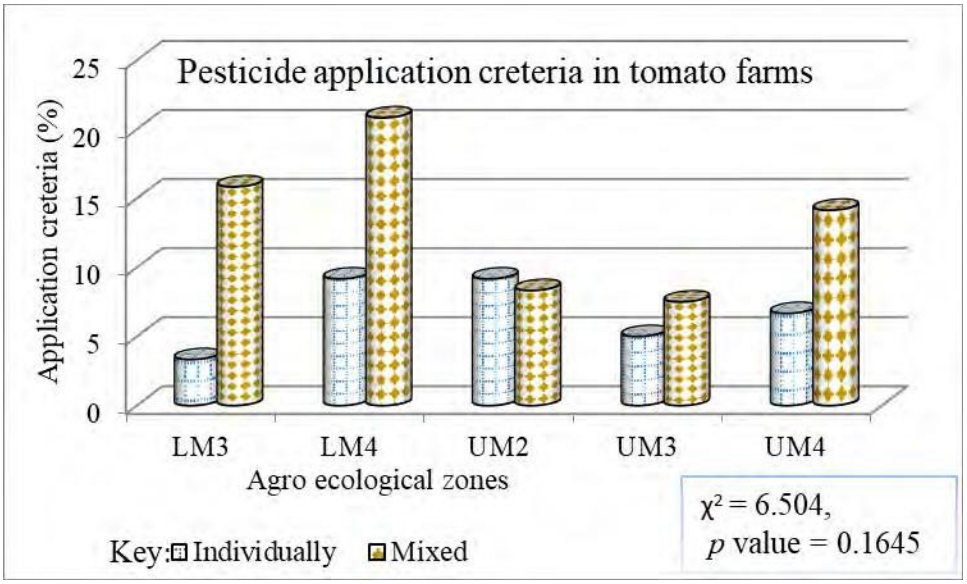

Figure 13: Percentage of farmers practicing different criteria of pesticide application in tomato farms in agro ecological zones of Kirinyaga County

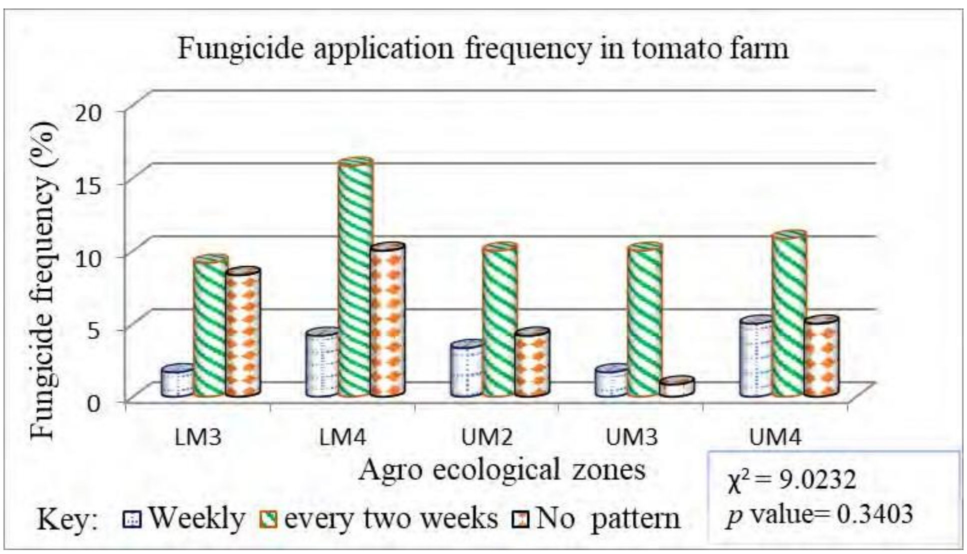

Figure 14: Percentage of farmers applying pesticide in tomato farms in different frequencies in agro ecological zones of Kirinyaga County

Table 39: Percentages of farmers applying different pesticide dose levels in tomato farms in agro ecological zones of Kirinyaga County

Agro ecological zone	Level of fungicide dose used by the farmer			Total
	Below recommended dose	Recommended dose	Above recommended dose	
LM3	0.83	10.83	7.50	19.17
LM4	5.83	15.00	9.17	30.00
UM2	5.00	7.50	5.00	17.50
UM3	0.83	6.67	5.00	12.50
UM4	3.33	12.50	5.00	20.83
Total	15.83	52.50	31.67	100.00

Chi Square = 7.192	*p* value = 0.5161

Pesticide level applied in tomatoes and observation of chemical withdrawal period in Kirinyaga

Pesticide dose level applied in tomatoes was no significantly (χ^2 (8, 30) = 8.1252, p = 0.4027) associated with failureto observing Chemical withdrawal period prior to harvesting (

Table **40**). However, farmers not observing withdrawal period and uses recommended dose were high at 46.67% while farmers who use lower doses but don't observed withdrawal period were lower at 16.67%. Farmers who sometimes observe chemical withdrawal period were not significantly (χ^2 (8, 52) = 6.9441, p = 0.5427) associated with level of fungicide dose applied. Lastly, farmers who observe fungicide withdrawal period all the time was significantly (χ^2 (8, 38) = 19.0487, p = 0.0146) associated with level of fungicide dose level applied (

Table **40**).

Table 40: Farmer's applying different level of pesticide dose and observation of chemical withdrawal period

Agro zone	Fungicide dose application (%)				*Chi* square	*P* value
	Chemical withdrawal period	Below required dose	Recommended dose	Over recommended dose		
LM4	Observed: No	0	20	6.67	8.1252	0.4027
LM3		0	10	10		
UM2		6.67	3.33	10		
UM3		3.33	3.33	3.33		
UM4		6.67	10	6.67		
Total		16.67	46.67	36.67		
LM4	Observed: All the time	5.26	7.89	10.53	19.0487	0.0146
LM3		0	15.79	5.26		
UM2		7.89	2.63	5.26		
UM3		0	5.26	10.53		
UM4		0	21.05	2.63		
Total		13.16	52.63	34.21		
LM4	Observed: Sometimes	9.62	17.31	9.62	6.9441	0.5427
LM3		1.92	7.69	7.69		
UM2		1.92	13.46	1.92		
UM3		0	9.62	1.92		
UM4		3.85	7.69	5.77		
Total		17.31	55.77	26.92		

Level of pesticide dose used in tomatoes in Kirinyaga County was not significantly (χ^2 (4, 120) = 3.7702, p = 0.438) associated with the education level of the farmer. Nonetheless, use of recommended dose was higher 27.5% among secondary education. Lower pesticide doses use was high among secondary schooled farmers (10%) with 0% for farmer post-secondary educated farmers ().

Table 41).

Table 41: Percentage of tomato farmers applying different level of pesticide dose and their education status

Amount of pesticide dose level applied	Education status of the farmer (%)			Total
	Below secondary	Secondary	Above secondary	
Below recommended dose	5.83	10	0	15.83
Recommended dose	17.5	27.5	7.5	52.5
Above recommended dose	8.33	18.33	5	31.67
Total	31.67	55.83	12.5	100
	Chi Square = 3.7702,	*p* value= 0.438		

Chemical withdrawal period before harvesting of tomatoes upon spraying was not significantly (χ^2 (8, 120) = 2.7702, p = 0.9479) associated influence with agro ecological zones. However, Agro ecological zone LM4 had high number farmers not observing chemical withdrawal period at 6.67% and lower in zone UM3 2.5% (Figure 15).

Legality of pesticides and used in tomato production and sources in Kirinyaga County

There was no significant (χ^2 (8, 120) = 11.3203, p = 0.1842) association between agro ecological zones and legal status of chemicals used to manage diseases in Kirinyaga County. However, the percentage of farmers who use illegal chemical in their farms were higher in agro ecological zone LM4 and UM3 each recording 8.335% and was low in zone LM3 and UM3. High percentages of farmers using legal pesticides were high in LM4 with 14.83 and lower in zone UM2 with 4.17% (Table 42).

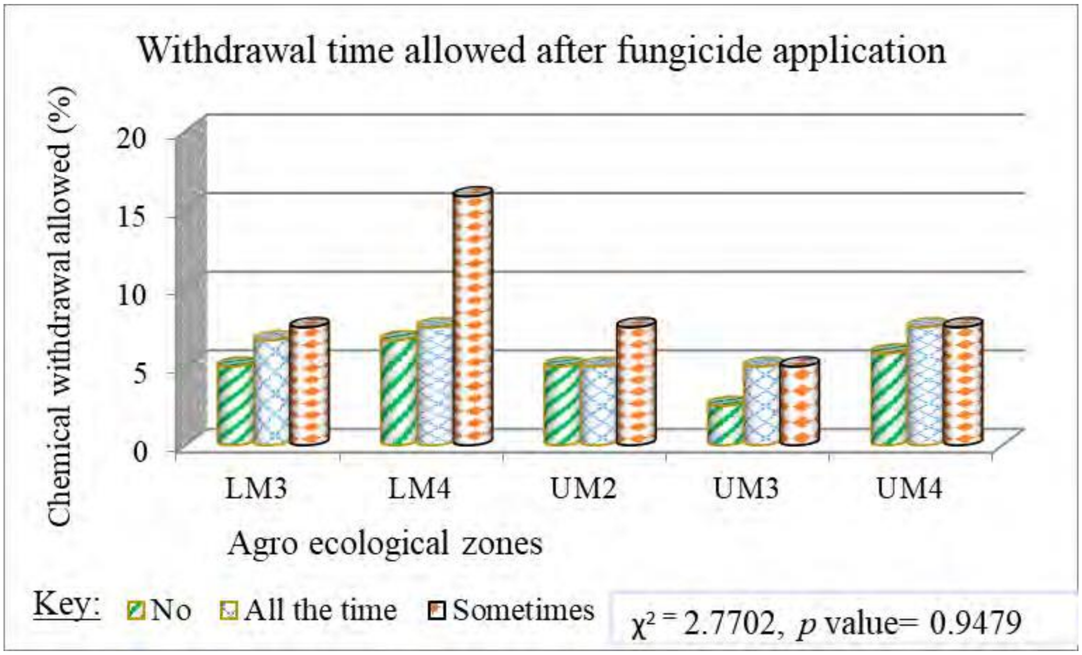

Figure 15: Tomato farmers observing chemical withdrawal period in Kirinyaga County

Table 42: Percentage of farmers using chemicals of different legal status in tomato farms in Kirinyaga in agro ecological zones of County

	Agro ecological zones (%)					
Chemicals legality	LM3	LM4	UM2	UM3	UM4	Total (%)
Yes, all	10.83	14.17	4.17	8.33	10.83	48.33
Not all	3.33	8.33	8.33	3.33	7.5	30.83
Don't know	5	7.5	5	0.83	2.5	20.83
Total	19.17	30	17.5	12.5	20.83	100
	Chi Square = 11.3203		*p* value = 0.1842			

The reason for use of illegal chemicals by tomato farmers was no significant (X^2 (12, 120) = 11.2633, p = 0.5065) association with agro ecological zones in Kirinyaga County. However, high percentage (28%) of farmers who use illegal chemicals opined that they are more effective when compared to legal counterparts while lower percentage 10.83% of the farmers cited availability of the illegal chemical as the reason for their use ().

Table 43).

Table 43: Tomato farmers using illegal chemicals for various reasons in agroecological zones of Kirinyaga

	Agro ecological zones (%)					Total
Why illegal Chemicals	LM3	LM4	UM2	UM3	UM4	
Readily available	2.5	2.5	2.5	0.83	2.5	10.83

Less costly	1.67	5	2.5	1.67	5.83	16.67
More effective	5.83	8.33	8.33	2.5	3.33	28.33
Don't use	9.17	14.17	4.17	7.5	9.17	44.17
Total	19.17	30	17.5	12.5	20.83	100
	Chi Square = 11.2633			*p* value = 0.5065		

The sources of illegal chemicals given by the tomato farmers were not significant (χ^2 (16, 120) = 15.988, p = 0.4538) associated with agro ecological zones. However, many farmers (34.17%) mentioned agro vet as source of illegal chemicals while sales among the farmers was least mentioned with 9.17% ()

Table 44)

Table 44: Farmers responding on illegal chemicals used in growing tomato in Kirinyaga

Sources of illegal chemicals	Agro ecological zone							
	LM3	LM4	UM2	UM3	UM4	Total	Chi value	*p*-value
In-Country vender	2.50	6.67	6.67	6.67	5.83	28.33		
Out-Country vender	5.83	5.83	4.17	0.83	4.17	20.83	15.988	0.4538
Agro vet	7.50	11.67	5.83	3.33	5.83	34.17		
Among farmers	1.67	4.17	0.83	0.0	2.5	9.17		
Don't know	1.67	1.67	0.0	1.67	2.5	7.5		

Knowledge and use of BCAs among tomato farmers in Kirinyaga County

The knowledge of or use of biological control agents among farmers did no differ significantly (χ^2 (8, 120) = 10.8463, p = 0.2106) across different agro ecological zones. However, 75.83% of famers noted that they have not heard or use, BCAs 22% of farmers have heard but not used BCAs and only 1.67% farmers reported to have used ().

Table 45).

Table 45: Percentage of tomato farmers' responses on Knowledge and use of Biological Control Agents in agro-ecological Zones of Kirinyaga County

	Agro ecological zone						Chi value	
Heard or use BCAs	LM3	LM4	UM2	UM3	UM4	Total		*p*-value
Heard and use (%)	0.00	0.00	1.67	0.00	0.00	1.67		
Heard not used (%)	4.17	5.83	3.33	4.17	5.00	22.50	10.8463	0.2106
Not heard (%)	15.00	24.17	12.50	8.33	15.83	75.83		
Total	1.67	1.67	0.0	1.67	2.5	7.5		

DISCUSSION

Tomato varieties grown, source of seeds

The percentages of tomato varieties grown by farmers differed with agro ecological zones. Variety such as terminator F1 was common in agro ecological zone LM4 which is slightly dry area. On the other hand, Rio tinto varieties were common in zone UM2 which is a cold area due to its proximity to Mount Kenya. Tomato variety reported in this study differs to those reported by Mwangi *et al.* (2015). Varietal differences may be attributed to continuous release of new tomato varieties which seems to be embraced by farmers.

The reasons given by tomato farmers for the particular variety grown statistically differed significantly (p<0.05) across agro ecological zones. Good marketability of the tomato variety was highly considered at 41% with tomato fruit size 22.50% being the second. In areas with extreme weather such as zone LM4 and UM2, varieties such as Terminator f1 and Rio tinto f1 respectively were preferred due to their adaptability. Further interrogation of farmers revealed that while Terminator could withstand dry areas, Rio tinto f1 could withstand cold associated with cold climate. Majorly, marketability and size of fruits tomato fruits influence choice of variety of tomato grown by the farmers. These findings differ to those of Testen *et al.* (2018) who reported that variety of tomatoes grown were selected based on fruit size at 60%, disease resistance at 25% and insect resistance at 25%.

Furthermore, the finding here contradicts Ochilo *et al.* (2019) who opined that the tomato varieties grown by the farmers was determined by the cost of seeds. Sources of tomato seeds were significantly associated with the agro ecological zones. Forty percent (40%) of tomato farmers interviewed obtained seeds from the agro vet and were followed by farmers who buy already germinated seedlings from the common supplier. The findings here collaborate with the findings of Mwangi *et al.* (2018) who reported that most farmers in Mwea West prefer raising their own seedlings. Though sources of planting materials in this study concurs with those of Testen *et al.* (2018) however, did not report on seedling supplier and friends as source of tomato planting materials.

Farmers' socio characteristic and knowledge on tomato diseases

The association between age of tomato farmers' and agroecological zones indicated that the distribution of farmers age across agro ecological zones were the same. However, farmers the age of 41-50 were slightly higher (34.45%) while those at the age of 18-30 were few 5.88%. The finding of the study differs with those of Mwangi *et al.* (2015) but agrees with those of Testen *et al.* (2018) on the higher numbers of tomato farmers at the age bracket of 41-50 years. However, the results differ 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 taking part in tomato farming may be to factors such as land scarcity and insufficient funds. Capital is required to rent land, purchase farm inputs such as fertilizer, pesticides and to pay workers. Further, youths have preference to urban employment as opposed to farming(Chinsinga and Chasukwa, 2012; Naamwintome and Bagson, 2013; Bezu and Holden, 2014).

There was no (p>.05) significant difference between the gender of tomato farmers across agro ecological zones of Kirinyaga County. However, there were more men in tomato farming than women. The gender of tomato farmers and the agro ecological zones were not statistically significant (p>.05) indicating that gender of tomato farmers was the same across different agro ecological zone. However, study the found out that tomato farming in the study area is dominated by males. Out of 120 tomato farmers interviewed, over 80% were male while female was below 20%. The current results on male domination of tomato farming corresponds to other findings (Anang *et al.* 2013; Mwangi *et al*., 2015; Testen *et al.*, 2018; Ochilo *et al* 2019). Dominance of tomato farming by men as opposed to women may be attributed to high physical and capital requirement (Quisumbing *et al*., 1995; Mwangi *et al*., 2015). Further, high level of risk associated with tomato farming may explain men dominance (Clottey *et al.*, 2009).

The ability of farmers to identify foliar fungal diseases was not significantly (p = 0.177) associated with agro ecological zones. However, only 25% of farmers reported ability to identify tomato diseases. Despite declaration on knowledge of tomato diseases, majority of farmers were however not able to name the causative agent of Early blight, Late blight and Septoria spot. Percentage of farmers who gave the correct causative agent for Early blight 51.67%, Late blight 40% and Septoria spot were 17.5%. Failure to give exact cause of the diseases may be attributedto farmers' diversity of knowledge source. For instance, the study found out that 51.67% farmers' gained knowledgethrough farming experience and 26.67% through friends. Some of the knowledge sources therefore could be misleading. Farmers' inability to link the diseases with their causal agents corroborates with other reports (Schreinemachers *et al.*, 2015 ; Testen *et al.*, 2018). In a related study, Assefa (2020) reported that only 3% of farmers identified the causative agent of late blight. The findings therefore indicate the need to train farmers on phytopathogens to improve their understanding for adequate crop disease management.

Pesticides use and compliance to the application guidelines in tomato production

There was significant (p < 0.05) association between pesticides application time in tomato farming and agro ecological zones. Whereas 69.1% of tomato farmers reported to apply pesticides prior to occurrence of disease symptoms, 20.83% of farmers only apply pesticides when disease symptoms are visible. Up to 21.67% of farmers inzone LM4 apply pesticides prior to disease symptoms appearance. The finding of this study contradicts those of Danquah *et al.* (2009) and Nyankanga *et al.* (2004) who reported that majority of farmers only apply pesticides on their crop when the symptoms are observed. Frequency of pesticides application in tomato production by farmers was not significantly (p > 0.05) associated with agro ecological zones. Majority of tomato farmers appear to apply pesticides after every two weeks. The results in this study correlate with other findings (Okolle *et al.*, 2016).

Agro ecological zones in Kirinyaga County were not significantly (p > .05) associated with fungicide doses levels used by the farmers. Whereas 52.5% of farmers apply recommended dose of pesticides, 31.67% uses doses above the recommended level. The findings in this study are in line with those of Schreinemachers *et al.* (2015) and Kariathi *et al*., 2016) who reported that tomato farmers over dosed tomato with pesticide treatment. Improper fungicides and chemical utilization practices such as frequency, timing and dose application observed in the study indicates inadequate knowledge on chemical use. Indiscriminate fungicide use as observed may results in serious health consequences (Mattah *et al.,* 2015). However, high pesticide and fungicide use points at the persistence of tomato pests and diseases in farms (Okolle *et al.,* 2016). Thus, fear of tomato losses among farmers have led to an increase in frequency and doses of fungicides and pesticides application as disease and pest preventive approach other than curative (Ngowi *et al.,* 2007).

The criteria for application of pesticides did not differ significantly ($p > .05$) among farmers across agro ecological zones. Many farmers were found to prefer mixing of pesticides and other chemicals together. The practice of mixing pesticides together in farms has been reported by many studies (Kariathi *et al.*, 2016; Mengistie *et al*., 2017;Matowo *et al*., 2020). For instance Ngowi *et al.* (2007) reported that 90% of farmers mix up to three pesticides in thetank and use the mixture in spraying crops. Chemicals used in agriculture such as bacteriocides, insecticides and fungicides are of different structures and may be incompatible. Thus, mixing chemicals may induce plant toxicity as well as contribute in the emergence of resistant pathogens and pests resulting from selection pressure (Ngowi *et al.,* 2007; Chouaïbou *et al.,* 2016). To emphasize the impact of mixing pesticides, it is documented by Ngowi *et al*. (2007) that mixing of insecticides, fungicides and water mineral content affects efficacy by neutralizing chemical effect or induces phytotoxicity like in the case of tomato, onion and cabbage.

Farmers compliance to chemical withdrawal period requirement prior to fruits harvest upon chemical applicationwas not significantly ($p > 0.05$) associated with agro ecological zones. The high number of tomato farmers who appeared not keen to this regulation should worry tomato consumers. While 43.7% reported that they sometimes selltomatoes without observing chemical withdrawal period, 25% reported not to observe chemical withdrawal period atall. The finding on chemical withdrawal time compliance corroborates with Danquah *et al.* (2009) and Kariathi *et al.*(2016) who found out that some tomato farmers sold their tomatoes before chemical withdrawal period. Accordingto Busindi (2012) and Kaye *et al.* (2015), tomato farmers may apply pesticides and harvest in span of one day as opposed to required seven days. Failure to comply with pesticide withdrawal period exposes consumers to chemical residues in food (Ayres *et al.*, 2010). In order to protect farmers from pesticides exposure emanating from poor farming practices training on chemical safety is inevitable.

Reason for the use of illegal chemicals in tomato farming did not differ significantly across the agro ecological zones ($p > 0.05$). The study found out that where legally accepted chemicals are perceived not to be effective or highly expensive, farmers have opted to use illegal chemicals. For example, 31.1% of tomato farmers who participated in this study admitted to have used illegal fungicides and pesticides in tomato farming. Many tomato farmers reported to apply illegal pesticides and fungicides due to their perceived higher efficacy when compared to legal substances in the market. Further, the low cost of illegal pesticides those entice farmers into using them. In a similar study, Danquah *et al.* (2009) reported that 42% of farmers used insecticides that are not recommended for tomatoes and justify such uses on their low prices. The inability of 19% of farmers to tell acceptability status of chemicals used in tomato farming call for the need for sensitization on fungicides use and safety.

According to Oduro-ofori *et al.* (2014) and Yemataw *et al.* (2017) education level of the farmer influences how they managed issues such as diseases occurrence and management in the farms. In this study, education level among tomato farmers in Kirinyaga County did not influence significantly ($p > .05$) the pesticide dose levels used in the farm. Though there were more farmers with secondary education (27.5%) using recommended pesticide dose as compared to those without post primary education 17.5%, those with post-secondary education were lower (7.5%). Farmers without post-secondary education were slightly higher in low and overdose pesticide use than their counterparts with or without post-secondary education which was against expectation. The results on the effect of education on dose level of fungicide application among farmers contradicts those of (Mbinda *et al.*, 2021) who reported that excessive use of pesticide in the farm declined with increasing education levels of the farmer.Education is helpful in farm activities as it empowers farmers in reading and follows instructions such as those in fertilizers and pesticides and use appropriate combinations.

Knowledge and use of biological control agents in tomato production

Farmers' knowledge and utilization of Biological Control Agents (BCAs) in tomato farming was not significantly associated ($p > 0.05$) with agro ecological zones in Kirinyaga. High number of tomato farmers 75.85% reported no knowledge of BCAs while only 1.69% of farmers have used BCAs and the remaining 22.5% other than having heard of BCAs, they have never used them. These findings are in line with those of Mkenda *et al.* (2020) who observed that many farmers are not aware of biological agents.

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 agro ecological zone to the next and terminator F1 appears to be the most dominant variety grown. Reasons for which farmers choose variety to grow differ across agro ecological zone where marketability of the fruits and fruit sizes are the top priority. Sources of knowledge of tomato diseases are varied and are highly contributed for by friend's/ neighboring farmers and history of tomato farming (Experience). There is inappropriate use of fungicides as well as use of illegal pesticides in tomato farming in Kirinyaga County. To cut down inappropriate pesticides in tomato farming, farmers and stakeholders should be sensitized on regulations regarding pesticide use, the need to stick to specified doses and use of integrated pest and disease strategies such as organic farming where necessary. Sensitization on pesticide use should be multi-sectorial and should involve community leadership, researches, pesticide dealers and consumers. Crackdown on fake pesticide should be enhanced both at the borders and at the farm to deter farmers from their use.

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