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The Alarming Spread of Banana Xanthomonas Wilt in Eastern Democratic Republic of Congo and its Impact on Food Security and Income

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ABSTRACT

Xanthomonas wilt of banana (caused by *Xanthomonas campestris* pv. *musacearum*) is an unforgiving disease. Rather than merely reducing yield, as do many diseases, it causes the fruit to ripen prematurely and rot. Since 2001, the disease has spread to several countries in east and central Africa. It was first observed in the territory of Masisi, 72 km northwest from Goma in North Kivu Province, DR-Congo in 2001. During a survey conducted in May 2006 in the framework of the USAID-funded Crop Crisis Control Project (C3P), Xanthomonas wilt was also observed in the Mahagi and Irumu territories, Oriental province (north-eastern DR-Congo close to the border with Uganda) and in the region between Beni (north Kivu, DR-Congo) and Bundibugyo (western Uganda). Here the disease had most likely spread from infected areas across the border in Uganda. It had also spread over an area with a 50 km radius in Kitchanga, Masisi, North Kivu. A survey conducted in May 2008 in the framework of the Belgian-funded project CIALCA, reported that Xanthomonas wilt had entered South Kivu (Minova, Kalehe territory). In north Kivu the disease is currently present in the districts of Masisi, Rutshuru, Beni, Nyiragongo and Walikale and in Oriental province the disease is currently present in the Mahagi and Irumu districts. The disease has thus spread over an area more than 600 km long (north-south axis). At least two million people in eastern DR-Congo are impacted by this disease which threatens food security and farm income. The most important means of dissemination are infected planting materials, contaminated farm tools and insect vector transmission. Extension efforts to contain the spread of Xanthomonas wilt are hampered by insecurity and inaccessibility of large parts of eastern DR-Congo.

Keywords: disease distribution map, north Kivu, south Kivu

INTRODUCTION

Bananas and plantains, predominantly grown by small-scale farmers, are the staple food for over 20 million people in DR-Congo (Bakelana and Mankangidila 1996). The production of bananas and plantains is affected by diseases of fungal, bacterial or viral origin (Biruma *et al*. 2007). Rather than merely reducing yield, Xanthomonas wilt of banana (caused by *Xanthomonas campestris* pv. *musacearum*; Tushemereiwe *et al.* 2003, 2004) causes premature ripening, rotting and total loss of fruits. Eventually the plant dies. After decades of being confined to Ethiopia (Yirgou and Bradbury 1968, 1974) production losses of up to 80% have been observed in heavily affected areas of Uganda and eastern DR-Congo, where the disease was first observed in 2001 (Tushemereirwe *et al.* 2004; Ndungo *et al.* 2004, 2006) Initially, infections were mainly on 'Kayinja', a juice banana known elsewhere as 'Pisang awak' (*Musa* ABB group) (Tushemereirwe *et al*. 2003; Kagezi *et al*. 2006; Kalyebara *et al*. 2006; Tushemereirwe *et al*. 2006; Smith *et al*. 2008). Since 2001, the disease has spread to several countries in east and central Africa. Xanthomonas wilt is primarily spread by insects that transfer inoculum from male buds of diseased plants to those of healthy plants (Tinzaara *et al.* 2006, 2007). The disease also spreads through contaminated garden tools (Yirgou and Bradbury 1974) and infected planting materials (Bagamba *et al*. 2006).

The first visible symptom of an inflorescence infection on banana is wilting of male bud bracts, followed by drying of the rachis, then premature fruit ripening and finally bunch rotting, followed by wilting and yellowing of leaves. The disease also affects pre-flowering plants which get infected either from infected mother plants or by contaminated garden tools. These pre-flowering plants develop yellow wilting leaves. Internally, cross-sections of the pseudostems show yellow bacterial ooze (**Fig. 1A**), while the cross sections of the banana fingers show rusty brown stains (**Fig. 1B**).

There are no known resistant *Musa* cultivars (Ssekiwoko *et al*. 2006b; Tripathi *et al*. 2008). However, it is thought that some cultivars are able to escape the disease because of their inflorescence morphology (Buddenhagen 1987; Tripathi *et al*. 2009). Natural infections have only been found in *Ensete ventricosum* and *Musa* spp. and not in any other cultivated or wild host plants in the east and central African region (Ssekiwoko *et al.* 2006a).

When Xanthomonas wilt was initially detected in eastern Africa several control measures were recommended,

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Fig. 1 (**A**) Cross-section of a pseudostem showing yellow bacterial ooze; (**B**) Cross sections of banana fingers showing rusty brown stains.

including de-budding with a forked stick, disinfection of cultivating tools with bleach (NaOCl) or by heat, and destruction of diseased plants/mats to eradicate or reduce disease spread. This strategy was based on experience in controlling other banana bacterial wilt diseases with similar epidemiology to Xanthomonas wilt (Turyagyenda *et al.* 2006).

In DR-Congo, Xanthomonas wilt was first identified in 2004 in the territory of Masisi, collectivity of Bashali, locality of Kitchaga, on the Bwerere hills, 72 km northwest from Goma in North Kivu Province, but local farmers reported that it had been present since 2001 (Ndungo *et al.* 2006). In subsequent years, the disease spread at this location at a speed of around 5 km per year mainly through contaminated farm tools. During a survey conducted in May 2006 in the framework of the USAID-funded Crop Crisis Control Project (C3P), Xanthomonas wilt was also observed in the Mahagi and Irumu territories, Oriental province (north-eastern DR-Congo close to the border with Uganda) and in the region between Beni (north Kivu, DR-Congo) and Bundibugyo (western Uganda) (www.c3project.iita.org). Here the disease had most likely spread from infected areas across the border in Uganda as the Virunga National Park is a natural barrier between the Masisi region and the region north and north–west of Beni. The disease had also spread over an area with a 50 km radius in Kitchanga, Masisi, North Kivu.

The spread of the disease in eastern DR-Congo has not yet been halted. It was deemed necessary to obtain an updated picture of the spread of Xanthomonas wilt in eastern DR-Congo to guide extension work and training on control measures so as to reduce the impact of the disease impact on food security and income.

MATERIALS AND METHODS

Surveys using questionnaires were conducted in the districts of Kalehe, Idjwi, Kabare and Walungu in South-Kivu province, in the districts of Masisi, Rutshuru, Lubero, Beni, Nyiragongo and Walikale in North-Kivu province and in the districts of Irumu and Mambasa in eastern parts of the Oriental province. Altitude and geographical coordinates of the survey sites were measured with a GPS. The surveys were conducted from February 14 till May 15, 2008.

In each district, four subdivisions were selected basing on banana importance in the community; in each subdivision, five key informants were interviewed. The district agricultural officer assisted with the selection of community leaders and at least 5 key informants for in-depth discussions on Xanthomonas wilt. Subsequent focus group discussions were held with 10 to 25 farmers twice per district. Photos of Xanthomonas wilt infected plants and typical disease symptoms (*i.e.*, yellow ooze and fruit discoloration) were used during the interviews. Farmer knowledge on Xanthomonas wilt symptoms, date of first appearance in farm or village and on means of disease spread were recorded. In addition, knowledge of disease control options, current application of these control measures and sources of clean planting material were recorded. Farmers were also requested to list all banana constraints/other diseases in their banana or plantain fields. In areas infected with Xanthomonas wilt the survey team also recorded information on the susceptibility of cultivars grown.

Field observations were made along a 25-50 km long transect in each district. Banana farms were visited and Xanthomonas wilt was diagnosed from visible symptoms (*i.e.*, yellow bacterial ooze in the pseudostem or real stem and discoloration of fruit pulp). The garden tools which were used for assessing diseased plants were disinfected using sodium hypochlorite (*i.e.*, household bleach/Jik).

Table 1 The development of Xanthomonas wilt in eastern DR-Congo.

Year	Collectivity	Territory	Province	Dominant *Musa* groups
2001	Bashali	Masisi	North Kivu	AAA-EA (37%), AABB (Kisubi 30%), AAB-Plantains (20%), AAA-Cavendish
2002	Bwito	Rutshuru	North Kivu	AAA-EA (40%), AABB-Kisubi (30%)
2003	Osso	Masisi	North Kivu	AAA-EA (45%), AABB-Kisubi (40%)
2005	Watalinga	Beni	North Kivu	AAA-EA (45%), AAB-Plantains (30%), AABB-Kisubi (20%)
	Ruwenzori	Beni	North Kivu	AAA-EA (42%), AAB-Plantains (40%), AABB-Kisubi (10%)
	Bakumu	Nyiragongo	North Kivu	AAA-EA (45%), AAA-Cavendish (25%), AABB-Kisubi (10%)
	Boga	Irumu	Orientale	AABB-Kisubi (40%), AAA-EA (25%), AAB-Plaintain (20%)
	Mahagi	Mahagi	Orientale	AAB-Plantains (38%), AAA-EA (28%), AABB-Kisubi (20%)
	Beni-Mbau	Beni	North Kivu	AAB-Plantains (48%), AABB-Kisubi (25%)
2007	Minova	Kalehe	South Kivu	AAA-EA (65%), ABB-Mugombozi (14%), ABB-Kivuvu (11%)
	Bwisha	Rutshuru	North Kivu	AAA-EA (38%), AABB-Kisubi (29%), AAB-Plantains (18%)
2008	Idjwi-North	Idjwi	South Kivu	AAA-EA (65%), AAA-Cavendish (20%), ABB-Kivuvu (10%)
	Idjwi-South	Idjwi	South Kivu	AAA,Cavendish (20%), ABB-Kivuvu (10%)
	Wanianga/Ntoto	Walikale	North Kivu	AAB-Plantains (60%), AABB-Kisubi (18%), AAA-EA (12%)
	Oicha/Mamove	Beni	North Kivu	AAB-Plantains (65%), AABB-Kisubi (20%), AAA-EA (12%)
	Beni-Banande Kainama	Beni	North Kivu	AABB-Kisubi (50%), AAA-EA (27%)
	Kiwanza	Rutshuru	North Kivu	AAA-EA (38%), AABB-Kisubi (29%), AAB-Plantains (18%)

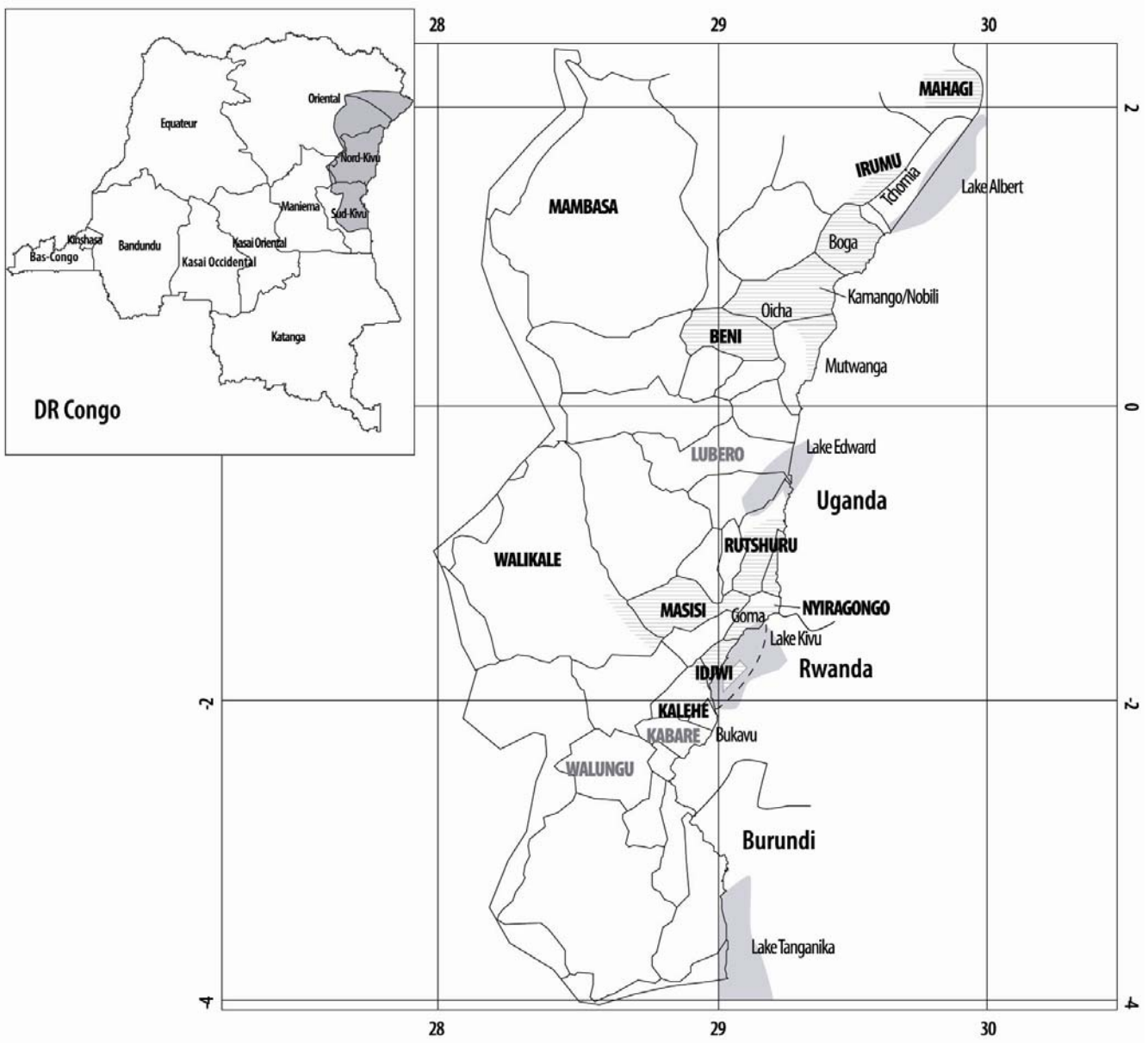

Fig. 2 Spread of Xanthomonas Wilt in Eastern DR-Congo. The grey horizontal lines indicate the zones where Xanthomonas wilt is present; the district names are marked in uppercase bold for districts with Xanthomonas wilt and are marked in uppercase grey for surveyed districts with no Xanthomonas wilt. The dot in Masisi district, north Kivu indicates the site where Xanthomonas wilt was first observed in 2001.

RESULTS AND DISCUSSION

The most affected province remains North-Kivu where the disease was first reported in 2001 (**Table 1, Fig. 2**) (Ndungo *et al*. 2006). So far five districts are affected: Nyiragongo, Masisi, Rutshuru, Beni and Walikale. FAO, Goma has conducted several sensitizations campaigns during the period 2005-2008 and has uprooted several hectares of diseased mats under a food for work campaign (http://c3project.iita.org). Xanthomonas wilt has also been observed in South-Kivu in the district of Kalehe (Kihata and Mahuge situated 14 km from Minova towards lake Kivu and 55 km west of Goma) and in the district of Idjwi (Kashofu in Idjwi-South and Bumpeta in Idjwi-North). No diseased plants were observed in the districts of Kabare and Walungu. In Oriental province the disease is currently present in the districts of Mahagi and Irumu (**Fig. 1**).

The disease has thus spread over an area more than 600 km long (north-south axis). At least two million people in eastern DR-Congo are affected by this disease which threatens food security and farm income.

The outbreak of Xanthomonas wilt around Beni, North Kivu most likely originated through cross-border trade in bananas with Uganda, while the outbreak in Gisenyi, Rwanda may have resulted from the movement of displaced persons from Masisi in north Kivu. Hence special attention is needed along the long border line of DR-Congo with Burundi, Rwanda and Uganda in order to reduce cross-border movement of the disease.

The most important means of dissemination are infected planting materials, contaminated farm tools and transmission by insect vectors as is the case in Uganda (Buddenhagen and Elsasser 1962; Eden-Green 2004; Tinzaara *et al.* 2007). Returning refugees may also contribute to the spread of this disease by inadvertently using diseased banana suckers to establish new banana plantations. Insect vector transmission is widespread in the area between Beni, North Kivu and Bundibugyo (western Uganda) (at 1,100 masl) where 'Pisang awak' (*Musa* ABB group) is widely cultivated.

Although Xanthomonas wilt affects all types of banana there is a variation in susceptibility. The most susceptible cul-tivars are 'Pisang awak' (*Musa* ABB genome) and 'Mugombozi' (*Musa* ABB genome), followed by the plantains and 'Kamaramasenge' (*Musa* AAB genome) and the east African highland beer and cooking types (*Musa* AAA-EAHB). The AAA-EAHB varieties with persistent male bracts and flowers were described by the farmers as less susceptible. This is in line with reports from Uganda and

Ethiopia (Addis *et al*. 2004) that the absence of bract and flower scars/wounds prevents the entry of the bacteria in a plant's vascular system. The AAA-EAHB are more susceptible than the AAA-Cavendish types which are in turn more susceptible than 'Nakasimbu' ('Yangambi Km5' – *Musa* AAA group).

Due to insecurity, inaccessibility of large parts of eastern DR-Congo, the vastness of the infected banana growing regions and financial constraints, extension efforts to contain the spread of Xanthomonas wilt have so far been limited. Development and extension activities related to Xanthomonas wilt have been conducted in the framework of the USAID-funded Crop Crisis Control Project (C3P) (http://c3project.iita.org/). FAO Goma, North Kivu has also carried out training and diseased mat eradication work in Masisi and Minova. Extension activities focusing on soil fertility, germplasm, and pest and diseases have started in several locations in South and North Kivu in the framework of CIALCA (www.CIALCA.org). This work will also focus on Xanthomonas wilt in regions already affected by the disease or regions under threat. In addition, during the past months NGOs, such as ACF South Kivu (www.actionagainsthunger.org), have started with Xanthomonas wilt extension activities. ASARECA (www.ASARECA.org) has launched, during early July 2008, a regional Xanthomonas wilt research and development project which will carry out activities in Burundi, DR-Congo, Kenya, Rwanda, Tanzania and Uganda.

A major bottleneck when re-establishing previously infested fields is access to clean planting material. Training in macro-propagation has been conducted and macro-propagators are being established at several locations in North and south Kivu (CIALCA 2009). However, sensitization efforts need to expand to all infected banana and plantain growing regions in order to prevent a major disruption in food supply and income generation. Farmers need to be trained in macro-propagation techniques in order to produce large numbers of clean banana and plantain plantlets. In addition, government institutions need to be involved in the sensitization process.

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REFERENCES

Addis T, Handoro F, Blomme G (2004) Bacterial wilt (*Xanthomonas campestris* pv. *musacearum*) on Enset and banana in Ethiopia. *InfoMusa* **13 (2)**, 44-45

Bagamba F, Kikulwe E, Tushemereirwe WK, Ngambeki D, Muhangi J, Kagezi GH, Ragama PE, Eden-Green S (2006) Awareness of Banana Bacterial wilt control in Uganda: 1. Farmers' perspective. *African Crop Science Journal* **14 (2)**, 157-164

Bakelana K, Makangidila K (1996) *Country Report: The State of Banana in Zaire*, INERA, Kinshasa, Zaire, 20 pp

Biruma M, Pillay M, Tripathi L, Blomme G, Abele S, Mwangi M, Bandyopadhyay R, Muchunguzi P, Kassim S, Nyine M, Turyagyenda L, Eden-Green S (2007) Banana *Xanthomonas* wilt: a review of the disease, management strategies and future research directions. *African Journal of Biotechnology* **6**, 953-962

Buddenhagen IW (1987) Disease susceptibility and genetics in relation to breeding of bananas and plantains. In: Persley GJ, De Langhe E (Eds) *Banana and Plantain Breeding Strategies*, ACIAR Proceeding **21**, ACIAR Canberra, pp 95-109

Buddenhagen IW, Elsasser TA (1962) An insect spread bacterial wilt epiphytotic of Bluggoe banana. *Nature* **194 (4824)**, 164-165

CIALCA (2009) Consortium for Improving Agriculture-based Livelihoods in Central Africa. Summary Technical Report, Final report phase 1, Jan 2006 – Dec 2008. Supported by the Directorate General for Development Cooperation (DGDC), Belgium, 91 pp

Eden-Green S (2004) How can the advance of banana Xanthomonas wilt be halted? *InfoMusa* **13 (2)**, 38-41

Kagezi GH, Kangire A, Tushemereirwe WK, Bagamba F, Kikulwe E, Muhangi J, Gold CS, Ragama P (2006) Banana bacterial wilt incidence in Uganda. Special issue. Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. *African Crop Science Journal* **14 (2)**, 83-91

Kalyebara MR, Ragama PE, Kagezi GH, Kubiriba J, Bagamba F, Nankinga KC, Tushemereirwe W (2006) Economic importance of the banana bacterial wilt in Uganda. *African Crop Science Journal* **14 (2)**, 93-103

Ndungo V, Bakelana K, Eden-Green S, Blomme G (2004) An outbreak of banana Xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the North Kivu province of the Democratic Republic of Congo. *InfoMUSA* **13 (2)**, 43-44

Ndungo V, Eden-Green S, Blomme G, Crozier J, Smith JJ (2006) Presence of banana xanthomonas wilt (*Xanthomonas campestris* pv. *musacearum*) in the Democratic Republic of Congo (DRC). *Plant Pathology New Disease Reports* **55 (2)**, 294

Smith JJ, Jones DR, Karamura E, Blomme G, Turyagyenda FL (2008) An analysis of the risk from *Xanthomonas campestris* pv. *musacearum* to banana cultivation in Eastern, Central and Southern Africa. Bioversity International, Rome, 31 pp. Available online: http://www.promusa.org/index.php?option=com_content&task=view&id=72

Ssekiwoko F, Taligoola HK, Tushemereirwe WK (2006*b*) *Xanthomonas campestris* pv *musacearum* host range in Uganda. Special issue. Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. *African Crop Science Journal* **14 (2)**, 111-120

Ssekiwoko F, Tushemereirwe WK, Batte M, Ragama PE, Kumakech A (2006a) Reaction of banana germplasm to inoculation with *Xanthomonas campestris* pv *musacearum.* Special issue. Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. *African Crop Science Journal* **14 (2)**, 151-155

Tinzaara W, Gold CS, Karamura E, Tushemereirwe WK, Blomme G, Turyagyenda LF (2007) Understanding the mode of transmission of banana *Xanthomonas* wilt for its management. ISAR National Conference. Sustainable agricultural productivity for improved food security and livelihoods. 25th-28th March 2007; Kigali Serena Hotel, Kigali, Rwanda, pp 181-195

Tinzaara W, Gold CS, Ssekiwoko F, Tushemereirwe WK, Bandyopadhyay R, Abera A, Eden-Green SJ (2006) Role of insects in the transmission of banana bacterial wilt. Special issue. Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. *African Crop Science Journal* **14 (2)**, 105-110

Tripathi L, Mwangi M, Abele S, Aritua V, Tushemereirwe WK, Bandyopadhyay R (2009) *Xanthomonas* wilt: A threat to banana production in East and Central Africa. *Plant Disease* **93**, 440-451

Tripathi L, Odipio J, Tripathi JN, Tusiime G (2008) A rapid technique for screening banana cultivars for resistance to *Xanthomonas* wilt. *European Journal of Plant Pathology* **121**, 9-19

Turyagyenda LF, Blomme G, Ssekiwoko F, Mukasa H, Eden-Green SJ (2006) On-farm assessment of banana bacterial wilt control options. The 4th International Bacterial Wilt Symposium. Programme and Abstracts Book. 17th-20th July 2006. The Lakeside Conference Centre, Central Science Laboratory, York, United Kingdom, p 58

Tushemereirwe W, Kangire A, Smith J, Ssekiwoko F, Nakyanzi M, Kataama D, Musiitwa C, Karyaija R (2003) An outbreak of bacterial wilt on banana in Uganda. *InfoMUSA* **12 (2)**, 6-8

Tushemereirwe WK, Kangire A, Ssekiwoko F, Offord LC, Crozier J, Boa E, Rutherford M, Smith JJ (2004) First report of *Xanthomonas campestris* pv. *musacearum* on banana in Uganda. *Plant Pathology* **53**, 802

Tushemereirwe WK, Okaasai O, Kubiriba J, Nankinga C, Muhangi J, Odoi N, Opio F (2006) Status of banana bacterial wilt in Uganda. Special issue. Banana Bacterial Wilt in Uganda: A disease that threatens livelihoods. *African Crop Science Journal* **14 (2)**, 73-82

Yirgou D, Bradbury JF (1968) Bacterial wilt of enset (*Ensete ventricosum*) incited by *Xanthomonas musacearum* sp.n. *Phytopathology* **58**, 111-112

Yirgou D, Bradbury JF (1974) A note on wilt of banana caused by the enset wilt organism *Xanthomonas musacearum*. *East African Agricultural and Forestry Journal* **40**, 111-114