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Distribution and farmers' knowledge on Fusarium wilt (Race 1) in cropping systems of Uganda

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The study aimed at understanding the spatial distribution of Fusarium wilt (FW) in different banana growing regions, ascertain the effect of management practices and plantation age on FW incidence, as well as investigate farmers' knowledge regarding the symptoms and spread of FW in Uganda. Individual interviews were conducted in 119 farms using a pre-tested questionnaire and field observations during a survey in major banana growing regions. Results indicate that FW is widely distributed across the banana growing areas with more occurrences (70%) in Kapchorwa district and majority of respondents (63.4%) reported increasing disease prevalence. A chi-square test performed revealed significant association between FW incidence and plantation age with more incidences (51.6%) recorded in older plantations (>20 years of establishment) than newly (1-5 years) established ones (11.1%). FW incidence was significantly associated with plantation management with higher incidences (86.9%) recorded in well managed plantations. Half of interviewed farmers could explain and distinguish symptoms associated with FW from other diseases, but only 38.4% of these could tell how the disease spreads; thus, a need for more concerted efforts in building the capacity of farmers to identify the symptoms and spread of FW for effective management program. We identified preliminary evidence that field abandonment is sometimes used as a last option for coping up with FW. Understanding the mechanism behind this requires more detailed research as well as establishing how farmers are managing FW culturally.

Key words: Fusarium wilt, farmers' knowledge, spatial distribution, Uganda.

INTRODUCTION

Banana and plantain are one of the major staple foods for over 50% of the population in Uganda (Karamura et al., 2012). In addition, banana is considered a key food security crop and a source of income for resource poor farmers. Uganda has the highest global per capita consumption levels of banana, estimated at 0.4-0.7 kg per day (FEWS NET, 2017). Seventy percent of the bananas grown in Uganda are consumed locally and the rest is sold on the domestic market to generate household income (UBOS, 2019). Depending on genome,

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banana serves several purposes, for instance; AAA (Cavendish, Gros Michel and East African Highland Bananas-EAHBs) are majorly used as deserts and cooking respectively, AAB (Pisang Awak, Silk and Pome) are grown for preparing juice and desert, AB (Sukali Ndizi, Kisubi) for dessert, ABB (Bluggoes) and AAAA (FHIAs mainly, 03, 17, 21, 23 and 25) for juice, desert and cooking. Therefore, the production of banana is demand-driven with the EAHBs also locally known as "matooke/cooking type", the most cultivated ones (Karamura et al., 2012). However, in the recent years, investing in dessert varieties especially Gros Michel is becoming lucrative and has become major export commodity not only in Uganda but in East Africa and the world. According to Fruitrop (2016), the global production of Gros Michel is at 14910.16 tonnes; of this, 4.1% come from East Africa mainly: Uganda (352.8 tonnes), Tanzania (173.1 tonnes), Burundi (86.496 tonnes), Kenya (72.1 tonnes) and Rwanda (70 tonnes).

Despite its importance, banana productivity has remained low (6.3 t ha^{-1} yr^{-1}) compared to the potential yield of 70 tonnes/ha/year obtained on station under proper management practices (Nalunga et al., 2015). Pests and diseases, declining soil fertility and drought stress are among the major factors attributing to this yield gap in Uganda (Nyombi, 2013; Tinzaara et al., 2014). Among the most devastating diseases is Fusarium wilt (FW), also known as Panama disease. It has been reported among diseases posing substantial threat to banana production especially to the dessert varieties (Karangwa et al., 2018; Kangire et al., 2000; Tushemereirwe et al., 2004).

FW has caused almost more than 60% in the field losses (Buregyeya et al., 2020). FW is a soil borne fungus caused by *Fusarium oxysporum* f. sp *cubense* (Foc). At present, four races of Foc have been documented (Mostert et al., 2017). These include race 1 that causes manifestation of the disease in Gros Michel (AAA), Silk (AB), Pome (AAB) and Pisang Awak (ABB), race 2 which attacks Bluggoe (ABB), race 3 that attacks *Heliconia* species and tropical race 4 (TR4) which attacks mainly Cavendish (AAA) varieties and all varieties susceptible to race 1 and 2 (Mostert et al., 2017; Dita et al., 2018), Race 1 has remained problematic to non-Cavendish varieties as recent surveys in Mozambique still confirm the status quo (Viljoen et al., 2020). Although this classification still holds, there is a growing concern yet to be confirmed that TR4 does not necessarily affect all species susceptible to Race 1 (Molina personal communication). The race system of *Foc* classification has been proven to be insufficient in distinguishing different *Foc* isolates from different parts of the world and therefore the Vegetative Compatibility Group (VCG) system has been used (Mostert et al., 2017). Currently, only race 1 has been reported in Uganda mainly on Gros Michel, Sukali Ndizi and Pisang awak under the VCGs 0124, 0125, 0128, 01212,01220 and 01222 (Karangwa et al., 2018; Tushemereirwe et al., 2004).

Since being identified in Uganda in 1952 (Leaky, 1970) entire fields of dessert banana varieties of Bogoya (Gross Michel), Kayinja (Pisang Awak), Sukali Ndizi and Kisubi (Ney Poovan) have almost been wiped out (Tushemereirwe et al., 2004). Fusarium wilt symptoms include wilting of the old leaves, splitting at the corm base, the xylem becomes reddish brown, plugged, thus hindering water and nutrient transport as the plant eventually dies (Ploetz, 2015a; Viljoen et al., 2017). Initially, yellowing of the leaves begins with the margin advancing towards the midrib and the petioles becomes brown and buckles, pseudostem splits above, discoloration of the corm and dead leaves hang around the pseudostem appearing like a skirt (Viljoen et al., 2017; Thangavelu et al., 2020). Expression of such symptoms has been widely used to identify Banana Fusarium wilt and collect samples for further laboratory characterisation and hence (Karangwa et al., 2018; Viljoen et al., 2017).

Foc can survive in the soils for more than 20 years as hard-cased chlamydospores, making it very difficult to eradicate (Ploetz, 2015b; Dita et al., 2018). Management of Fusarium wilt in other parts of the world where the Cavendish industry is grossly affected by the virulent TR4 has been through attempts at use of fungicides and chemicals, soil fumigation and complete destruction of Foc-infected plants (Viljoen et al., 2019). Most of these methods have proven expensive and unsustainable (Veena et al., 2014). Fusarium wilt being a soil borne disease needs to be sustainably managed (Dita et al., 2018).

For sustainable management of the disease, especially with the imminent threat of the presence of TR4 in neighbouring Mozambique in 2013, there is need to monitor diseases progress, understand how farmers are managing the disease as well documenting current knowledge about the same basing on community perception for an informed and participatory breeding program. Such information in Uganda is limited. The last study with closely related information was by Kangire et al. (2000); it is more than 20 years now and certainly a lot has changed. For instance, there are growing unsubstantiated claims that Fusarium wilt is more prevalent in well managed than abandoned plantations, others argue that Fusarium wilt is common in older plantations than recently established ones. In addition, knowledge about the spatial distribution of FW in Uganda is limited yet such information in vital in understanding disease pressure to map out hot spot experimental areas (Madden and Hughes, 1995), sampling program for disease losses (Liu et al., 2015) and determining areas where concerted management efforts should be put (Ristaino and Gumpertz, 2000). Information on spatial patterns of FW has been widely studied (Meldrum et al., 2013; Gudero et al., 2018; Liu et al., 2015; Heck et al., 2021) in other countries not Uganda.

Table 1. Percentage of respondents by gender and level of education.

Demographic characteristics	Number	Percent
Gender		
Male	75	63.0
Female	44	37.0
Total	119	100.0
Level of education		
Completed primary	44	37.0
Completed secondary	8	6.7
Completed university	10	8.4
Completed tertiary/vocational	30	25.2
Never went to school	27	22.7
Total	119	100.0

Therefore, this study aimed at: (1) understanding the distribution (spatial and within *Musa* spp.) and status of FW based on symptomatology within major banana growing areas, (2) investigate what is known by farmers in regard to symptom identification and spread and (3) ascertain the effect of plantation age and management practices on Fusarium wilt.

MATERIALS AND METHODS

The study used two different tools, namely: (1) individual interviews, (2) field observation based on symptomatology.

Individual interviews

Farmers from major banana producing areas of eastern, central and western Uganda were selected based on having at least 5 mats (a mat refers to collection of banana plants interconnected to original plant) of FW susceptible varieties. The sample was stratified according to altitude differences: (1) districts at high altitude (1450-1950), (2) districts at medium altitude (1200-1450 masl), and (3) districts at low altitude (1000-1200 masl). A total of 119 farmers were selected from four districts with contrasting altitudes namely, Kapchorwa, Isingiro, Kabarole and Sironko for high altitude; Ntungamo, Rubirizi, Rakai and Mukono for medium altitude; Mbale, Masaka, Luweero; and Kayunga for lower altitude. For each district, three sub counties were randomly selected and ten respondents with at least 5 mats of FW susceptible varieties chosen per sub county. Banana growing households distant from each other by at least five km with acreage between 0.5-20 were selected. The farmers were interviewed using an open-ended questionnaire aimed at generating data on demographic characteristics, plantation history, and knowledge about Fusarium wilt (FW), as well as information on resistance on grown banana varieties/clones.

Field observation

Following a Fusarium wilt disease symptom and management manual by Viljoen et al. (2017), a transect walk was conducted in plantation for each individual respondents to identify the presence or absence of FW symptoms on desert bananas (diseases incidence). For each plantation, symptomatic plants as explained by Viljoen et al. (2017) were split and checked for discoloration of the corm to confirm the presence of the disease on desert bananas, and upon this confirmation, the number of mats affected were counted and recorded.

Data analysis

Data were subjected to three packages for analysis: (1) Quantum GIS to develop maps on spatial distribution of the disease in study areas (2) Stata Version 15 (Stata Corporation. 2003) and Microsoft excel for inferential and descriptive statistics mainly means and frequencies as well as testing for associations between variables. Qualitative data was consolidated and disaggregated using queries to generate required tables for analysis. The filter function of Microsoft Excel was employed to eliminate outliers and check for wrong entries. The cleaned data was subjected to Pivot Table function of Microsoft and Stata version 15 for descriptive and inferential statistics. The chi-square test was performed to test the association between Fusarium wilt incidence and management status of banana plantations. All tests on inferential statistics were conducted at 95% confidence level.

RESULTS

Demographic factors within selected banana growing regions of Uganda

According to the individual interviews, male (63%) still dominates banana production as compared to their female counterpart (37%). On appropriateness of information provided, most farmers (77.3%) had completed primary school and above. However, 22.7% of the respondents engaged in banana farming had never received any formal education. It was interesting to note that university graduates owned a notable number of plantations 8.4%. Nevertheless, farmers who never went to school were reported (Table 1).

Table 2. Mean land size and period spent under banana production by respondents.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Age of respondent	119	41.1	11.5	19	72
Period grown banana (years)	119	25.2	9.3	2	50
Estimated total land area (acres)	119	4.3	5.5	0.3	35
Area under banana	119	2.8	4.8	0.3	30

Table 3. Plantation characteristics.

Characteristics	Number	Percent
Plantation age (years)		
1-5	25	21
6-10	13	10.9
11-15	19	16
16-20	6	5.0
>20	55	46.2
Not sure	1	0.8
No. of varieties on farm		
1-2	2	1.68
3-5	16	13.45
6-8	53	44.54
9-11	28	23.53
12-14	19	15.97
>14	1	0.84

Farmers' experience on growing banana and land size allocated to banana

Interviewed farmers had an average land size of 4.3 acres with some farmers owning up to 35 acres of land. Land ownership may not necessarily mean banana production; so to understand this, an interview was held to discern amount of land allocated to banana, and it was revealed that majority (66.3%) allocate their land to banana production. The interviewed farmers were majorly small-scale banana farmers with average banana acreage of 2.8 although very small pieces of 0.3 acres were recorded. Nevertheless, some farmers had scaled up banana production to 30 acres. Among these, the youngest was 19 years and the oldest 72, with an average age for all at 41. Additionally, all farmers had at least two years' experience in growing banana with an average experience at 25 years. The results also indicated that some farmers had grown banana for 50 years (Table 2).

Plantation characteristics in interviewed banana production areas

An assessment to understand plantation age revealed that majority (46.2%) were old plantations established 20 years and above. Albeit a notable number of new plantations were reported (21%), of these 5 were established after abandoning those severely hit by FW. It was also reported that majority of farmers (44.5%) prefer growing a mixture of varieties as opposed to pure stands of a single variety (1.7%) (Table 3).

Distribution and status of FW in selected banana growing regions

Spatial distribution

Symptoms associated with FW were widespread within selected banana growing areas with more prevalence in the eastern region of the country (Figure 2). There was a significant difference ($p < 0.05$) between FW incidence and districts. Generally, FW was more prevalent in eastern Uganda with Kapchorwa district showing highest incidence (70%), followed by Mbale (60%), and Sironko (60%) (Figure 2). Results further indicated that altitude did not have a significant contribution on FW incidence as this is evidenced by occurrence of high disease incidences in districts at high, medium and low altitudes.

Distribution of FW symptoms within Musa spp. *according to farmers' perspective*

EAHBs continue to be the dominant banana subgroup

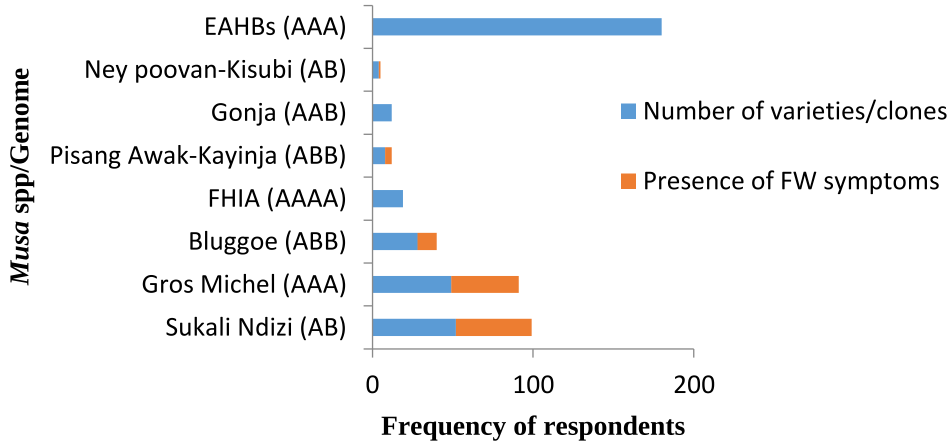

Figure 1. Frequency of distribution of FW within banana subgroups.

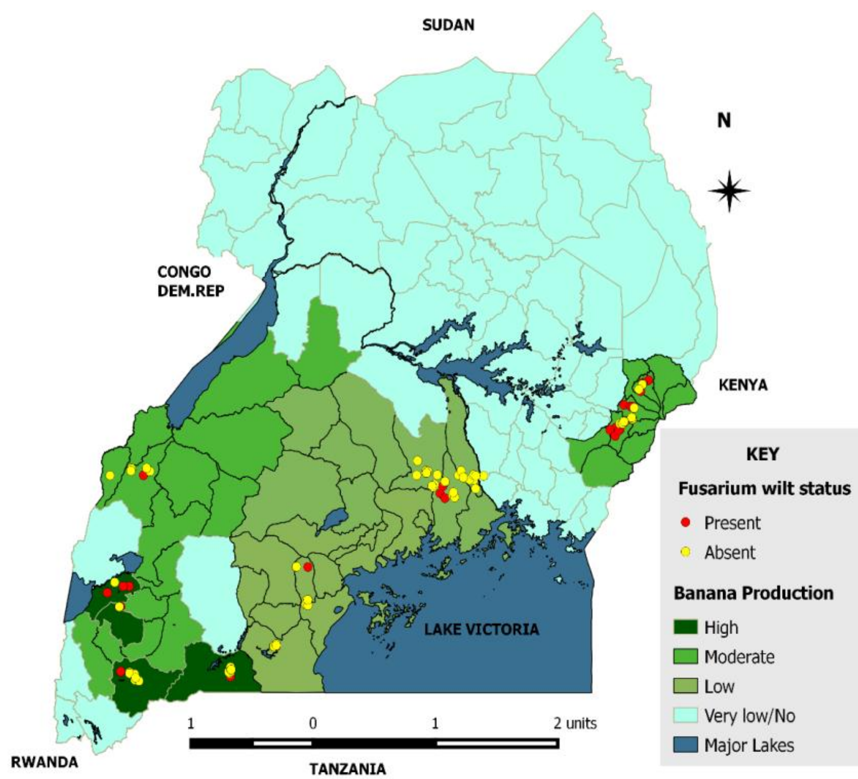

Figure 2. Spatial distribution of FW in major banana growing areas of Uganda.

grown in Uganda. Farmers' perception according to resistance, ranked Sukali Ndizi (AB) as the most susceptible *Musa* species followed by Gros Michel (AAB) and Bluggoe (ABB). Symptoms associated with FW were more observed in Sukali Ndizi and Gros Michel (Figure 1). Results further indicated that all clones of Pisang Awak (ABB) genome were reported susceptible and neither did any single farmer report symptoms associated with FW on FHIA (AAAA), Gonja (AAB) and KM5 (AAA) nor were such symptoms observed on the same varieties.

Status of FW in sampled banana growing areas

Symptoms associated with FW symptoms were observed in only 34.5% of the surveyed area. Out of these, more than 40% mats were infected, and the disease was

Table 4. Status of FW on farmer fields.

Status	Number	Percentage
Fusarium wilt status		
Present	41	34.5
Absent	78	65.5
Proportion Fusarium wilt infected mats (%)		
<10%	2	4.9
10-40% mats	21	51.2
40-70% mats	18	43.9
Farmer knowledge about Fusarium wilt progress		
Increasing	26	63.4
Decreasing	5	12.2
Constant	4	9.8
Not sure	6	14.6

Table 5. Farmer knowledge on the disease spread and symptoms of FW.

Knowledge	Number	Percentage
Ever heard about FW		
Yes	67	43.7
No	52	56.3
Farmer knows typical symptoms of FW		
Knows symptoms	57	50.0
Is mixed up with other diseases	8	7.0
Has no knowledge on symptoms of Fusarium wilt	49	43
Farmer knowledge about FW spread		
Knows spread	44	38.9
Has no knowledge on spread of Fusarium wilt	5	4.4
Confused with other diseases	64	56.6

reported increasing by majority (63.4%) of respondents (Table 4).

Understanding farmers' knowledge in regard to FW symptom identification and spread

In phytopathology, the design of an effective and efficient diseases management program depends on clear understanding of symptoms, spread and survival mechanism. We investigated to ascertain if farmers know typical symptoms of FW, how it spreads and how possible to manage it.

Farmers' knowledge on symptom identification and spread of FW

In a detailed interview, farmers were requested to explain the symptoms exhibited in FW infected plants and probed to reveal if such symptoms are not confused with Banana Xanthomonas Wilt (BXW) or other biotic stresses. Half of the respondents (50%) explained typical symptoms of FW (Table 5). Nevertheless, farmers still confuse FW with BXW and other disorders. For instance, farmers in Rubirizi district reported corm discoloration in EAHBs, yet these are known to be resistant to FW (Viljoen et al., 2017; Arinaitwe et al., 2019) (Plate 1). Understanding the spread of FW still remains a paradox to farmers, majority (56.6%) had no knowledge about the spread and only 38.9% could clearly describe the spread by associating it with soil movement from infected site'.

Effect of management practices and plantation age on FW incidence

A chi-squared test performed to test the association

Plate 1. Corm 'like' discoloration symptoms observed on EAHBs in Rubirizi District. Farm 1: At 1453 masl, Long: 300648.6 Lat: 2027.8; Farm 2: At 1457 masl, Long: 300657.2 Lat: 2019.6; Farm 3: At 1442 masl, Long: 300606.7 Lat: 1635.6.

Table 6. Association between FW incidence with plantation age and management.

Fusarium wilt Incidence	Plantation age (Years)					Plantation management status		
	1-5	**6-10**	**11-15**	**16-20**	**>20**	**Good**	**Fairly**	**Poor**
Present	4.0[d]	1.0	3.0	1.0	31.0	29.2[d]	1.80	6.0
	7.1[c]	3.2	6.7	2.4	20.6	86.49[c]	10.00	2.7
Absent	14.0	7.0	13.0	5.0	**20.0**	**50.50**	3.10	10.5
	10.5	4.7	9.9	3.5	30.4	73.44	1.56	25.0
Not sure	0.0	0.0	1.0	0.0	1.0	2.40	0.50	0.1
	0.4	0.2	0.3	0.1	1.0	100.00	0.00	0.0
Total	18.0	8.0	17.0	6.0	52.0	82.00	5.00	17.0
	$X^2(8) = 20.37$; *p value* = 0.009					$X^2(4) = 12.64$; *p value* = 0.013		

X^2 =Chi-square value with (8) degrees of freedom tested at 95% confidence level; d =Observed frequency and c =Expected frequency.

between FW incidence and management status of banana plantations was significant ($p < 0.05$) (Table 6). Remarkably, more incidences (86.5%) of FW were found in well managed farms (weeded, pruned, de-suckered with corms removed) than fairly managed (10%) and poorly/nearly abandoned farms (2.7%). Results further indicated a significant relationship ($p < 0.05$) between FW incidence and plantation age with highest incidences observed in older plantations established more than 20 years ago (Table 6).

DISCUSSION

Demographic factors within banana growing regions of Uganda

Fusarium wilt remains one of the most devastating diseases in several banana growing regions of the world and thus a global threat to banana production (Ploetz, 2015b; Kema et al., 2020). In this study, we identified the spatial distribution of FW in the banana growing areas and within banana subgroups, ascertained the effect of management practices and plantation age on FW incidence, as well as investigated how much information is known by farmers in regard to the symptoms and spread of FW in Uganda. Results showed that more males (63%) are involved in banana production than female (37%) in the major banana growing areas. The higher involvement of males in banana production suggest that men (males) are the likely more responsible for cash crops management than women as the latter mainly provide labour, although both males and females could be involved in decision making on the farms for increased income (Bjornlund et al., 2019; Rietveld et al., 2018).

Attaining formal education has been strongly correlated with adoption of management practices (Kikulwe and

Asindu, 2020; Ebewore, 2016). In our study, 22.7% of the respondents had never attained any formal education, implying that management practices devised to curtail Fusarium wilt, need to be simplified in a more user-friendly manner and employ practical means like farmer field schools. It was interesting to discover in this study that a notable number (8.4%) of university graduates owned banana farms and were engaged in daily management of plantations. It is envisaged that the future of agriculture lies in the hands of youths, as the need for youths into agriculture has been documented (Irungu et al., 2015; Mukembo and Edwards, 2020). In Uganda, the call for more youths in agriculture has been emphasized in the National Development Plan phase 3 (NDP III) (National Planning Authority, 2020). Finding ten youths already in banana farming in Uganda is evident to show that the country is on the right trend.

Findings further reveal that banana farmers had an average land size of 4.3 acres with about 66.3% allocated to banana production. Banana is a major food security crop accounting for much of farmers' income and is more profitable than annual food crops such as maize, sweet potatoes and cassava and thus the most important food crop in the country (Kiiza et al., 2004; Nyombi, 2013). The study was represented by farmers with depth in responding to questions related to banana farming as showcased by the average experience in banana production of 25.4 years, with some farmers recorded to have spent 50 years in this business.

Distribution (spatial and within *Musa* spp.) and status of FW based on symptomatology within major banana growing areas

Data on spatial distribution of Fusarium wilt remains scanty. This makes it difficult to map out hot spot experimental areas, sampling program for disease losses, and conducting cost benefit analysis studies on available management options for Fusarium wilt as highlighted by Staver et al. (2020). This study revealed a wide spatial distribution of symptoms associated with FW disease in all altitudes agrees with Gudero et al. (2018). However, there was a significant difference (p < 0.05) between FW incidence and districts. Kapchorwa, (a district on high altitude, 1950 masl) expressed highest incidence of symptoms associated with FW. The wide distribution of FW agrees with however, the results of altitude and FW contradicts with Karangwa et al. (2016) who reported high symptoms associated with FW at low altitudes. In Kapchorwa, it was observed normal for germplasm exchange between farmers; this traditional exchange of planting materials (sometimes infected) from one field to a healthy one could be the underlying reason for higher incidences of symptoms associated with FW observed in Kapchorwa.

Interestingly, no symptoms of FW were observed in sampled districts within low altitude (Kayunga and Luweero). There is a high likelihood that other factors apart from altitude contributed to this finding. For instance, Kayunga was the district where Banana Xanthomonas Wilt (BXW) was first observed in the early 2000's, with an impact that was unbearable and that forced farmers to uproot any symptomatic plant and mats, most of these mats were never recovered/ replanted, but rather the land was diversified to other income generating activities (Tushemereirwe et al., 2001). It is envisaged that, continued removal of infected plants could have reduced the inoculum and also reduce population of susceptible varieties, which is in agreement with Tushemereirwe et al. (2004).

In this study, we also found that the EAHBs were the most cultivated *Musa* species followed by Sukali Ndizi (AB), and Gross Michel (AAA), indicating their economic importance and consumer preferences (Figure 1). For instance, among deserts, Sukali Ndizi (AAB) is the most popular because of its compact bunch, short fingers and very sweet flavour when ripe (Gold et al., 2002). Farmers' perception according to resistance ranked Sukali Ndizi (AB) as the most susceptible *Musa* species followed by Gross Michel (AAB) and Bluggoe (ABB). In addition, all clones of Pisang Awak (ABB) genome were reported susceptible and with resistance to FW on FHIA (AAAA), Gonja (AAB) and KM5 (AAA). Our findings are consistent with Kangire et al. (2000) who reported that Sukali Ndizi (AB) variety is very much susceptible to FW. The findings are also consistent with Tushemereirwe et al. (2001) who reported that the FHIA varieties are resistant.

Results also showed that the least grown *Musa* species were Kayinja (ABB) and Kivuuvu (AB). Despite the low production of Kayinja and Kivuuvu, the contribution by the two in banana production system should not be underestimated. For example, Kayinja produces more juice for beer production as compared to the indigenous beer locally known as "*Mbidde*" whereas Kivuuvu is preferred in some areas for cooking compared to EAHBs due to low production costs (Bagamba et al., 2006). However, during an epidemic of Banana Xanthomonas wilt in an area, Kayinja and Kivuuvu are the first to be infected (Tushemereirwe et al., 2001). Thus, their susceptibility has tremendously contributed to reduction in mat stands and given that both varieties are susceptible to the two diseases, the decline in mat stands is highly likely to continue unless proper management strategies are reinstated.

Understanding farmers' knowledge regarding FW symptom identification and spread

Like other diseases, FW can effectively be managed when accurate diagnosis of the diseases through symptomatology and other DNA based methods are correctly done (Dita et al., 2018). Farmers normally rely

Plate 2. A field abandoned due to FW infection.

on symptoms for understanding the disease and devise management strategies. We investigated to ascertain how much is known about symptoms and spread of FW and found out that 50% of the respondents could explicitly explain typical symptoms of FW without confusing it with other *Musa* spp. diseases such as BXW, of which only 38.9% could understand how the disease spreads. This shows that limited information occurs on identification and spread. FW spread was predominantly confused with BXW as evidenced by farmers practicing removal of male inflorescence and stating that FW was spread through same by the bees, while others were strongly disinfecting tools after cutting a susceptible plant. It is known that being a soil-borne pathogen, dispersal for FW takes place by passive movement of soil particles and spores in soil propagules at short and long distance mainly by water runoff and (or) animals (Dita et al., 2018). The knowledge gap for symptom identification and spread could be one of the underlying factors for continuous spread of FW in sampled areas and more research needs to be directed towards this direction to build the capacity of farmers in understanding symptoms and spread so that they can attach meaning to management practices proposed.

Effect of management practices and plantation age on FW incidence

The study also revealed that plantation age plays a significant role in incidences of FW disease. The highest incidences of FW were observed in older plantations established more than 20 years ago. The effect of plantation age on disease incidence in banana has not received enough attention; nevertheless, scanty studies have been conducted (Mobambo et al., 1996; Karangwa et al., 2016). While conducting a study on distribution and incidence of banana Fusarium wilt in East and Central Africa, Karangwa et al. (2016) found out that plantation age was significantly associated with FW incidence with prevalence more pronounced in plantations of 10-30 years. This is consistent with our findings. Although this interaction has not adequately been investigated, it could be linked with the long duration that the pathogen stays in soil (Stover, 1972). This means that plantations which are already infected will remain as secondary inoculants for a long period. Therefore, as the field becomes old, more and more pathogens could accumulate in the soil if proper soil management practices such as sterilization, application of bio control, soil amendments are not performed over time (Ploetz, 2015b).

The chi-square conducted revealed an association between Fusarium wilt and management, with higher incidences in well managed plantations, than poorly/nearly abandoned plantations. Well managed plantations involve several agronomy practices for instance mulching and weeding (sometimes with a hoe). These encourage continuous soil disturbance which promotes movement of spores in infected sites (Alabouvette, 1986). For this reason, more incidences are more pronounced in well managed plantations than poorly/nearly abandoned ones which receive less soil disturbance. For the first time, our study reports field abandonment as one of the managements practices used in Uganda (Plate 2). It was reported that instead of cutting down entire plantation, abandoning the field and still harvest a substantial yield is a better option. According to FAO (2019), this practice has been commonly used in Philippines as a worst-case Fusarium wilt management practice. Understanding the mechanism behind this claim will require further research involving field experiments but could also be linked with the concept of suppressive soils being left undisturbed. Alabouvette (1986) reported the role of soil microflora in supressing FW. The author asserts that soils abundant with micro-organisms tend to have a suppressive effect, probably poorly managed or abandoned fields receive minimal disturbance thus encouraging more microbial growth which significantly contribute to soil suppression. In addition, abandoned plantations could be more nutrient-rich due to high microbial activity, and recently, Nowembabazi et al. (2021) revealed the enormous importance of nutrients especially potassium in reducing FW incidence in apple bananas.

Conclusion

The study revealed a notable number of growing university graduates in banana production. Fusarium wilt in banana is widely distributed in the major banana growing areas of Uganda with Kapchorwa district showing the highest incidences. According to farmers, Sukali Ndizi (AB), Gross Michel (AAB) and Bluggoe (ABB) were ranked susceptible to FW in that order whereas FHIA (AAAA), Gonja (AAB) and KM5 (AAA) were considered resistant. The disease was reported to be increasing by the majority, and the drivers for this increment were majorly limited knowledge on the spread that encourages management practices similar to BXW as well as traditional exchange of germplasm especially dessert ones. At least, half of the interviewed farmers know how to separate symptoms associated with FW from other banana diseases especially BXW. However, a majority are still challenged with understanding how the disease spreads and how it can be managed. Fusarium wilt symptoms were more pronounced in older plantations with 20 years from date of establishment and such symptoms are common within well managed plantations. Also, higher incidences of FW wilt observed in older plantations as well as well managed plantations need to be further investigated. Interestingly in this study, we found out field abandonment as a strategy for managing already infected field. This study predisposes array of research in near future, for instance the effect of intercrops in supressing FW, a detailed study on how farmers are managing FW in Uganda, understanding the mechanism of field abandonment in managing FW as well as the role of variety mixtures in supressing FW.

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CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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