Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 12, No. 4, p. 194-202, 2018
http://www.innspub.net

INNSPUB

RESEARCH PAPER OPEN ACCESS

Status of *Fusarium* wilt disease and plant parasitic nematode on banana in Northern and Southern highlands of Tanzania

Hassan Shabani Mduma*, Patrick Ndakidemi, Ernest Mbega

School of Life Science and Bioengineering, Nelson Mandela African Institution of Science and Technology, Arusha, Tanzania

Article published on April 30, 2018

Key words: Incidence, Severity, Nematode, *Fusarium* wilt

Abstract

A study to examine the status of *Fusarium* wilt disease and plant parasitic nematode on banana in Northern and Southern highlands of Tanzania was conducted in January 2017 at Meru District in Arusha and Rungwe District in Mbeya region Tanzania. Forty eight farms in twelve villages were scored for *Fusarium* incidence, severity and nematode damage using scale of 1-5 for severity of *Fusarium* wilt disease and a scale of 1-5 for nematode root damage (in percentage). Incidence of *Fusarium* wilt was expressed as the percentage of diseased plants in every field under study. The results indicated that the severity of *Fusarium* wilt disease was at highest score (72%) at Singisi in Meru District while the lowest score (25.83%) obtained at Mpuguso ward in Rungwe District. The highest incidence (11.48%) was found to be at Nkoaranga ward followed by Akheri (8.95%) in Meru District while the lowest incidence (0.83%) were found at Mpuguso in Rungwe District. Highest score for nematode damage (37.5%) was found at Kimo ward in Rungwe District while the lowest score (17.5%) was observed at Lufingo ward in Rungwe District. The current study shows that *Fusarium* wilt incidence and severity is high in Meru District while nematode damage is high in Rungwe District.

***Corresponding Author:** Hassan Shabani Mduma ✉ shabanih@nm-aist.ac.tz

Introduction

Bananas (*Musa* spp) is a giant herbaceous perennial plant that belongs to the genus Musa. It is divided into four groups; Callimusa, Australimusa, Eumusa and Rhodochlamys, (Simmonds and Shepherd, 1955). The origin of Banana is believed to be South East Asia (Jones, 2000). There are more than 1000 cultivars of banana worldwide which are mainly triploids (2n = 3x = 33), often sterile and parthenocarpic (Heslop-Harrison, 2011). Generally, modern classifications of banana cultivars follow Simmonds and Shepherd's system in which cultivars are placed in groups based on the number of chromosomes they have and species they are derived from (Karamura *et al.,* 2012).

East Africa region has remained to be the largest producer and consumer of bananas in Africa where per capita consumption of banana ranges from 230 to 450 kg person^{-1} year^{-1} (FAOSTAT, 2016, 2012; Smale, 2006). The East African highland bananas, such as Matooke (AAA-EA), the Illalyi (AAA), and Mchare (AA) (Karamura *et al.*, 2006) are important staple as well as cash crops for majority living in the plateaus (Karamura *et al.,* 2012).

Bananas are good source of potassium, carotene, vitamin E, thiamine (B1), riboflavin (B2), niacin, pyridoxine (B6), folic acid, pantothenate, biotin and vitamins C (Kumar *et al.*, 1992). It is a rich source of carbohydrate, fibre, fat and protein (Mohapatra *et al.*, 2010). Banana leaves and dry pseudo stems are used as animal feeds and for wrapping food stuffs and in thatching houses, handcrafting of mats and as agricultural mulch (Frison and Sharrock, 1999).

Tanzania cultivates about 400,000 hectares of land that produces about 3.7 MT of which the biggest proportion (i.e. 2.5 million MT) comes from Kilimanjaro and Kagera regions (Kilimo Trust 2012). Other regions which produce banana in the country include Kigoma, Mbeya, Arusha, Tanga, Mara and Morogoro region (Mgenzi and Mkulila, 2004).

Despite its importance, banana yield is unceasingly declining in Tanzania (Van Asten *et al.*, 2005). For example, in some locations of the country the production has declined from 18 tonnes/ha in the 1960s to less than 6 tonnes/ha in 2000 in Kagera region (Mgenzi *et al.*, 2005; Sikora *et al.*, 1989; Walker *et al.*, 1984). Such decline in production has been associated to various abiotic and biotic factors including soil fertility problems, drought, insect pests and diseases (Swennen *et al.*, 2013). Among the destructive pests of banana, plant parasitic nematodes such as *Pratylenchus goodeyi* and *Radopholus similis* have been mentioned to cause serious damage to banana in a variety of environments (Coyne *et al.,* 2014). These organisms feed, migrate and multiply inside banana roots and corms causing root-tissue necrosis and root system reduction which then cause damage to plants, impaired transport and uptake of water and nutrients resulting in reduced plant growth and yield (Viljoen *et al.,* 2016). In addition, the anchorage function of the root system is adversely affected resulting in plant toppling (Gowen & Queneherve, 1990). The wounds resulting from nematode attack can also provide avenue for entry and infestation by soil-borne fungal organisms such as *Fusarium oxysporum* f. sp. *cubense* (*Foc*) causal agent of *Fusarium* wilt of banana (Inagaki & Powell, 1969). This disease is also known as Panama disease because it first became epidemic in Panama in 1890 and proceeded to devastate the Central American and Caribbean banana industries that were based on the 'Gros Michel' (AAA) variety in the 1950s and 1960s, (Perez, 2004). Fusarium wilt disease is in the same rank with some most devastating plant diseases of other crops such as wheat rust and potato blight in terms of crop destruction (Dean *et al.,* 2011). It disrupts the plant's water conducting vessels resulting in yellowing and wilting of leaves (progressing from older to younger leaves). Inside a vertical section of the pseudostem, brown, red or yellow lines have been reported to be a characteristic attribute of the disease, the lines which also appear as rings in pseudostem cross-section (Ong, 1996; Viljoen, 2002). As a result of infestation the internal section of the pseudo stem rot extensively (Ong, 1996).

There are four recognized races of the pathogen which are separated based on host susceptibility as follows: race 1 affects Gros Michel, Lady Finger (AAB) and Silk (AAB), race 2 affects cooking bananas such as 'Bluggoe, race 3 affects *Heliconia* spp., a close relative of banana, and is not considered to be a banana pathogen, and race 4 which is a more virulent form of the pathogen cause disease in Cavendish banana (Viljoen, 2002; Ploetz, 2005).

Despite the destructive role that plant parasitic nematode and *Foc* disease have on banana, the status of these pests infestation especially on the East African Highland Bananas (EAHB) which is a unique group of bananas found in East African plateau has not been established in Tanzania. It is clearly known that a complex interrelationship between nematode and *Foc* in bananas produce a combined effect which is greater than the sum of their separate effects (Jonathan and Rajendran 1998). Thus, the aim of this study was to assess the incidence and severity of *Fusarium* wilt disease and nematode infection on banana growing in Meru and Rungwe Districts located in the main banana growing regions in Northern and Southern Highlands of Tanzania, respectively.

Material and methods

Location

This study was conducted in two districts one from Northern highland - Meru District located in Arusha region and another from Southern highland, Rungwe District located in Mbeya region Tanzania. These districts were selected due to their importance in banana production and also based on complains from farmers on *Foc* and nematodes, the two problems of which their status was unknown.

Assessment of proportional numbers of banana cultivars

Four wards in Meru and four wards in Rungwe Districts with information on existence of different banana cultivars were selected and used in the study (Table 1). To quantify the number of banana cultivars per farm in each ward, six randomly selected banana farms of about 1-2 acres each (two farms per village) were selected.

In each farm, number of each banana cultivar was recorded and its proportion by number in the farm was determined by dividing number of its count by total number of banana plants in the field x 100%.

Assessment of Fusarium wilt disease incidence, disease severity and nematode damage

Disease incidence was quantified by dividing the number of infested plant units by total number of plants in the field x 100%. Disease severity was quantified based on external symptoms of the disease by inspecting individual plants from each banana variety using a scale of 1 to 5 as established by Viljoen *et al.* (2016) with modification. Using the established scale, 1 described; no visual leaf symptoms, 2; = 1-33% of older banana leaves turning yellow, 3; = 34-66% of older leaves turning yellow with some hanging down the pseudostem, 4; = 67-95% of the leaves turning yellow and necrotic with leaves hanging down the pseudostem and 5; = 96-100% plant dead with brown leaves hanging down the pseudostem. Scoring nematode damage was done by estimating visual damage of root (as a percentage) using a scale of 1 to 5 adopted from Speijer and De Waele (1997). Systemic sampling pattern was used in order to accommodate the patchy nature of nematode distribution where five plants were selected for nematode scoring in every farm. From each plant, five functional roots of 10 cm length were randomly selected, washed with water to remove soil and sliced lengthwise. Scoring was done on one half of the root for the percentage of root cortex showing necrosis. As each of the five isolated roots usually carries 20 marks (Speijer and De Waele, 1997), the proportion damage under each root was estimated and the sum damage proportions was used as final score in percentage.

Results

Common banana cultivars in the study area

The results showed that, cultivar Mchare was the most common grown banana with proportions ranging from 65.76% in Akeri ward to 72.35% in Singisi ward followed by cultivar Grand Naine which had a proportional ranging from 16.30% in Shagarai ward to 19.0% in Akeri ward in Meru District (Table 1).

The results also showed that the most common grown banana cultivar in Rungwe District was Plantains which ranged from 27.3% at Kiwira ward to 47.65% at Kimo ward, followed by Matoke bananas which ranged from 22.30 at Kimo ward to 32.0% at Lufingo ward (Table 1). Information on commonality for other varieties covered in this study is as shown in Table 3.

Table 1. Number (%) of common Banana cultivars in selected wards of Meru and Rungwe Districts as characterized during this study.

Ward	District	Banana cultivar and their proportional number (%) per farm				
		Mchare	Matoke	Plantain	Cavendish	Sukari ndizi
Mpuguso	Rungwe	5.89	28.9	37.28	26.40	0.90
Kimo	Rungwe	2.73	22.35	47.65	29.27	1.19
Lufingo	Rungwe	2.23	34.00	33.33	25.50	1.24
Kiwira	Rungwe	4.20	33.39	27.30	30.20	0.73
Shangarai	Meru	67.39	11.7	1.33	16.30	1.09
Akheri	Meru	65.76	10.69	0.68	19.00	1.89
Sing'isi	Meru	72.35	8.07	1.79	16.14	1.20
Nkoaranga	Meru	71.86	9.24	0.87	17.03	0.87

Source: This study

Fusarium wilt disease incidence, disease severity and nematode damage in the study area

The results showed that *Fusarium* wilt disease and banana nematodes were found to be present in all villages under study in Arumeru and Rungwe Districts (Table 2). However, there was significant different (p≤0.001) between the incidences of *Fusarium* wilt disease in the study area. The highest *Fusarium* wilt disease incidence (11.48%) was recorded at Nkoaranga ward while the lowest disease incidence (0.83%) was recorded at Mpuguso Rungwe District.

Table 2. Fusarium wilt disease incidence, disease severity and nematode damage in Meru and Rungwe Districts as established in this study.

Ward	District	Fusarium wilt disease Incidence (%)	Fusarium wilt disease severity (%)	Nematode damage (%)
Mpuguso	Rungwe	0.83a	25.83a	22.50bc
Kimo	Rungwe	1.50a	52.50abc	37.50a
Lufingo	Rungwe	1.57a	32.17ab	17.50c
Kiwira	Rungwe	2.72a	54.67abc	30.83ab
Shangarai	Meru	7.94b	63.33bc	34.17ab
Akheri	Meru	8.95b	55.83abc	35.00a
Sing'isi	Meru	9.30b	72.00c	30.83ab
Nkoaranga	Meru	11.48b	48.33abc	30.00ab
Mean	na	5.53	50.58	29.80
Lsd	na	3.82	32.88	11.97
F-statistics	na	***	*	**

Means followed by the same letter(s) are not significantly different based on the Bonferroni multiple test a p=0.05., na= not applicable. ns=non-significant., *=significant at P≤0.05,**= significant at p≤0.01 and *** significant at p≤0.001.

However, such disease incidences were based on overall evaluation in each surveyed field regardless of existence of resistant banana varieties. Thus results for specific cultivar related disease incidences indicated that only Mchare and Sukari ndizi cultivars were susceptible to *Fusarium* wilt disease with incidences of 46.84% on cultivar Sukari ndizi at Lufingo ward to 59.9% on cultivar Mchare at Kiwira ward both in Rugwe District (Fig. 1).

The results also showed there was significance different (P≤0.05) between *Fusarium* disease severity on banana cultivars in the study area (Table 2). *Fusarium* wilt disease severity ranged from as high as 59.17% on cultivar Sukari ndizi at Lufingo ward in Rungwe District to 70.33% on Mchare at Sing'isi ward, Meru District (Fig. 1). The results also showed that all banana cultivars in the study area were susceptible to nematode and the damage was significant different (p≤0.01) (Table 2 and Fig. 2).

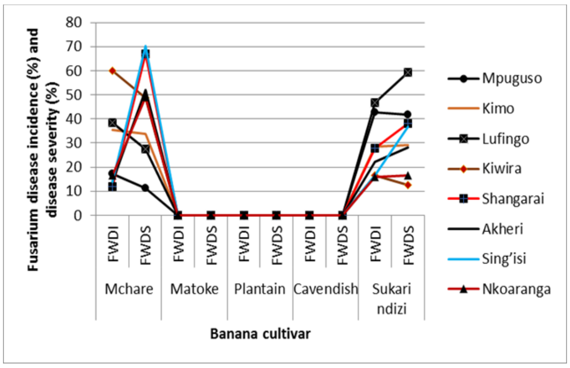

Fig. 1. *Fusarium* wilt disease incidence (FWDI) and disease severity (FWDS) on common banana cultivars in the study area.

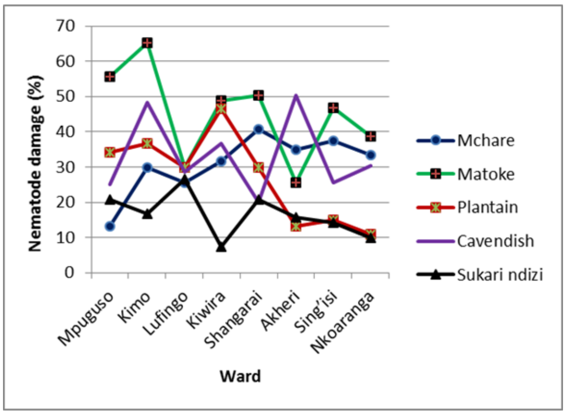

Fig. 2. Nematode damage on common banana cultivars in the study area.

The highest score for nematode damage (37%) was recorded at Kimo ward in Rungwe District followed by Akheri (35%) and Shangarai (34.17%) in Meru District while the lowest score (17.5%) was recorded at Lufingo ward in Rungwe District (Table 2). On different cultivars, the results showed that Matoke bananas was the most susceptible of all with damage levels of as high as 50.35% at Shangarai ward in Meru District to 65.12% at Kimo ward in Rungwe District (Fig 2). Other banana cultivars with high nematode damage levels were Grand Naine (50.26%) at Akeri ward, Meru District, Plantains (46.62%) at Kiwira, Rungwe District and cultivar Mchare (40.83%) at Shangarai ward, Meru District (Fig.2).

Discussion

This study has revealed that common grown banana varieties under the study area are Mchare, Matoke, Plantain, Grand Naine and Sukari ndizi. However, the importance of each cultivar differs between the two sites. While Mchare cultivars are highly grown in Meru District, important banana cultivars in Rungwe District are Plantains and Matoke bananas. This was also reported by Karamura (2006) who mentioned Meru-Kilimanjaro axis to be dominated by Mchare banana. Similarly, Maruo (2007) reported plantain to be playing a key role in consolidating the development of the Nyakyusa (ethnic group in Rungwe district) rural community. In this study, *Fusarium* wilt disease and nematode were reported to be present in both Meru and Rungwe districts. The highest score for *Fusarium* wilt disease incidence and severity was recorded in Meru District on Mchare varieties. One of the reason for high incidence and severity of *Fusarium* wilt disease in this region might be due to high cultivation of susceptible cultivars which are Mchare (Koka and Swennen 2017) and Sukari ndizi (Viljoun *et al.*, 2016) compared with Rungwe District. In addition, farming systems in Meru District differ from those found in Rungwe. During dry season, farmers do irrigate their banana field using surface/furrow irrigation method which essentially cause movement of pathogen from infected plants to the health ones through running water (Ploetz, 2006).

Farmers in Arumeru also use banana plants (leaves and pseudostem) as feeding material to their cattle, therefore pruning of functional leaves for animal feed with the same machete across the field without disinfection is another way of spreading the disease (Ploetz, 2006) which lead to the increase of disease incidence. However, the proportion of incidence to the total number of plants is low because farmers normally do not withstand keeping diseased plants in the field for long period. They destroy diseased plant as soon as they see symptoms of *Fusarium* wilt unless the symptoms occurred at a later stage when the bunch is close to maturity. Plantain, Matoke, and Grand Naine which are highly grown in Rungwe district are all resistant to *Foc* race 1, a causative agent of *Fusarium* wilt disease (Kashaija *et al.*, 1994; Speijer *et al.*, 1994) which lead to have low disease incidence compared with Meru District.

Relative to Meru district, there is no furrow irrigation in Rungwe and therefore, spread of pathogen through irrigational water is avoided. Also most of the farmers in Rungwe do not keep animals therefore no extensive pruning of leaves which reduces disease incidence.

The highest nematode damage between the two sites was reported to be in Rungwe District. However, the difference observed was small when compared with Meru District. The small difference in nematode damage might be contributed by presence of similar susceptible varieties to nematode (Matoke and Grand naine) INIBAP, (1997) in both regions and similarity in climatic conditions. For example, Nkwamansa village in Arumeru District located 1406 meters above sea level is similar to Kalalo in Rungwe District which has an altitude of 1415 meters above sea level. Normally nematodes distribution is much influenced by altitude (Price 2000). For example, the occurrence of *Radopholus similis* rapidly declines at elevation above 1300 meters above sea level while *P. goodeyi* decreases below 1200 meters above sea level. *Helicotylenchus multicinctus* and *Meloidogyne* spp. are high at lower altitude (Elsen *et al*., 2000; Speijer and Fogain, 1999). However, there are some nematode species like *P. goodeyi*, with unique characteristics. They have much more restricted distribution and are said to have a lower temperature preference than others and its distribution is closely linked to altitude and the higher latitudes of the cooler banana growing areas of up to 1500 meters above sea level. (Bridge *et al.,* 1997). When looking on the specific crop, Matoke bananas has been affected more by nematode compared with other varieties. This is because Matoke, the East African Highland Bananas (AAA-EA) is more prone to *Pratylenchus goodeyi* which is the most prominent specie in East African Highland Bananas and found in many banana growing areas (Elsen *et al*., 2000).

Conclusion and recommendation

The present findings gave insights on the status of *Fusarium* wilt disease and nematodes on banana in Rungwe and Meru District. Both sites have shown to have *Fusarium* wilt and nematode but differ in incidence primarily due to susceptibility and resistivity of the varieties toward *Fusarium* wilt disease and nematode and management systems. Rungwe District grow more of the resistant varieties to *Fusarium* wilt disease compared with Meru therefore has low disease incidence. The data suggest that, the best way to reduce incidence and severity of both *Fusarium* wilt disease and nematode is by the use of resistant varieties and good management practices. Nematode population can be reduces by normal management practice like mulching as reported by Talwana *et al.* (2003) who observed that population of nematode (*R. similis*) was less in mulched mat compared with non-mulched mats. However, chemical control by the use of different types of nematicides exists. It is difficult to control *Fusarium* wilt disease by using any chemical method because the pathogen can survive for long periods in the soil and cannot be eradicated by any fumigant (Stoffelen *et al.* 200). The best way is the use of resistant varieties.

Acknowledgement

This work has been made possible by the financial support from IITA-Arusha Banana breeding program and The Nelson Mandela Institution of Science and Technology. We wish also to acknowledge support from District Executive Directors of Rungwe and Meru District for allowing us collecting data in their Districts. Lastly we would like to thank all extension officers in both Rungwe and Meru Districts for their cooperation during data collection.

References

Bridge J, Fogain R, Speijer P. 1997. The root lesion nematodes of banana. Musa Pest Fact Sheet **2,** 1-4.

Coyne DL, Nicol JM, Claudius-Cole B. 2014. Practical plant nematology: A field and laboratory guide. 2nd edition. SP-IPM Secretariat, International Institute of Tropical Agriculture (IITA), Cotonou, Benin p. 2-22.

Dean R, Jan Al, Van KZA, Pretorius KE, Hammond K, Antonio DP, Pietro DS, Jason JR, Marty D, Regine K, Jeff E, Gary DF. 2011. The Top 10 fungal pathogens in molecular plant pathology. Molecular Plant Pathology **13,** 614-626.

Elsen A, Speijer PR, Swennen R, De Waele D. 2000. Nematode species densities, root damage and yield of banana (*Musa* spp.) in Uganda. African Plant protection **6,** 31-34.

FAOSTAT. 2012. The Agricultural production. FAO; http: //faostat3.fao.org/browse/Q/QC/E.

Frison E, Sharrock S. 1999. Musa production around the world trends, varieties and regional importance. In: Networking banana and plantain: INIBAP Annual Report 1998. INIBAP, Montpellier, France p 42–47.

Gowen SR, Queneherve P. 1990. Nematode parasites of bananas, plantains and abaca. In: Plant Parasitic Nematodes in Subtropical and Tropical Agriculture. M. Luc, RA Sikora, J. Bridge. Eds. CAB International p. 431-460.

Heslop-Harrison JS. 2011. Genomics, banana breeding and super domestication. Acta Hort; 897:55–62. Horry JP, Ortiz R, Arnaud E, Crouch JH, Ferris RSB, Jones DR, Mateo N, Picq C, Vuylsteke D. 1997. Banana and Plantain. In: Biodiversity in Trust. Conservation and use of Genetic Resources in CGIAR centres. Fuccilo D, Sears L, Stapleton P. Eds. Cambridge University Press p. 67-81.

Inagaki H, Powell NT. 1969. Influence of the root-lesion nematode on black shank symptom development in flue-cured tobacco. Phytopathology **59,** 1350–1355.

INIBAP. 1997. INIBAP Technical Guidelines 1. Screening of *Musa* Germplasm for Resistance and Tolerance to Nematodes. In: Speijer PR, De Waele D. International Network for the Improvement of Banana and Plantain, Montpellier, France p 62-78.

Jonathan EI, Rajendran G. 1998. Interaction of *Meloidogyne incognita* and *Fusarium oxysporum* f.sp. *cubense* on Banana. National Agricultural Research Project on Banana, Sugar cane Research Stations. Nematol. Medit **26,** 9-11.

Jones DR. 2000. History of Banana Breeding. Diseases of Banana, Abaca and Ensete. CABI Publication, Wallingford, UK p. 544.

Karamura DA, Karamura EB, Tinzaara W. 2012. Banana cultivar names, synonyms and their usage in Eastern Africa. Bioversity International, Uganda p. 6-23.

Karamura DA, Njuguna J, Nyamwongo P. 2006. Kenyan Musa Expedition. Bioversity, Montpellier, France p. 13-19.

Kashaija IN, Speijer PR, Gold CS, Gowen SR. 1994. Occurrence, distribution and abundance of plant parasitic nematodes on bananas in Uganda. Preliminary results of a diagnostic survey. In: Adipala E, Bekunda MA, Tenywa JS, Ogenga-Latigo MW, Mugah JO (Eds). Proceedings of the first international crop science conference for Eastern and Southern Africa, Kampala 14-18 June 1993. African Crop Science Society **2,** 99-104.

Kilimo Trust. 2012. Banana Value Chain(s) in the EAC: consumption, productivity and challenges p. 3-8.

Koka S, Swennen R. 2017. Characterization of Banana Based Farming Systems in the Arumeru District, Arusha-Tanzania. Proceedings of the 19th International Conference on Agronomy and Cropping Systems (Toronto, Canada), June 15-16, 2017. International Journal of Agricultural and Biosystems Engineering **Vol 4,** No: 6, 2017

Kumar KPS, Bhowmik D, Duraivel S, Umadevi M. 1992. Traditional and Medicinal Uses of Banana. Journal of Pharmacognosy and Phytochemistry **3,** 51-65.

Maruo S. 2007. Development of the Plantain-based Culture of the Nyakyusa of Southern Tanzania. African Study Monographs, Suppl **34,** 21-38, March 2007 21.

Mgenzi SRB, Mkulila IS. 2004. Banana cultivar names, synonyms and their usage in Tanzania, (Lujugira-mutika sub-group), Presentation at 'Workshop on Banana Synonyms in East Africa,' 24-26th March, 2004.

Mgenzi SRB, Mkulila SI, Blomme G, Gold CS, Ragama PE, Karamura EB, Nkuba JM. 2005. The effect of pest management practices on banana pests in the Kagera region of Tanzania. In: G. Blomme CS, Gold EB Karamura. Eds. Farmer-participatory testing of integrated pest management options for sustainable banana production in eastern Africa. Proceedings of the workshop on farmer-participatory testing of IPM options for sustainable banana production in Eastern Africa, held in Seeta, Uganda, 8-9 December 2003. Montpellier, France, INIBAP p. 43-52.

Mohapatra D, Mishra S, Sutar N. 2010. Banana and its by-product utilization: an overview. Journal of Scientific and Industrial Research **69,** 323–329.

Ong KP. 1996. *Fusarium* wilt of banana in a Cavendish banana in a commercial farm in Malaysia. In: New frontiers in resistance breeding for nematode, *Fusarium* and Sigatoka (1995, Kuala 70 Lumpur, MY). 1996. Proceedings. Frison EA, Horry JP, De Waele D. Eds. Montpellier, FR. INIBAP p. 242.

Pérez-Vicente L. 2004. *Fusarium* wilt (Panama disease) of bananas: an updating review of the current knowledge on the disease and its causal agent. In. Memorias de XV Reunion Internacional de ACORBAT (Oaxaca, MX) p. 1-14.

Ploetz RC. 2005. Panama Disease: An old nemesis rears its ugly head. Plant Health Progress doi:10.1094/PHP-2005-1221-01-RV.

Ploetz RC. 2006. *Fusarium* wilt of Banana is caused by several pathogens referred to as *Fusarium oxysporum* f.sp *cubense*. Phytopathology **96,** 653-656.

Price NS. 2000. The biogeography of the banana nematode *R. similis* and *P. goodeyi*. In: Craenen K, Ortiz R, Karamura EB, Vuylsteke DR. 1996. Eds. Proceedings of first International conference on banana and plantain for Africa, Kampala, 14-18 October. Acta Horticulturae 540, 431-440.

Sikora RA, Bafokuzara ND, Mbwana ASS, Oloo GW, Uronu B, Sheshu-Reddy KV. 1989. Interrelationship between banana weevil, root lesion nematode and agronomic practices, and their importance for banana decline in the United Republic of Tanzania FAO Plant Protection **37,** 151-157.

Simmonds NW, Shepherd K. 1955. The Taxonomy and Origin of Cultivated Bananas. Journal of the Linnean Society of London (Botany) **55,** 302-312.

Smale M. 2006. Assessing the impact of crop genetic improvement in sub-Saharan Africa: Research context and highlights. In: Melinda, S., Edmeades, S., and De Groote. Eds. Promising Crop biotechnologies for smallholder farmers in East Africa: Bananas and Maize. Genetic Resources Policies Briefs p. 19-2006.

Speijer PR, De Waele D. 1997. Screening of Musa Germplasm for Resistance and Tolerance to Nematodes. INIBAP Technical Guidelines 1. International Network for the Improvement of Banana and Plantain, Montpellier. p. 47.

Speijer PR, Fogain R. 1999. Musa and Ensete nematode pest status in selected African countries. In: Frison EA, Gold CS, Karamura EB, Sikora RA. Eds. Mobilizing IPM for sustainable banana production in Africa. Proceeding of workshop of banana IPM, Nelspruit, South Africa. 23-24 November 1998 (Montpellier, France: INIBAP) p. 99-108.

Speijer PR, Gold CS, Karamura EB, Kashaija IN. 1994. Banana weevil and nematode distribution patterns in highland banana systems in Uganda: Preliminary results from diagnostic survey. In: Adipala E, Bekunda MA, Tenywa JS, Ogenga-Latigo MW, Mugah JO. Eds. Proceedings of the first international crop science conference for Eastern and Southern Africa, Kampala, Uganda, 14-18 June 1993. African Crop Science Society p. 285-289.

Stoffelen R, Verlinden R, Pinochet J, Swennen R, De Waele D. 2000. Host plant response of *Fusarium* wilt resistant Musa genotypes to *Radopholus similis* and *Pratylenchus coffeae*, International Journal of Pest Management **46,** 289-293.

Swennen R, Blomme G, Van Asten P, Lepoint P, Karamura E, Njukwe E, Tinzaara W, Viljoen A, Karangwa P, Coyne D, Lorenzen J. 2013. Mitigating the impact of biotic constraints to build resilient banana systems in Central and Eastern Africa. In: Vanlauwe B, Van Asten P, Blomme G. Eds. Agro-ecological intensification of agricultural systems in the African Highlands. Routledge, 2 Park Square Abingdon p. 85–104.

Talwana HAL, Speijer PR, Gold SC, Swennen RL, De Waele D. 2003. A comparison of the effects of the nematodes *Radopholus similis* and *Pratylenchus goodeyi* on growth, root health and yield of an East African Highland Cooking Bananas (*Musa* AAA-group). International Journal of Pest Management **49,** 199-204.

Van Asten PJA, Gold CS, Wendt J, De Waele D, Okech SHO, Ssali H, Tushemereirwe WK. 2005. The contribution of soil quality to yield and its relation with other banana yield loss factors in Uganda. In: Blomme G, Gold CS, Karamura E. Eds. Proceedings of a workshop held on farmer participatory testing of IPM options for sustainable banana production in Eastern Africa. Seeta, Uganda, 8–9 December 2003. International Plant Genetic Resources Institute, Montpellier p. 100–115.

Viljoen A, Mahuku G, Massawe C, Ssali RT, Kimunye J, Mostert, G, Ndayihanzamaso P, Coyne DL. 2016. Banana Pests and Diseases: Field Guide for Disease Diagnostics and Data Collection. International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria p. 11-34.

Viljoen A. 2002. The status of Fusarium Wilt (Panama disease) of banana in South Africa. South African Journal of Science **98,** 1–4.

Walker PT, Hebbleswaithe M, Bridge J. 1984. Project for banana pest control and improvement in Tanzania EEC report for the Government of Tanzania. London, Tropical Development and Research Institute p.129.