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Burrowing nematode (*Radopholus similis*) abundance, distribution and agronomic impact on bananas in Kirinyaga County, Kenya

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Summary: Burrowing nematodes (*Radopholus* spp.) are the most significant parasites of bananas (*Mus*a spp.) world over. They feed on the root tissue of bananas resulting to toppling disease at the fruit bearing stage. This study assessed the impact of farmers selected agronomic practices that influenced distribution of burrowing nematodes. We also assessed the abundance of *Radopholus* spp. across four AEZs namely; UM 2, UM 3, LM 3 and LM 4 of Kirinyaga County, Kenya. Purposive sampling was done on April, 2024 targeting farmers that grew 'dwarf Cavendish' variety of bananas, those that grew an average of 25 banana stems and those whose farms that were 1km apart. A structured questionnaire was issued to ninety farmers to collect demographic information and to determine their awareness of burrowing nematodes and toppling disease. Soil and banana root samples were also collected to determine abundance and distribution of burrowing nematodes. Data from the questionnaire and samples was subjected to R -statistical software and analysed at $p \leq 0.02$. The study revealed that majority of banana farmers practised mixed cropping and were not aware of toppling disease associated with *Radopholus* spp. It also revealed that majority of banana farmers were male and of > 50 years of age. The findings also showed *Radopholus* spp was rarely distributed in lower AEZs of LM 3 and LM 4 compared to *Pratylenchus* spp. which was pre-dominantly distributed in upper AEZs of UM 2 and UM 3 in both soil and root samples.

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Key words: Agro-Ecological Zones (AEZs), agronomic practices, Cavendish, farmers, *Radopholus*

Introduction

Agriculture is crucial to Kenya's economy, with bananas being a significant crop, contributing to 34.5% of all fruits grown in Kenya (Ntabo et al., 2024). The total production of bananas in Kenya is valued at approximately 236 million USD which accounts for 72,486 Ha of land under production (AFA, 2020). Kenya ranks among the top producers of bananas where production is mainly by small holder farmers predominantly in Counties such as Embu, Kisii and Nyamira and an export market valued at 21 Mt (FAO 2017, 2019). Bananas are rich in carbohydrates, starch, sugar, and minerals accounting for more than 25% of energy in food in Africa (Borges et al., 2020). Despite this, banana production faces substantial challenges from both environmental factors like temperature and water and biological threats such as diseases and pests (Rao, 2016). Among the most economically damaging pests are plant parasitic nematodes (Crow & Sikora, 2012), resulting to production losses of 30-60% (Kamira et al., 2013; Sikora et al., 2018). In Africa, yield losses in EAHB caused by nematodes are estimated at 50% (Gaidashova et al., 2009; Coyne et al., 2018**)** which are highly susceptible to nematode attack. Dessert cultivars such as 'Cavendish' which are grown for export are highly susceptible to *R. similis* that causes toppling disease (Quénéhervé, 2012).

This burrowing nematode (*Radopholus* spp.) is among the main PPNs affecting *Musa* spp. (Reddy et al., 2007; Waweru et al., 2014). It causes toppling disease leading to significant crop losses ranging from 30% to 80% in banana plantations (Gowen et al., 2005). The burrowing nematode damages the root tissue, causing the banana plants to lose support and fall over (Brooks, 2004). The distribution of *R. similis* is more on lower altitude areas with warm temperature (Blomme et al., 2012). Kenyan farmers often lack sufficient knowledge on effective and economically viable ways to manage these nematodes (Michel et al., 2010). It has been reported that differences in soil type, agronomic activities and climate can influence biological activities of nematodes that cause destruction to bananas (Lambert, 2009). Current solutions like nematicides are expensive and highly toxic, making them unsuitable for many farmers. This highlights the urgent need for sustainable, manageable, and cost-effective alternative nematode management strategies. The main objective of the current study was to determine how agronomic practices among banana farmers in Kirinyaga County influenced occurrence and abundance of *Radopholus* spp. The study also assessed population densities and distribution patterns of *Radopholus* spp. compared to *Pratylenchus* spp. in four AEZs of Kirinyaga County. This research provides useful information which can be used to improve management of Burrowing nematodes and improve banana production in Kirinyaga County.

Materials and methods

Description of study area

The study was undertaken in Kenya's former Central Province, Kirinyaga County which spans 1,478.1 square kilometers and is home to 610,411 residents (KNBS, 2019). Its geographical coordinates are between latitudes 0◦ 37’ S and 0◦ 45’ S and longitudes 37◦ 14’ E and 37◦ 26’ E. The county's elevation varies significantly, ranging from 1,158 to 5,199 meters above sea level, with Mount Kenya forming its highest point. Kirinyaga boasts diverse Agro-Ecological Zones (AEZs**)** across five sub-counties, including marginal cotton zones (LM 3 and LM 4), various coffee zones (UM 1, UM 2, UM 3), and the predominantly tea-dairy zone (LH 1) situated at the foothills of Mount Kenya (Fredrick *et al*., 2022). The study was focused on AEZs UM 2, UM 3, LM 3 and LM 4**.** These AEZs are spread across five sub counties of Kirinyaga namely: Kirinyaga west, Kirinyaga central, Kirinyaga east, Mwea east and Mwea west. The county experiences two distinct rainy seasons: long rains from April to May, averaging 610.4 mm, and shorter rains from October to November, averaging 523.1 mm. Temperatures fluctuate, with an average annual high of 33.8 ◦C and an average low of 5.5 ◦C. The soils across its five AEZs include humic nitosols, eutric nitosols, and pellic vertisols (***Figure 1***).

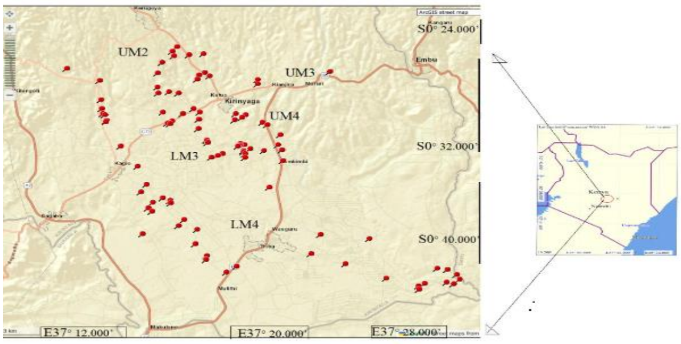

Figure 1: Map of Kirinyaga County showing AEZs UM 2, UM 3, UM 4, LM 3 and LM 4 (Source: Fredrick et al., 2022)

Research design and sampling procedure

The study was conducted in the four AEZs of Kirinyaga County during long rains for (April-May) and short rains (October – November) in 2024 in open fields for diagnostic purposes. A sample size of 50 farmers was determined using Yamane’s formula defined by- $n= N/ (1+Ne^2)$

Where:

n= Sample size

N= Target population

e= Standard error of 0.05

Ten farmers were selected from each in each AEZ across the five sub counties of Kirinyaga through simple random sampling due to homogeneity of population with respect to banana farming. The farmers were sampled from areas with different soil texture and cultivation practices which may influence nematode population (O’Bannon, 1977). The farmers were selected from a target population of ninety households having met the criteria of growing an average of 25 banana stems, ‘dwarf cavendish’ and were 1 km apart. A total of fifty soil and root samples were collected from the four AEZs for laboratory analysis to determine population densities and distribution patterns in the County. A structured questionnaire was administered also during collection of soil and root samples to determine farmers’ agronomic practices that influence occurrence and abundance of burrowing nematodes in Kirinyaga County.

Administration of a questionnaire

A structured questionnaire was administered to ninety households selected for sampling. This was important to gather extensive data where multi-stage sampling technique (Mugenda & Mugenda, 2003) was used to select farmers. They were selected based on characteristics such as demographic information, land use practices and farmers’ awareness about burrowing nematode that were approximately of 1 km apart. Information obtained from the questionnaire was analysed and used to advice farmers on appropriate methods in controlling burrowing nematodes (*Radopholus similis*).

Collection of root and soil samples

Sampling was done at random from 10 points within the farmer’s land to exclude bias using cross- diagonal sampling pattern. Three soil cores and roots from each sampling point were taken for processing. Sampling was done at a furrow depth (5-25 cm depth of cultivated land). The top 5 cm of soil was discarded. The bunching sucker’s roots on one side were removed from the mother plant and the subsequent sucker using a soil auger. There was also manual collection of a 25×25×25 cm soil block, which was nearly the width and depth of a regular shovel. Five roots were collected from each banana with about 500 ml of soil. Samples from each farm were bagged in paper bags, labelled with details of the farmer and transported using cooler boxes to the laboratory for further processing. The samples were stored at room temperature awaiting analysis.

Homogenisation of samples

Thirty samples from each farm were homogenised by mixing in a bucket before taking a sub sample which was sufficient for analysis. This was also done mechanically using hands to minimize damage to nematodes. After homogenisation, 50 grams of the composite mixture from each farm with roots was placed in a plastic bag for laboratory analysis.

Extraction of burrowing nematodes from the roots

The burrowing nematodes were extracted from banana roots using blender and filter method (Bezooijen, 2006). This was so because it was much faster and more efficient because of larger surface of extraction dish. Plant roots were rinsed with water and cut into 1 cm pieces. A sub sample of 10 g was placed in a domestic blender, submerged with water and mixed appropriately for 5 seconds (10,000 rpm). Nematode filters were placed in extraction sieve and secured using a clamping ring.

The sieve was set on a filter paper in a decanting tray filled with water, along with a cross piece and a watch glass. The suspension from the blender was poured onto the watch glass. Extraction dish was placed in a vibrations free place. After 48 hours extraction time, the suspension was transferred from the dish into 100 ml beaker for analysis and the sieve was taken out of the dish (Coyne et al., 2007).

Extraction of burrowing nematodes from soil sample

The soil samples were homogenised where a 100 cm^3 composite sample was used to extract burrowing nematodes using modified Baermann funnel method (Coyne et al., 2007). This method uses the principle of mobility of nematodes. A paper towel was used to cover the sides and bottom of a plastic tray that had a plastic mesh placed on it. The paper towel was evenly covered in soil. The soil layer was moistened by adding clean water to the inside edge of the collecting dish, and was left undisturbed for 48 hours. After the suspension was drained out of the tray onto 25 um sieve, the nematodes were rinsed off in a tiny beaker filled with 25 ml water. After settling for an hour, the water in the 25 ml beaker was concentrated to 10 ml.

Fixation of burrowing nematodes

After extraction, the nematode suspension was concentrated into a small volume of water (<20 ml) by decanting. It was then heated to a temperature of 50-60 ºC by partially immersing the container with nematode suspension in a large volume of water at approximately 80-90 ºC (off the boil) for a few minutes. The sample was allowed to cool before adding an equal volume of double strength fixative (40% formaldehyde), or 70 ml to the entire nematode solution. Nematodes were processed further after being left for 24 hours. On a heated glass microscope slide, nematodes were placed in a drop of lacto glycerol at 60 ºC.

Identification of burrowing nematodes

A stereoscopic dissection microscope (10-100 X) at the Department of Plant Sciences was used for positive identification of burrowing nematodes and marched with morpho-anatomical features as described by Siddiqi (1971). These were: Body length, width and shape; cuticle thickness, striation and annulation; Stylet and oesophagus.

Data analysis

The data collected from farmers using a structured questionnaire about demography and agronomic practices was subjected to R- statistical software. Data was presented inform of tables and graphs. The Population density of burrowing nematodes was determined by counting nematodes using the Roman Tally System. The total number of nematodes counted was multiplied by total volume of the soil suspension to calculate the total number extracted from 100 ml of soil sample. Data was also analysed using R-statistical software at p≤ 0.05. The distribution patterns of burrowing nematodes and lesion nematodes were also presented in form of graphs in different AEZs of the five sub counties.

Results

Socio demographic data of farmers from Kirinyaga County

The results revealed that the majority of banana farmers across all sub-counties were male Mwea West having the highest number of male farmers, followed by Mwea East (12) and Kirinyaga Central Kirinyaga East had the least (***Figure 2***). This distribution indicates that while women are involved in banana farming, their presence is less pronounced (***Figure 2***). The results revealed that the majority of banana farmers in all sub-counties were elderly, aged above 50 years (***Figure 3***). However, there was an exception in Mwea West, where the majority of farmers were aged between 41 and 44 years. It was also revealed that the age groups 25-30 and 41-44 years showed no significant impact on the number of banana farmers in Kirinyaga Central, Mwea West, and Ndia (***Figure 3***).

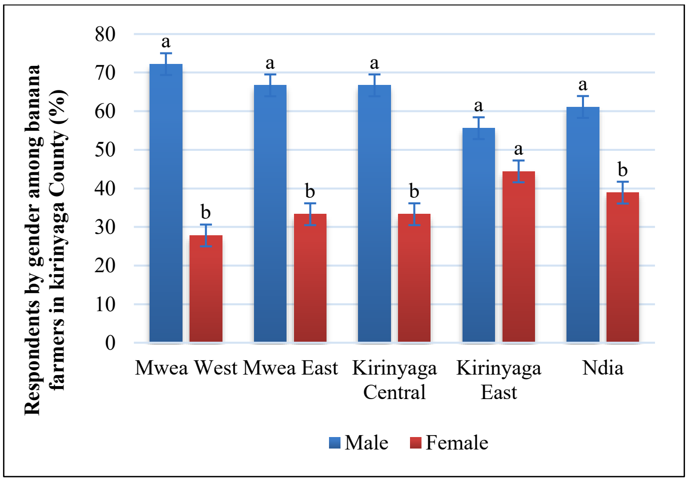

Figure 2. Gender of banana farmers in Kirinyaga sub counties. Column bar with different letter(s) show significant difference in method used at P≤0.05

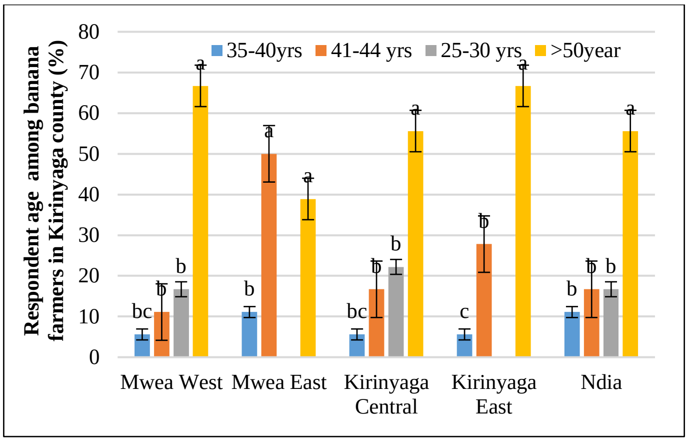

Figure 3. Age of banana farmers in Kirinyaga sub counties. Column bar with different letter(s) show significant different in method used at P≤0.05

Farm size in land use and practices among banana farmer in Kirinyaga County

The results revealed that the majority of banana farmers practiced mixed-cropping, with 100% of farmers from Ndia sub-county engaging in this practice. Kirinyaga Central, Mwea East, and Mwea West also had high rates of mixed-cropping at 94.4% (***Table 1***). Mono-cropping was practiced in four sub-counties: Kirinyaga Central, Mwea East, and Mwea West, each with 5.6%. Relay cropping was only observed in Kirinyaga East, where 16.7% of farmers practiced it (***Table 1***).

Farming enterprise and farm systems in land use and practices among banana farmer in Kirinyaga County

Crop enterprise was the most commonly practiced across all sub-counties (***Table 2***). Kirinyaga Central and Kirinyaga East had the highest participation rates at 94.4%, followed by

Table 1. Percentage proportion of banana farms in Kirinyaga county.

	Mwea west	*Mwea east*	*Kirinyaga Central*	*Kirinyaga East*	*Ndia*
Variables					
Farm size					
<1 Acres	38.9a	22.2b	27.8b	44.4a	88.9a
1.1-2 Acres	27.8b	50.0a	38.9a	38.9a	5.6b
2.1-3 Acres	22.2b	22.2b	22.2b	16.7b	
>3.1 Acres	11.1c	5.6bc	11.1bc		5.6b
P value	0.002	0.03	0.03	0.021	<0.001

Mean in the same column followed by same letter(s) are not significant difference using least significant difference LSD test, α =0.05

Table 2. Percentage proportion of land used for different agronomic practices in Kirinyaga County.

	Kirinyaga central	*Kirinyaga East*	*Ndia*	*Mwea East*	*Mwea West*
Variables					
Farm enterprise					
Crops	94.4a	94.4a	88.9a	83.3a	72.2a
Crops & Livestock	5.6a	5.6a	5.6b	11.1b	22.2b
Mixed farming	0	0	5.6b	0	5.6c
Crop & Commercial	0	0	0	5.6b	0
P value	<0.001	<0.001	0.007	0.01	0.02
Farm systems					
Mixed cropping	94.4a	77.8a	100	94.4a	94.4a
Mono cropping	5.6b	5.6b		5.6b	5.6b
Relay cropping		16.7b			
P value	0.002	<0.001	ns	<0.001	<0.001

Mean in the same column followed by the same letter(s) are not significant different using LSD test, α = 0.05

Table 3. Percentage proportion of pests prevalence and source of information about pests in Kirinyaga County.

	Kirinyaga Central	*Kirinyaga East*	*Ndia*	*Mwea East*	*Mwea west*
Variables					
Pest in banana					
Nematode + weevil	38.9a	5.6a		38.8a	5.6cd
Weevil + aphid	33.3ab			22.2b	5.6cd
Weevil	22.2b		11.1b	33.3a	27.8b
Nematodes	5.6c	77.8a	72.2a		50a
Banana aphids		16.7b	5.6bc		11.1c
Monkey			5.6bc		
Nematode + Weevil + aphid				5.6c	
Not Known			5.6bc		
P value	<0.001	<0.001	0.003	0.004	0.002
Source of information on pest					
Radio + AEE	50a	66.7a	38.9a	27.8a	55.6a
AEE Officer	27.8b			22.2b	
Radio+ AEE+ Grandparent	27.8b	33.3b		27.8a	
Radio			27.8b		
University student			11.1c		
AEE Officer+ Grandparent			11.1c		38.9b
Grandparent			5.6cd		
Radio+ TV+ AEE				11.1c	
Radio+ Internet				5.6cd	
Radio+ Tv + Internet				5.6cd	
Not known					
P value	0.003	<0.001	0.003	<0.001	<0.001

Mean in the same column followed by the same letter(s) are not significant different using LSD test, α = 0.05

Table 4. Percentage proportion of knowledge, disease and damage caused by burrowing nematode.

	Kirinyaga Central	*Kirinyaga East*	*Ndia*	*Mwea East*	*Mwea West*
Variables					
Know of burrowing nematode					
Yes	72.2a	83.3a	11.1b	22.2b	16.7b
No	28.8b	16.7b	88.9a	77.8a	83.3a
P value	<0.001	<0.001	<0.001	<0.001	<0.001
Knowing of Toppling disease					
Yes	100	100	83.3a	100	94.4a
No			16.7b		5.6b
P value	ns	ns	<0.001	ns	<0.001
If yes what portion of damage					
Less than half of farm	55.6a	61.1a	16.7b	72.2a	55.6a
Half of farm	44.4b	38.9b	61.7a	27.8b	38.9b
Whole farm			5.6bc		
P value	<0.001	<0.001	<0.001	<0.001	<0.001

Mean in the same column followed by the same letter(s) are not significant different using LSD test, α = 0.05

Table 5. Percentage proportion occurrence of toppling disease and management practices among farmers in Kirinyaga County.

	Kirinyaga Central	*Kirinyaga East*	*Ndia*	*Mwea East*	*Mwea west*
Variables					
Season toppling occurs					
Cold & wet	55.6a	66.7a	72.2b		38.9b
Dry & hot	44.4b	33.3b	27.8b	100	61.1a
P value	<0.001	<0.001	<0.001		<0.001
Management practices					
Roguing	66.7a	50a	66.7a	50a	55.6a
Resistant cultivar & Roguing	22.2b	11.1c		22.2b	22.2b
Resistant cultivar	11.1c		16.7b	22.2b	22.2b
Application of ash		38.9b	5.6bc		
Uprooting			11.1b		
Resistant cultivar and chemical				5.6c	
P value	<0.001	<0.001	0.02	0.007	0.03

Mean in the same column followed by same letter(s) are not significant difference using least significant difference LSD test, α = 0.05

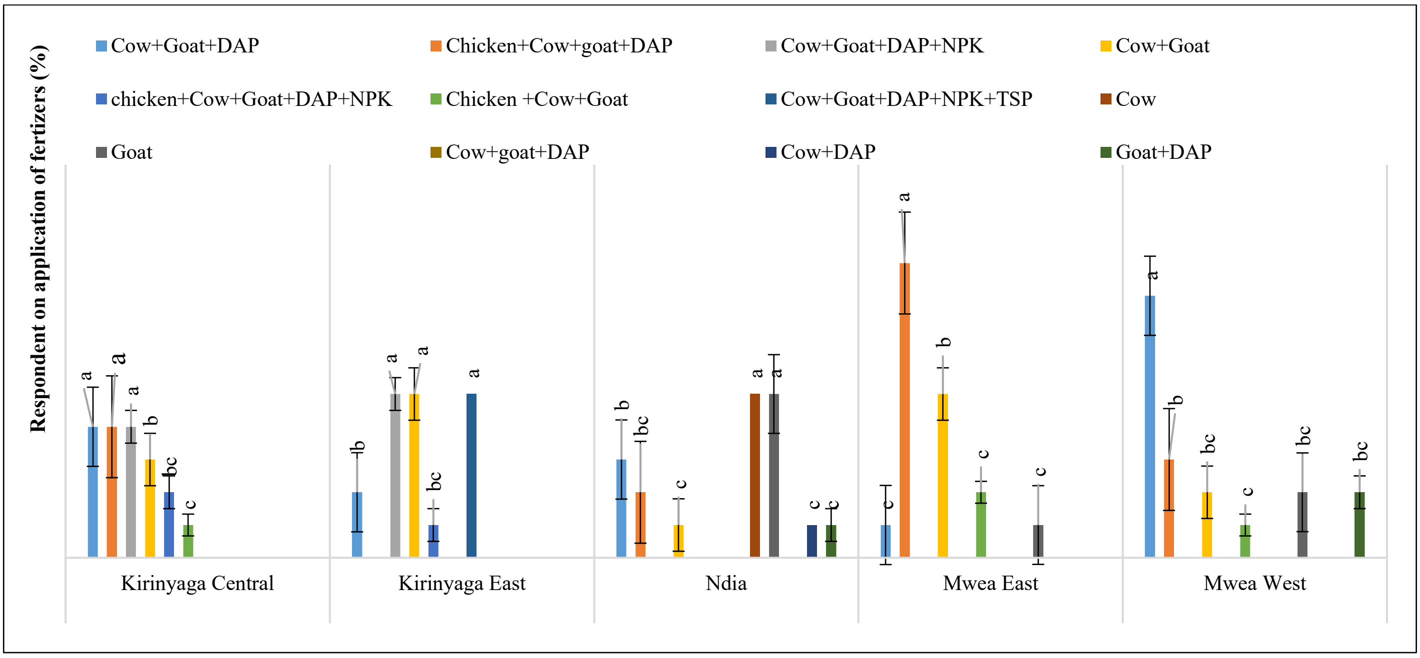

Figure 4. Application of fertilizer among banana farmers in Kirinyaga sub-County.
Column bars with different letter(s) show significant difference in methods used at P≤0.05

Ndia (88.9%), Mwea East (83.3%), and Mwea West (72.2%). In terms of crop and livestock enterprise, Mwea West led with 22.2%, followed by Mwea East with 11.1%, while the other sub-counties recorded 5.6%. Additionally, mixed farming was practiced by 5.6% of farmers in both Ndia and Mwea West (***Table 2***).

Application of fertilizer among banana farmers in Kirinyaga sub counties

The majority of the respondents relied on both inorganic and organic fertilizers for nutrient supply to their banana crops (***Figure 4***). In Kirinyaga Central, there was no significant difference among farmers using various mixtures: cow manure + goat manure + DAP; chicken manure + cow manure + goat manure + DAP; and cow + goat + DAP + NPK (Figure 4). Similarly, in Kirinyaga East, no significant differences were observed. Farmers used of cow manure + goat manure + DAP + NPK; cow + goat manure; and cow manure + DAP. In Mwea West, the nutritional application showed no significant differences between the use of cow manure + goat manure; sole goat manure; and goat manure + DAP (***Figure 4***).

Common pest and the source of information among banana farmer in Kirinyaga County

Pests were common and diverse across all sub-counties. In Kirinyaga East, nematodes were the most abundant, affecting 78.8% of farms, followed by Ndia with 72.2%, and Mwea West with 50% (***Table 3***). Nematode and weevil infestations were mostly recorded in Kirinyaga Central and Mwea West, with 38.9% of farms affected. Weevil and aphid infestations were recorded mainly in Kirinyaga Central, impacting 33.3% of farmers (***Table 3***). In Mwea West, weevil infestations were most common, affecting 33.3% of farmers. Nematode, weevil, and aphid infestations were recorded together in Mwea East, affecting 5.6% of farmers (***Table 3***).

Regarding the sources of information, the majority of farmers revealed that a combination of radio and extension officers was most commonly used. This combination was most prevalent among farmers from Kirinyaga East (66.7%), followed by Mwea West (55.6%) and Kirinyaga Central (50%), and with the least usage recorded in Mwea East (27.8%). Extension officers were the primary source of information in Kirinyaga Central (27.8%), followed by Mwea East (22.2%). Additionally, university students were also a source of information on banana pests for 11.1% of farmers in Ndia sub-County. In the context of an increasingly internet-savvy society, the combination of internet and radio emerged as a source of information in Mwea West, reaching 5.6% of farmers. Despite this, the adoption of internet-based information sources remains slow. These insights provide a comprehensive view of pest distribution and the various sources of information utilized by farmers across the sub-County.

Farmers' awareness of the burrowing nematodes, toppling disease and area affected in banana farm

Majority of the banana farmers Ndia (88.9%), Mwea east (77.8%) and Mwea west (83.3%) were not aware of the burrowing nematodes existence in their farms (***Table 4***). Whereas farmers in Kirinyaga east (72.2%) and Kirinyaga central (83.3%) were aware of the burrowing nematodes. Most of the banana farmers expressed the seriousness of the incidence noting that less than half of their farm was affected with highest percentage with 72.2% from Mwea west, followed by Kirinyaga East 61.1% and 55.6% with both Mwea west and Kirinyaga west (***Table 4***). In Ndia sub-County farmers recorded that the whole farm was infested with toppling disease at proportional of incidence of 5.6%. Most interviewees (61.7 %) from Ndia sub-County revealed the disease incidences were expressed in half of their farm under banana, followed by Kirinyaga Central (44.4%) and least Mwea East (27.8%).

Occurrence of the toppling disease and the management practices among banana farmers in Kirinyaga

Most interviewees perceived the disease to be weather dependent, with 72.2% believing that the disease was spread during the cold & wet season in Ndia, and 66.7% from Kirinyaga East while Mwea east had the least with 0% respondent. On the other hand, under dry and hot climate farmers revealed that toppling disease was severe with Mwea east at 100%, followed at 61.1 % of farmers from Mwea West and 44.4% in Kirinyaga Central controlled PPNs using four different options (***Table 5***). There was similarity in both farmers' disease control measures among the sub counties. Upon disease detection, 66.7% of the respondents' used rouging method in Kirinyaga Central as well as Ndia followed by 55.6% from Mwea west (***Table 5***). As long synergism control measures, 22.2% used both resistant cultivar and rouging in Kirinyaga Central, Mwea west and Mwea east (***Table 5***). Resistant cultivars and chemical use were experienced in Mwea east with 5.6% of farmers only.

Abundance of burrowing nematode recorded in Kirinyaga soils among banana farmers

All the farms that were sampled had their soil and root infested with *Pratylenchus* spp. and *Radopholus similis* (***Figures 5-6***). The abundance of these nematodes across the AEZs differed significantly (P<0.05) in the soil samples. The highest *Pratylenchus* sp. infestation was recorded in UM 2 and the lowest in LM 4. *Radopholus similis* in the soil were most abundant in UM 3 and least in LM 3. The results revealed no significant difference in the abundance of *Pratylenchus* spp. in soil samples from the Agro-ecological zones (***Figure 5***).

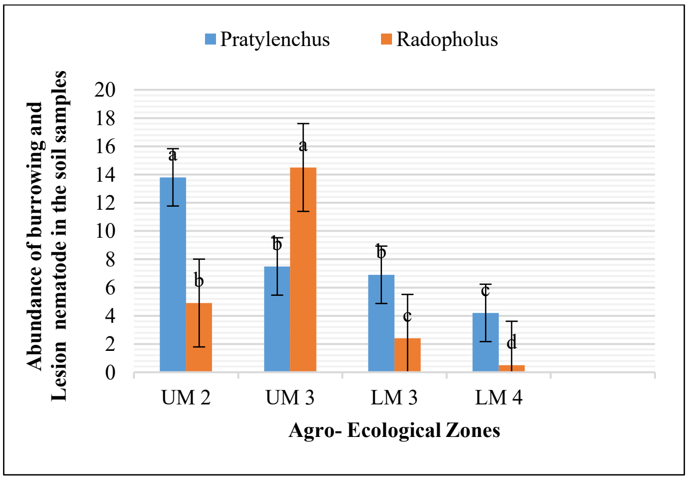

Figure 5. Abundance of burrowing nematode recorded in Kirinyaga soils among banana farmers in in AEZs UM 2, UM 3 , LM 3 and LM **4.** Column bar with different letter(s) show significant difference in method used at P≤0.05.

The recovery of *Radopholus similis* in the roots of banana plants showed significant differences, with *Pratylenchus* spp. being most prevalent in UM 3, followed by UM2, and least in LM 4. Significant differences in the abundance of *Pratylenchus* spp. were recorded among farms in the Kirinyaga counties. There was also a significant difference in the abundance of *Radopholus similis* in banana roots across all sub-counties. The highest population of *Radopholus similis* was recorded in UM 3, followed by UM 2, and the lowest LM 3 at P<0.05 (***Figure 6***).

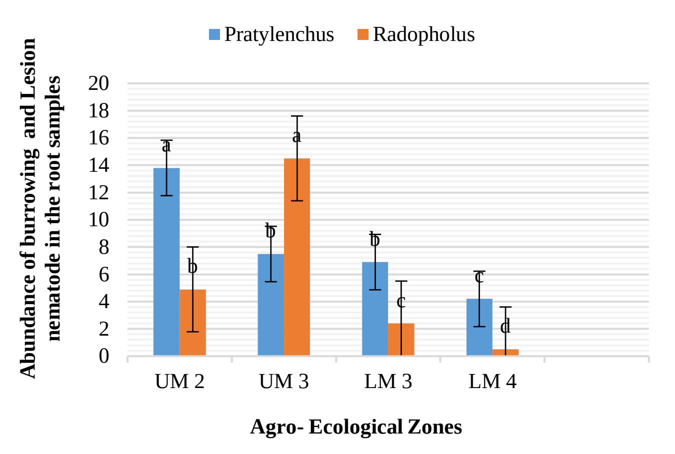

Figure 6. Abundance of burrowing nematode recorded in banana roots among banana farmers in AEZs UM 2, UM 3, LM 3 and LM 4. Column bar with different letter(s) show significant difference in method used at P≤0.05

Discussion

The results of the research revealed that men comprised the majority of Kirinyaga County's banana farmers. This highlighted a possible trend or cultural inclination towards men engaging in this particular agricultural activity. This confirms prior studies that showed men usually assume control of a cash crop once if it turns commercial (Muyanga, 2008). Most banana farmers were ≥ 50 years, which is consistent with preceding studies showing younger farmers, are more likely to diversify to other forms of crops (Ibrahim et al., 2009). This age distribution might reflect generational shifts in farming practices and the engagement of different age groups in agricultural activities. In the five sub counties, small scale farmers-controlled banana sector, cultivating less than one acre of land confirming prior studies that suggested the same (Birthal et al., 2007 & El-Showk et al., 2007) resulting to a decline in banana production and earnings (Ashfaq et al., 2008). In all of Kirinyaga's AEZs mixed farming took precedence. This could be a consequence of reduced land masses, as indicated by Birthal et al., 2007.

In order to minimize nematode infestation, a majority of farmers utilized a combination of inorganic and organic fertilizers. This supported research showing that nematodes decreased by the use of both organic and inorganic amendments to the soil in soil health management (Olowe et al., 2019; Araya et al., 2021). The most prominent pests of bananas were nematodes. This proved that nematodes are among the major global banana pests (Coyne, 2018). The main pests of bananas in Kenya include nematodes, banana weevils, and thrips (Wachira, 2013). For information regarding nematodes, radio and extension agents were heavily counted upon. In addition, a significant number of farmers in Kirinyaga County were unaware that burrowing nematodes existed. This demonstrated that farmers are not knowledgeable regarding the pests and diseases that affect their vegetables (Abang et al., 2014; Auwal et al.., 2015; Lutuf et al., 2018).

Middle-aged farmers knew more about nematodes than older farmers due their exposure to agricultural knowledge. Therefore, focused extension services are necessary to educate farmers about nematodes due to the gap in awareness (Nico, 2021). This further led to significant losses ascribed to nematodes, which supported previous research showing literacy was a significant production influence (Awan et al., 2012). In Kirinyaga, toppling disease caused by burrowing and lesion nematodes was common. The findings from this study suggest that different combinations of organic and inorganic fertilizers were utilized without significant variation in their application across the regions. Few farmers adopted chemical control and resistant cultivars, and most relied on rogueing as their sole nematode control strategy. Lack of appropriate knowledge and training related pests may be a factor for the low adoption of current control approaches.

Furthermore, the study revealed that *Pratylenchus* sp. exceeded *Radopholus* sp. in both soil and root samples in UM 2 and UM 3 AEZs. This supports previous research by Nyang'au et al. (2021) that demonstrated that *Pratylenchus goodeyi* was more common in high altitude regions (1600 M asl) than low altitude regions. This may be because EAHB is mostly grown in high-altitude regions that are vulnerable to lesion nematodes (Karamura, 1998). In both soil and root samples, *Radopholus similis* was rarely distributed in AEZs LM 3 and LM 4 which confirms by previous studies by Nyang'au et al. (2021) which showed *R. similis* was infrequently detected in low altitude areas. This could be attributed to farmers diversifying to other crops which confirm that multiple cropping systems is effective in reducing populations of PPNs (McSorley, 2001).

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