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Fusarium Wilt of Banana in Kisii County, Kenya

KENNEDY MOSETI MOMANYI[1, 2], JAMES WANJOHI MUTHOMI[1] and JOHN WANGAI KIMENJU[1]

[1]Department of Plant Science and Crop Protection, University of Nairobi, P.O Box 29053-00625, Kangemi, Kenya.
[2]Department of Agronomy, Rongo University, P.0 Box 103, 40404, Rongo, Kenya.

Abstract

Banana categorized as third in world's key starch crops after cassava and sweet potatoes and it is the fourth most widely grown crop after rice, wheat and maize. The crop accounts for over 70 % of farmer's earnings in Kisii county of Kenya. Farmers growing the crop are facing several challenges including depletion of soil fertility, low yields and diseases especially *Fusarium* wilt caused by *Fusarium oxysporum* f.sp. *cubense* (Foc). A study was conducted to determine the status of this disease in Kisii County. Ten farms were sampled in each Agro-ecological zone and in each farm four symptomatic and four non-symptomatic mats were sampled. Incidence was determined by relating banana seedlings affected and the total number of banana seedlings planted while severity was determined by measuring the extent of the damage/brown discoloration of the stem in length. Banana roots and pseudostem cuttings that were infected with the disease were used for isolation of the pathogen. *Fusarium* wilt is common in banana producing regions of Kisii County, however, the management practices are poor and do not meet the required strategies for controlling the disease. It was established that only; wood-ash and poultry manure were used by a few farmers in managing this disease. Present report is an attempt to improve the understanding of distribution and diversity of Foc in banana producing regions of Kisii County thereby aiding formulation of appropriate mitigation measures which the farmers can adopt locally.

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Keywords
Banana;
Incidence;
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Introduction

Banana categorized as third in world's key starch crops after cassava and sweet potatoes and it is the fourth most widely grown crop after rice, wheat and maize. Bananas are grown in a wide range of altitudes and are largely cultivated under rain

CONTACT Kennedy Moseti Momanyi kmmoseti@yahoo.com Department of Plant Science and Crop Protection, University of Nairobi, P.O Box 29053-00625, Kangemi, Kenya.

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fed conditions. In Kenya it is grown by small scale farmers who own approximately 0.3 hectares.[1] In Kenya banana is a key crop that is grown for both subsistence and commercial use covering 82,518 ha.[1] Nyanza and Western Provinces account for 30 % production, while Central and Eastern Provinces accounts for 26 %.[2] According to Dijsksra and Magori,[3] banana yield gave over 70 % of earnings to farmers in Kisii. Banana produces bunches throughout the year thereby providing a steady supply of food and earnings to the farmers.

Farmers growing the crop are facing several challenges including depletion of soil fertility, low yields and diseases especially *Fusarium* wilt caused by *Fusarium oxysporum* f. sp. *cubense*.[4,5] *Fusarium* oxysporum f. sp.*cubense* (Foc) is a soil borne pathogen that has a long survival time in the soil even in adverse conditions. The disease has caused severe damage on the crop and has continued to cause numerous losses all over Africa where bananas are grown. In a survey that was done in Kenya, the incidence of *Fusarium* wilt gave a figure as high as 80% in parts where Gross Michel (susceptible) waswidely grown . The spread of the disease is extensive and its causal pathogen is therefore the most extensively disseminated.[5] Planting material, water, soil particles, footwear and tools can efficiently disseminate the pathogen.[6] The fungus can survive as chlamydospores in the soil for a long time and has a long latent period. *Fusarium* wilt is confined to xylem; and the symptoms are more pronounced on susceptible banana varieties. Systemic infection in the vascular tissue of the pseudostem is blocked in tolerant varieties since there is obstruction of the pathogen by the plant. Old leaves show wilting symptoms followed by their death and sometimes splitting at the base of the pseudostem, is noticed . The younger leaves develop symptoms, die, and collapse at the base forming a skirt around the pseudostem before the plant eventually dies.[6] The disease is usually intense during the wet and warmer seasons. Due to the effect of this disease on banana yields and lack of the disease control strategy,it is therefore important that we understand the extent of its occurrence and distribution, as well as the locally available methods of managing it in Kisii County.

Materials and Methods

Description of the Study Site

The location of Kisii County is to the South of the former Nyanza Province. It makes up one of the forty seven counties in Kenya. It neighbours Narok County to the South whereas Nyamira County to North East, and both Migori and Homabay Counties to the West. It lies between latitude 0° 30' and 10°S and longitude 34°38' and 35° E 7. The survey was done in agro-ecological zones of lower upper midland one (UM1) and lower Highland (LH2). The County is categorized into the following agro-ecological zones: lower Highland (LH1 and LH2) and lower upper midland (UM1). It has been determined that 75% of Kisii County is in the Upper midland whereas the remaining 25% is in the lower highland.[7] Bimodal rainfall pattern is received annually in Kisii County giving it an average of 1500mm of rainfall per year.[7] This is due to the highland equatorial climate experienced in Kisii County. Therefore between March and June long rains come and between September and November, short rains are experienced. The respective temperatures for the two rain patterns in the County ranges from 21° - 30°C maximum and 15° - 20°C minimum.[7]

Red volcanic soils (nitosols) that have a lot of organic matter to greater depths are common in several parts of the County .The rest, which is twenty five per cent of the County comprises of Clay soils (Phaezems) with poor drainage, red loams and sandy soils.[7] Kisii County is endowed with reliable rainfall pattern and arable land that supports both livestock and crop production. The County is agriculturally able to support growth of all crops because of the reliable rainfall where the common crops grown include maize, bananas, coffee, tea etc.

Determination of Incidence and Severity of *Fusarium* Wilt and Isolation of Pathogen

The survey to determine the status of *Fusarium* wilt in Kisii County was carried out in the month of June 2015. The survey that was done comprised of a questionnaire and personal observations. Sampling was confined to cover upper midland (UMI) Suneka and Mosocho divisions and lower highland (LHI) in Keumbu and Nyamache divisions.[7] This is because more than 95% of Kisii County is in Agro-ecological Zones UM1 and LH1. Ten farms were sampled in each Agro-ecological zone and in each farm four symptomatic and four non-symptomatic mats were sampled.

Incidence of *Fusarium* wilt was determined byrandomly selecting ten farms in each Agro-ecological zone and in each farm, four symptomatic and four non-symptomatic banana mats were sampled. The symptoms that were used to identify the samples included light yellow coloration and wilting starting with aged leaves at the base, longitudinal splitting on the base leaf sheaths just above the ground forming a skirt, where leaves collapse forming a skirt around the pseudostem, spiky young leaves among others. Incidence of *Fusarium* wilt was determined by counting the bananas that had *Fusarium* wilt symptoms in a banana mat then divided by the total number of the bananas in that mat times 100 to get percentage incidence. A total of eight banana samples were selected randomly from each farm. This comprised of four samples that were symptomatic and four that were asymptomatic.

Roots of banana samples were washed using tap water to remove soils that adhered to them. They were then air dried on absorbent paper. After drying on the absorbent paper, the samples were placed in brown khaki paper bags as the pseudostem samples and stored in a freezer. From the freezer the banana samples were removed and cut into pieces of two millimeters length. The pieces were then sterilized on the surfaces by soaking them in 1% Sodium hypochlorite solution. The cut portions were then rinsed three times with distilled water.[6] The portions were bloat dried and five pieces were picked using sterile forceps and plated onto plates of potato dextrose agar (PDA) amended with streptomycin and tetracycline antibiotics(which was pre-treated with 10mls of both streptomycin prepared by dissolving 200mg in one liter of sterile water and 0.5g of tetracycline antibiotics in 100ml of water). The Petri dishes with the five pieces of banana cuttings were then sealed and incubated at room temperature (22-28°C) and relative humidity of 55-70%, for seven days. After seven days cultures were observed and data on pathogens collected. Isolates of Foc were identified according to their microconidia, macroconidia, chlamydospores as morphological characteristics and through their cultural appearances.[6]

Data Analysis

The statistical analysis was performed using SPSS version 20 statistical software. Descriptive statistics analysis was done involving percentages, means, and frequencies of variables to describe the characteristics of respondents, their current knowledge and practices regarding general banana production. Data collected from the laboratory was statistically analyzed using Fisher's Analysis of Variance technique on Genst at Software program version 15. Treatment means were compared on the basis of least significant difference at the 0.05 (5%) probability levels.

Table 1: Socio-economic characteristics of banana farmers in Kisii County

Variable	Description	Agro-ecological zones		Mean
		LH1	UM1	
Education level	Primary	60.0±15.3	50.0±14.2	55.0±14.8
	Secondary	35.0±15.3	45.0±14.2	40.0±14.8
	Tertiary	5.0±15.3	5.0±14.2	5.0±14.8
Age	30-39	5.0±4.4	15.0±0.3	10.0±2.2
	40-50	20.0±4.4	15.0±0.3	17.5±2.2
	above 50	15.0±4.4	14.0±0.3	14.5±2.2

Results

Socio-Economic characteristics of the Banana Growing Farmers

Majority of the farmers (55%) attained only Primary Education 40% of them had attained secondary education while 5% of the respondents had tertiary education. The majority of the farmers (60%) in LH1 had slightly higher score on education than farmers in UM1 (Table 1). Majority (55%) of the respondents in both sites were in age bracket of 40-50 followed by those in the age bracket above 50 years. The farmers had an average age of 46 with a range of 20 - 60 years old.

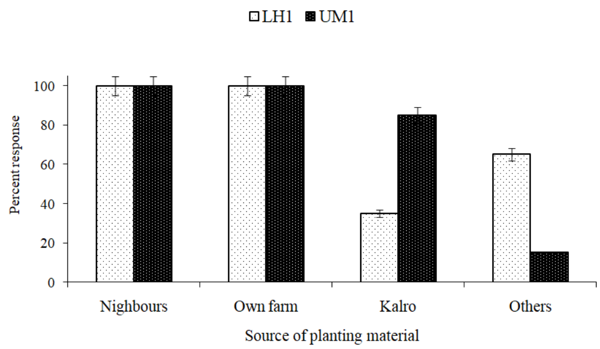

Fig.1: Sources of banana planting materials used by farmers in Kisii County. Sample population

Banana Production and Management

All the farmers used suckers as the planting material for establishing new gardens. They obtained their suckers from their own farm and from neighbours. Also farmers in LH1 (65%) obtained suckers from Jomo Kenyatta University of Agriculture & Technology (others). However, a few other farmers (35%) obtained the planting from a research centre, Kenya Agricultural And Livestock Research Organization (KALRO) Kisii, situated in the County (Figure 1).

Table 2: Proportion of farmers growing different crops in different agro-ecological zones

Crops grown	Agro-ecological Zones		Mean
	LH1	UM1	
Banana	100.0a	100.0a	100.0a
Coffee	55.0b	20.0bc	37.5bc
Maize	85.0a	90.0a	87.5a
Fodder	50.0b	35.0bc	42.5b
Vegetables	45.0b	90.0a	67.5b
Tea	55.0b	10.0c	32.5bc
Sugarcane	40.0b	55.0b	47.5b
Millet	15.0c	25.0c	20.0c
Mean	55.6	53.1	54.4
LSD (p≤0.05)	22.1	29.7	23.4

LSD- least significant difference, LH1- lower humid 1, UM1- upper midland 1, Means followed by same letter(s) within each column are not significantly different at P ≤ 0.05

Commonly grown crops in the two agro-ecological zones were bananas, coffee, maize and tea (Table 2). All the farmers in both sites had planted bananas in their farms (100%). Majority of the respondents in both sites planted other food crops such as maize (87%), vegetables (67%) and sugarcane (48%). About 43% of the interviewed farmers grew fodder as a cattle feed. All the farmers grew apple banana (100%) as one of the improved banana varieties in both agro-ecological zones while 95% of the respondents in LH1 and 55% in UM1 grew Ng'ombe a traditional banana variety. Ng'ombe (75%) was the most popular local variety grown in both agro-ecological zones while apple variety (100%) and Ugandan green (90%) were the main improved/exotic banana varieties in the both zones respectively (Table 3). Other improved/exotic varieties grown include: Valery (AAA), Gross Michel (AAA), Chinese Cavendish (AAA), Grand Nain (AAA), Nusung'ombe (AAA-EA), Bokoboko (ABB), Gross Michel 3 (AAA), Fhia 17(AAA), Gross Michel 2 (AAA), and Hybrid apple banana (AAB).

Table 3: Local and improved/exotic banana varieties planted by farmers

local cultivars (%)			exotic variety (%)		
Local Variety	**LH1 (n=20)**	**UM1 (n=20)**	**Improved/exotic variety**	**LH 1 (n=20)**	**UM1 (n=20)**
Ng'ombe	95.0	55.0	Apple banana	100.0	100.0
Nusung'ombe	25.0	0.0	Giant apple	25.0	65.0
Bokoboko	15.0	25.0	Varaley	0.0	15.0
Gross Michel 3	0.0	10.0	Gross Michel	0.0	35.0
Fhia 17	10.0	70.0	Uganda green	100.0	80.0
Hybrid apple banana	0.0	40.0	Chinese Cavendish	30.0	15.0
Gross Michel 2	0.0	55.0	Grand Nain	15.0	25.0
Mean	20.7	36.4		38.6	47.9
LSD (P≤0.05)	31.5	23.8		40.2	31.3

LH1- lower humid 1, UM1- upper midland 1

Table 4: Major pests and diseases associated with bananas in agro-ecological zones LH1 and UM1

Pests and diseases	Agro-ecological zones		
	LH1	**UM1**	**Mean**
Black Sigatoka	65.0a	55.0b	60.0a
Fusarium wilt	60.0a	85.0a	72.5a
weevils	30.0b	10.0c	20.0b
Moles	30.0b	40.9b	35.5b
Thrips	15.0bc	10.0c	12.5bc
Cigar-end rot	5.0c	10.1c	7.5c
Nematodes	0.0c	40.1b	20.1bc
Mean	29.3	35.7	32.5
LSD (P≤0.05)	23.5	26.2	23.0
CV (%)	16.3	18.4	26.6

LSD- least significant difference, LH1- lower humid 1, UM1- upper midland 1, Means followed by same letter(s) within each column are not significantly different at P ≤ 0.05

The major diseases of banana reported by the farmers (Table 4) included: *Fusarium* wilt (73%), Black Sigatoka (60%) while the major pests included moles, weevils and nematodes. Majority of the farmers in UM1 reported *Fusarium* wilt as the most devastating banana disease followed by Black Sigatoka. In terms of pests, moles (41%) were reported as the main pest destroying bananas in the field. In agro-ecological LH1, majority of the farmers reported Black Sigatoka as the main disease (65%), this was followed closely by *Fusarium* wilt. The pests mentioned by the farmers include weevils, moles and thrips. The major diseases reported by farmers (Table 5) were *Fusarium* wilt of banana (73%), Black Sigatoka (60%), while major pests included moles, weevils and nematodes. Majority of the farmers in UM1 reported that *Fusarium* wilt was the most devastating banana disease followed by Black Sigatoka. In terms of pests, moles (41%) were reported as the main pest destroying banana in the field. In agro-ecological zone LH1, majority of the farmers reported Black Sigatoka as the main disease affecting bananas (65%), this was followed closely by *Fusarium* wilt as stated by 60% of the respondents. The pests mentioned by the farmers were weevils, moles and thrips.

Table 5: Constraints affecting banana production in agro-ecological zone LH1 and UM1

Production constraint	Agro-ecological zones		
	LH1	UM1	Mean
Diseases	65.0b	95.0a	80.0a
High labour cost	65.0b	60.0b	62.5b
Lack of market	60.0b	65.0b	62.5b
Low market prices	90.0a	85.0a	87.5a
Lodging	5.0c	5.0c	5.0c
Pests	65.0b	80.0b	72.5a
High transport cost	75.0a	65.0c	70.0a
Mean	26.5	29.3	27.9
LSD (P≤0.05)	24.5	27.1	25.0
CV (%)	33.4	36.4	28.9

Means followed by same letter(s) within each column are not significantly different at P ≤ 0.05

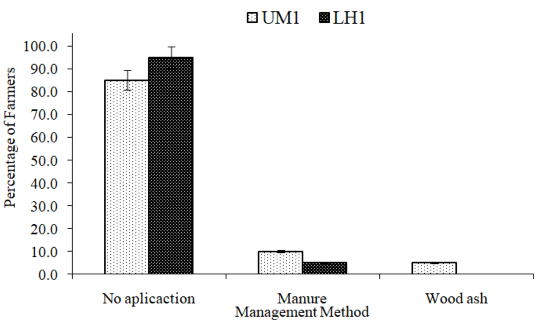

Fig. 2: Percentage of farmers who used different methods to manage *Fusarium* wilt in the two Agro-ecological zones

Majority of the interviewed farmers in ago-ecological zone LH1 (95%) and UM1 (85%) did not manage the banana diseases with any management method (Figure 2). However, only a few (10%) in UM1 and (5%) in LH1 applied manure as a method of managing banana diseases. A few other farmers (5%) in UM1 used wood ash to manage the diseases.

Incidence of *Fusarium* Wilt

There were significant differences (p≤0.05) in asymptomatic banana samples collected from the two agro-ecological zones. Higher incidences of *Fusarium* wilt disease was found in agro-ecological zone UM1 compared to LH1 (Table 6). There was consistency in disease incidence in the sites; however, high disease incidence of 78% was observed in UM1 in Sub County Mosocho and the lowest disease incidence was observed in Sub County Suneka. In agro-ecological LH1, no significant variation in *Fusarium* wilt pathogen was found between treated plots according to Tukey's test (ANOVA) at p≤0.05. The incidence of *Fusarium* wilt of banana in symptomatic samples varied between the agro-ecological zones at p≤0.05 with Agro-ecological zone UM1 having high incidences of *Fusarium* wilt disease compared to agro-ecological zone LH1. However, there were no significant differences between the Sub Counties surveyed.

Table 6: Incidence (%), of *Fusarium* wilt on banana samples infected with *Fusarium oxysporum* in Kisii County

	AEZs		
Sub County	**LH1**	**UM1**	**Mean**
Suneka	26.0b	60.0a	43.0a
Mosocho	26.0b	78.0a	52.0a
Keumbu	22.0b	74.0a	48.0a
Nyamache	32.0b	74.0a	53.0a
Mean	26.5	71.5	49.0
LSD (P≤0.05)	11.5	11.5	7.2
CV (%)	65.8	65.8	65.8

Means followed by same letter(s) within each column are not significantly different at P ≤ 0.05 LSD: least significant difference; CV: coefficient of variation

Table 7: Incidence (%), of *Fusarium* wilt disease on banana samples infected with *Fusarium oxysporum* in Kisii County

Sub County	**LH1**	**UM1**	**Mean**
Suneka	42.3b	79.0a	60.7
Mosocho	42.0b	82.7a	62.3
Keumbu	39.3b	81.0a	60.2
Nyamache	44.7b	79.7a	62.2
Mean	42.1	80.6	61.4
LSD (P≤0.05)	12.2	12.2	12.2
CV (%)	55.2	55.2	55.2

Means followed by same letter(s) within each column are not significantly different at P ≤ 0.05 LSD: least significant difference; CV: coefficient of variation

Discussion

Majority of the farmers in the study areas were 40-50 years of age with up to primary school level of education. The results concur with those of[8] where they stated that most farmers had an average of primary education. According to Mwangi and Kariuki,[9] education increases the uptake of new agricultural technologies including the use of newly released and improved banana varieties. Educated farmers look for suitable agricultural knowledge to boost their production. The findings of this study confirms the previous results by Mwangi and Kariuki,[9] and Julius,[10] whose report gave a positive correlation between adoption and education of new technologies in agriculture. Education improves productivity of the human factor and makes people more aware of opportunities to earn a living.[11] According to Unterhalter,[12] education is a measure of human development and is therefore a basic requirement needed for household improvement.

A part from banana, farmers in the study area also planted maize, vegetables, sugarcane and fodder crops which are mainly used as cattle feed. Other crops grown include tea, millet, and coffee. These crops were seen as complimentary to the major crops and were planted between the major crops as intercrops and for crop rotation. According to Karangwa *et al*.,[13] intercropping systems have suppressive ability on plant diseases by creating an environment that is not conducive to diseases. Intercropping suppresses plant diseases through various mechanisms such as change of vector dispersal, changing the morphology of the host, physiology and moisture, as well as preventing the pathogen entry.[14, 15] Intercropping has also been reported to improve soil fertility thus increasing yield through processes such as atmospheric nitrogen fixation, smothering weeds and boosting the available nutrients the soil through regulation soil pH.[14] Other findings indicate that crop rotation affects severity and disease development in the field. For instance rotations with non-cereal crops reduce severity of crop diseases but this is dependent on crop type. This result agrees with those reported by Karangwa*et al*.,[13]

The small-scale farmers in Kisii County plant both local and improved banana varieties sourced mainly through the informal seed systems. Ng'ombe was the most popular local variety grown in both agro-ecological zones while apple variety and Ugandan green were the main improved/exotic banana varieties in the both zones respectively. Other improved/exotic varieties grown included: Valery, Gross Mitchel, Chinese Cavendish and Grandnain. Other varieties planted include NusuNg'ombe, Bokoboko, Gross Michel 3, Fhia 17, Gross Michel 2, and Hybrid apple banana. Farmers preferred to grow the improved banana varieties because they are high yielding, palatable, easy to cook, and are able to tolerate disease compared to the local cultivars. All the farmers used banana suckers as planting material which they obtained mostly from their own farms and neighboring farmers. The same results were reported by Lwandas *et al*.,[16] where majority of banana famers obtained their suckers from neighbouring farmers. However, the level of reliance on KALRO as source of planting material varied significantly within the two Agro-ecological zones. The reason for this may be due to season variability, household characteristics such as wealth status and the level of production.[17] These planting material or suckers were not certified and probably were the main source of dissemination of *Fusarium* wilt pathogens among the farmers.[18] Use of planting material of improved and certified cultivars from relevant organizations could increase the yield and reduce the disease incidences. According to Birachi *et al*.[17] many farmers benefit from planting these improved varieties, however, access is still a challenge.

The study highlighted the dominance of banana variety ng'ombe and apple in LH1, while Uganda green dominated in UM1. This aspect confirms the relative importance of banana in the Kisii culture.[19] The reason for the dominance of the three varieties could be due to their sweet taste, their ability to yield high and disease tolerance ability. Several studies have high yielding capability of banana as one of the reasons for massive adoption. Due to current surge in *Fusarium* wilt, farmers have embraced the use of improved varieties so as to stem out the disease.[19]

Constraints to banana production in Kisii County

Farmers reported various biotic and abiotic constraints affecting banana production in Kisii County, chief among them being diseases followed by pests. Other mentioned constraints include high labour and transport costs, and fluctuations in market prices. The same results were reported by Ouma and Jagwe,.[20] Interviewed banana producers prioritized these constraints as key to low yield. These results are in agreement with the report by Njau *et al*.[21] who in their findings noted plant diseases as the major constraint to banana production. Other reported constraints include low market prices, and high transport costs. From the survey it was found that Foc was present in the two agro-ecological zones and the presence of more than one symptom was noted on a single plant. These observations in the field were confirmed through pathogen isolation from wilting symptomatic plant parts. Other noted symptoms included yellowing of older leaves progressing from the base to the top where younger leaves are up to the unfolded central leaf which remains erect and green, the same symptoms were reported by earlier researchers.[5, 22] Splitting of the base of the pseudostem was also observed, particularly on young, rapidly growing plants.[23] The results concur with those reported by Ploetz,[24] and Li *et al*.[18] where symptomatic pseudostems had various contaminations with Foc. This disease is regarded as one of the most damaging diseases of banana[25] and can wipe an entire farm of susceptible banana varieties. According to Tushemerirwe *etal*.,[25] FHIA clones were considered resistant while Gross Michel appeared susceptible; however, these varieties were only adopted by few farmers. The failure by farmers to adopt the resistant banana varieties calls for increase in the number of extension officers who are able to teach farmers the benefits of technology adoption.

Interestingly, the symptoms were common in Agro-ecological zone UM1 when compared to Agro-ecological LH1. The high presence and incidence of this disease in bananas in UM1 zone is because of the environmental conditions that make *Fusarium* spp. pathogens to thrive best. Therefore the conditions of the soil coupled with the cropping systems and the environmental may also influence the severity of *Fusarium* wilt agro-ecological zones across regions. According to Li *et al*.[26] limited knowledge of banana *Fusarium* wilt by the small scale farmers, use of suckers obtained from neighbouring farmers for replanting instead of certified banana suckers promotes rapid spread of the disease. Once the disease is introduced within the farm, the pathogen being soil borne will survive in the fields for longer periods and therefore will affect subsequent banana crops.[27] Apart from *Fusarium* wilt, the farmers also reported Black Sigatoka as another common banana disease while the major pests included moles, weevils and nematodes.

Majority of the interviewed farmers did not manage the disease;, however, only a few in both agro-ecological zones applied manure as a method of managing *Fusarium* wilt of banana while a few others in UM1 used wood ash to manage the diseases. The study demonstrates that manipulation of the soil environment following application of organic manure and wood ash can greatly reduce the severity and incidence of this disease in bananas. Our findings reinforce those that were reported by Fang *et al*.[28] in their work where soil pH was manipulated using organic matter to which resulted in reduction of severity and impact of this disease. These findings highlight the potential of further exploring wood ash to manipulate soil pH in order to manage the disease. The management of plant diseases with organic manure may be associated with reduced aggressiveness and infection of the pathogen[23, 28] while improving the plant vigour as a result of increased soil nutrient status.

Conclusions

Fusarium oxysporum f.sp. *cubense* is widely distributed in Kisii County. The management practices that are currently applied by the farmers in the county do not meet the required strategies for the management of this disease. Therefore this understanding of the distribution and diversity of *Fusarium oxysporum* in banana producing regions of Kisii County becomes an eye opener to the stakeholders to combat the disease through concerted effort using the locally available materials as recommended.

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Conflict of Interest

The authors declare no conflict of interest exists

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