



## Banana *Xanthomonas* wilt in the DR Congo: Impact, spread and management

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### ABSTRACT

*Objective:* Since 2001 *Xanthomonas* wilt (BXW) has drastically reduced banana productivity in over 8000 km<sup>2</sup> of farmland in Nord Kivu Province of eastern Democratic Republic of Congo. Banana constitutes the major source of income and staple diet for 700,000 residents of the affected area and an additional approximately five million people who depend on banana in the neighboring regions. This paper looks at some of the factors that have contributed to disease spread and presents strategies that could contribute to effective management.

*Methodology and results:* The paper is based on a review of existing published literature, technical reports and some outcomes of disease surveys carried out in the eastern DRC. The dominant banana cultivar grown is Pisang Awak which is highly susceptible to BXW. The affected region is in the high altitude agroecological zone and disease appears to be transmitted through a combination of mechanisms including insect vectors and natural factors, e.g. water splash. Mechanical tools have less importance in disease spread, largely due to low effort made by farmers to management of banana plantations. In threatened areas, disease management has focused on training farmers to recognize disease and effective preventive measures. In affected areas efforts have been mostly directed to reducing inoculum and halting disease spread by destroying infected mats.

*Conclusion and applications of findings:* Poor and inconsistent implementation of management measures, either due to lack of knowledge, persisting civil instability or lack of resources among other factors continue to limit success in managing the disease. Recent surveys show that the disease is spreading westwards, with increased risk of further spread through the Congo basin to key *Musa* producing regions in central and west Africa. Some of the factors that could slow down the westward spread of BXW include sparse human populations in the forest zone, unfavorably hot ecological conditions in the forest, and higher plantain densities in western DRC.

**Key words:** DR Congo, Banana *Xanthomonas* wilt, impact, spread, management, agroecology.

### INTRODUCTION

Banana and plantain are highly important crops in the Democratic Republic of Congo (DRC) for food security, income generation and employment opportunities. The crops also

provide essential environmental protection services in shielding soil from erosion by water on the steep hillsides. In 2004 total production was estimated to be 282,520 tons of banana

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and 1,071,900 tons of plantains (FAOSTAT, 2006). The popular cultivar in eastern DRC is Pisang Awak (ABB) occupying nearly  $\frac{3}{4}$  of the land cropped with bananas in Nord Kivu Province. This cultivar, locally called Kisubi, is mostly grown for production of banana beer which is highly demanded in local markets. Other cultivars grown include East African Highland bananas (AAA) for cooking, dessert bananas (Sukari Ndizi, AAB and Cavendish, AAA), and plantains (AAB) (Ndungo *et al.*, 2005). In eastern DRC bananas are a major part of the staple diet, complementing other sources of food. The fruits can be cooked, eaten as a dessert, or processed into juice and banana wine, or into banana flour (Nchimba) which is a highly nutritious energy source.

Banana *Xanthomonas* Wilt (BXW) is a devastating bacterial disease caused by *Xanthomonas campestris* pv *musacearum* (Xcm). The disease was reported originally in Ethiopia on *Enset ventricosum*, a close relative of banana in 1968 (Yirgou and Brandbury, 1968). The same strain of *Xanthomonas* attacking *Ensete* was isolated a few years later from banana, in 1974. Outside of Ethiopia BXW was first reported in Uganda in 2001 (Tushemereirwe *et al.*, 2004), in central districts of Uganda, where the disease spread fast before effective measures could be taken to contain it. The presence of BXW in DR Congo was formally reported in 2004 (Ndungo *et al.*, 2005). However, farmers in the affected area indicated having noticed the disease from as early as September 2001 (Bakelana and Ndungo, 2004). In addition to Uganda and DR Congo, BXW is present in Rwanda (Muhinyuzwa and Gaidashova, 2006), Tanzania (Mgenzi *et al.*, 2006), Kenya and Burundi (unpublished).

Within DR Congo the first outbreak was reported on Bwera hills in Kichaga locality of the Masisi territory located in the eastern province of Nord Kivu (Ndungo and Kijana, 2004). Nord Kivu province is situated in East Congo lying between 0°58'N - 02°03'S and 27°15' - 29°58'E. Bwera hill, where the disease appeared first is located close to five small lakes referred to as Mokoto. The major town from Bwera/Kichanga is Goma, but there is considerable little exchange of people between the regions due to the relatively poor state of roads and insecurity that has persisted over the last few years. However, the insecurity has also caused frequent migration of people in the regions as they seek to escape war, a factor that might have contributed to spread of disease.

Considering the rather isolated and remote location of the Mokoto lakes at Bwera, there has been considerable speculation as to how BXW might have entered the area. Reports from Bwera residents indicating unusual sightings of birds have led to speculation that the initial inoculum may have been deposited by migrating birds, which reportedly land on the shores of the lake in particular seasons of the year. Proponents of this theory argue that these birds might have passed through locations in Ethiopia where they could have picked up the pathogen. However, based on the reports of disease outbreaks in both Uganda and DRC, it would seem that outbreaks occurred almost simultaneously in both countries, around the end of 2001. In Uganda, where no migratory birds have been reported close to the initial infection areas, it was speculated that the disease was introduced inadvertently by soldiers returning from war areas in western Uganda, and who might have had contact with bananas from DRC. This theory might have merit considering that plantains and bananas from DRC are routinely sold in western Uganda. None of these theories have been investigated to determine how BXW moved from Ethiopia to the Great Lakes region. As the diseased area widened within the Kichanga area, a second epicenter was observed on Hembe hill almost 10km from Bwera. A curious observation was that the banana farms in between the two epicenters were not diseased (Bakelana and Ndungo, 2004), which might be indicative of an aided dispersal mechanism.

The specific location where the initial BXW outbreak occurred at lies at a high altitude with temperature varying between 15 -20°C and rainfall averaging 1500mm yr<sup>-1</sup>. Based on data obtained from few surveys, initial reports appeared to suggest that the disease was spreading relatively slowly, at a rate of about 2.5 km yr<sup>-1</sup> (compared to the situation in Uganda), having expanded from one plantation in 2001 to several villages within a 10km radius after four years (Ndungo *et al.*, 2005). Upon further inspection of the affected site during a survey in October 2005, the disease was observed to have spread further with an additional (third) epicenter established. One epicenter was located at 1817m above sea level (asl) (S01 19 470; E029 02 031), being 8km away from the epicenter at 1784masl (S01 14 929; E029 02 113), and 15km from the next site at 1603 masl (S01 21 803;E028 58 291). In May 2006 a more detailed survey of the diseased area was

undertaken which revealed dramatically expansive areas affected by the disease, within a 50km radius. The disease had spread throughout the collectivity of Bashali and Oso in Masisi and Bwito in Rutshuru territory. In further surveys carried out during October 2006 more outbreaks were confirmed in Mutwanga area close to Butembo/Beni, which is further north of Kichanga, and even much further north in Mahagi near Bunia.

#### Disease symptoms, spread patterns and factors

*Xanthomonas* infections cause wilting of banana leaves, fruits ripen prematurely and rot, and eventually the entire plant and mat dies. Internal tissues in the pseudostem produce copious yellowish bacterial ooze and where present, the floral raceme exhibits partial necrosis or blackening of both the male bud and the most recently formed immature fruits (Eden-Green, 2005). On flowered plants, *Xcm* usually penetrates into the plant through moist cushions exposed when male flowers fall. Thus, symptoms are often observed first on the male bud and the rachis after the last fingers have formed. In the DRC, where much of the area affected by BXW is at high altitude (above 1600 masl) preliminary studies on disease spread (Mwangi *et al.*, 2006a) have showed that <50% of infections initiate at the male flower cushions, which is low compared to >75% of symptoms that initiate on male buds in the mid-altitude areas in Central Uganda. These observations have been interpreted as being indicative of less involvement of insects in disease transmission in these areas. It is suspected that the low temperatures in DRC averaging 15-20°C (Bakelana and Ndungo, 2004), which are similar to those observed in Ethiopian areas affected by BXW (Addis *et al.*, 2004), could reduce activity and/or populations of insect vectors of *Xcm*.

Observations in DRC show that in fields where wilt is already well established, >25% of diseased plants are infected before flowering, as compared to less than 10% of pre-flowering infections in the mid altitudes (Mwangi *et al.*, 2006a). The presence of a large number of plants that are infected before flowering suggests the existence of another mechanism of disease spread, besides insect vectors. In South west Uganda, e.g. Ntungamo, Mbarara and Bushenyi districts, banana plantations are highly valued and intensely managed. In the sporadic outbreaks of BXW that have occurred in these areas, the disease was noted to spread rapidly

due to use of contaminated tools, i.e. machetes and pangas used to trim leaves from banana trees. In contrast, banana farms in eastern DRC receive little management attention and therefore there is much less incidence of disease spread through tools. One difference, though, is that bananas in DRC are usually intercropped with cocoyam, groundnut or beans. In such a situation, disease could spread through hoes that are used for weeding, planting or harvesting the intercrops. It is also common to find animals grazing freely in some banana plantations in DRC. Animals could also carry disease on their mouthparts or on soil stuck to their hooves. In Uganda goats have been observed to spread disease as they browse (Mwangi, M., personal observation).

In the higher altitude areas, it is usual to observe prolonged banana leaves, especially during the rainy seasons. Extended precipitation increases the relative humidity while cloudy weather during the day reduces penetration of sunrays, leading to reduction in evaporation of water from the surface of leaves (Robinson, 1996). Studies under laboratory conditions simulating the effect of prolonged leaf wetness on infection process have shown that moisture on leaves is an important factor in *Xanthomonas* spread as well as survival and establishment on a plant (Mwangi *et al.*, 2006a). Rainfall can enhance pathogen spread through water splash between plants that are close to each other. Due to poor plantation management in the DRC, banana mats typically grow into a cluster of closely spaced stems and leaves, with some mats having over 40 stems in a cluster. This close clustering can enhance development of humid microclimates that would be favorable to disease development. Dense mats are also more likely to have higher incidences of mother-to-sucker and mat-to-mat transmission of bacteria, either splash effects or through root contact below ground. Water could also spread bacteria downhill in infected residues or eroded soil.

The presence of *Ensete ventricosum* on the hillsides around Bwere has been noted to be another important factor in the spread of BXW in DR Congo. Enset is the major host of *Xcm* in Ethiopia and the only other known natural host of the pathogen (Eden-Green, 2005). Infected Enset plants have been observed in the DR Congo especially starting 1740masl. Although Ensete grows as a wild plant, some of the local communities cultivate it and use leaves for roofing while the dried seeds

are ground and used to increase the potency of local brews. Effective management of BXW in eastern DRC must take into consideration appropriate measures to ensure disease reservoirs do not thrive within the Ensete population.

#### Impact of BXW

The BXW pandemic has had a significantly negative impact on food security and income of the affected population. The pandemic reduced banana production from an estimated 20 tons/ha/year, to virtually zero (Ndungo et al., 2005), with revenues falling from \$1600/ha/yr to nothing. Bananas were the main source of livelihoods for a majority of the population in Nord Kivu province, with over 90% of land occupied by cv Pisang Awak (Ndungo et al., 2005). The impact of the disease is all the worse due to the rapidity with which it decimates a plantation. Farmers have reported an average period of about six months from outbreak to total devastation of a plantation. As an indicator of loss, a farmer who owns 1.5 ha of banana with 2/3 of the plantation being cv Pisang Awak could produce an average of 50 jerricans of banana beer each month (each jerrican 20L). Two years after his farm was attacked by BXW the beer yield had reduced to 5 jerricans per month, equal to a 90% reduction. The price of a jerrican of beer has also increased from 400 to 1000 Francs within two years.

The total area of the affected Masisi and Rutshuru territories in North Kivu province measures about 8 000 km<sup>2</sup> and has about 700,000 inhabitants (100 000 households). Considering the rapid spread of the disease, the population in the area immediately threatened in both North and South Kivu, and Ituri district is estimated to be five millions (900 000 households). On average each household owns at least 0.5 ha of banana plantation. If BXW spreads to the threatened areas, the projected loss will eclipse 720 Million US dollars annually, with severe adverse impact on livelihoods. In times of normal production, North Kivu province was exporting part of its banan products to Rwanda and western parts of Uganda. There are also opportunities for small scale processing locally for upscale export business, e.g. a company (Gourmet Gardens) has its own farms and has also contracted over 3000 farmers to grow bananas for export in dried form to Europe. The continuing spread of BXW threatens the sustainability of these agricultural based enterprises.

#### Responses to BXW in DRC: challenges and opportunities

Knowledge of the mechanisms of BXW transmission is important for designing effective management strategies. If transmission is through insect vectors the focus would be on timely removal of the inflorescence which mostly attracts. Where transmission is mainly through contaminated tools effective measures would be to disinfect tools when in use or restricting use of tools unless when absolutely necessary. The measures taken to manage BXW have been based generally on disease status, e.g. whether disease is present, absent or threatening. It is estimated that 50% of the 8000km<sup>2</sup> affected in DRC is in the post epidemic phase, having lost most banana plantations and no longer dependent on banana for livelihoods. The remaining 50% is in epidemic phase but some level is still taking place. All areas beyond the affected area are considered threatened, although the risk varies depending on distance from the epidemic area.

#### Responses in pre-epidemic zone

Pre-epidemic areas include all banana producing areas that are not yet affected, but are threatened by the disease. Appropriate measures include raising awareness of the disease, and training on symptom recognition and preventive measures. The objective is to build capacity so that farmers can maintain surveillance and report new outbreaks to clearly identified authorities, who should be well prepared to take prompt action. To date these recommendations have not been very well implemented in DRC, largely because the affected area has been experiencing civil instability and government institutions have not been well facilitated. Although an informal surveillance and reporting mechanisms has evolved over time, responses have been lacking or slow and not well coordinated. Weaknesses in coordination are viewed as one of the reasons as to why the BXW has spread over large areas.

#### Responses in epidemic zone

In areas where outbreaks have already occurred, recommendations have included creation of a disease-free buffer zone or *cordon sanitaire* to interrupt natural spread. Farmers are advised to remove all infected banana plants and also to remove male buds (Blomme et al., 2005) on their healthy mats, and avoid using tools within their plantations until all diseased

plants have been identified and removed. The major challenge in this zone has been difficulties encountered in removing infected mats, which requires intense labor and effort.

One of the most problematic features of BXW (and other banana bacterial wilt diseases) is that they cause wilting and death of individual suckers but they rarely kill the whole stool (Thwaites *et al.*, 2000). Latent infection persists in the affected stool and may subsequently give rise to wilting of daughter suckers, thus perpetuating a source of infection within affected fields. Disease eradication thus would require destruction of all the affected stools and taking measures to prevent them from re-sprouting. In DRC most farmers either abandon the infected fields, or at most only chop down the infected plants and heap them around the farm. The stumps that remain after cutting down stems usually sprout rapidly and thus require repeated efforts to cut them down and prevent their re-growth (Mwangi *et al.*, 2006b). An alternative approach to mat removal has been tried, using herbicides. Application of Glyphosate (Roundup) or 2,4D to kill banana mats that are infected with BXW, which has been tried in Uganda (Blomme *et al.*, 2006), was also tried in the DRC. Glyphosate was found to be inappropriate since it acts on the root system and plants only wilt slowly, and thus continue to supply inoculum. 2, 4D, on the other hand, was viewed as unsuitable after trials showed it can kill cocoyams that are widely intercropped with bananas (*own unpublished data*).

#### *Responses in the post-epidemic zone*

The post epidemic areas include all areas where plantations have been destroyed to the extent of losing over 70% of the banana mats. In such areas the most immediate need is usually to find alternative sources of food and income. To cope with the BXW pandemic, farmers in Masisi have turned to other enterprises e.g. burning charcoal, harvesting wood. Data from a survey carried out in April 2006 (*own data unpublished*) show farmers' preferred crops for substituting the infected bananas would be cassava (14%), maize (13%), sorghum (11%), groundnut (9%), soja (8%), Irish potato (8%) and sweet potato (3%). Curiously, cocoyams which are almost universally intercropped with bananas in the area were not mentioned as a preferred substitute crop.

In addition to changing eating habits, changing the main cultivated crops has introduced new challenges. For example,

farmers' efforts to dry cassava before storage has not been easy in Masisi, partly due to long moisture days with few sunshine hours, but also apparently due to lack of processing skills. Cassava stored before it is completely dry often gets contaminated with fungal molds which reduce its quality and increase health risk due to potential accumulation of mycotoxins (Bandyopadhyay *et al.*, 2006). Other challenges are due to lack of well established marketing systems for the new substitute crops. Removal of bananas from hillsides exposes soil to erosion, which adversely affects the environment. Intense harvesting of trees to harvest timber or burn charcoal for income generation has also adversely affected the environment.

Interaction with farmers in the affected areas shows that in the long term there is a strong interest to return to banana production, if sustainable solutions to the BXW are found. The lack of Xcm resistant banana cultivars is a serious challenge since the disease has to be managed based on cultural options. Recent studies have shown that Xcm has a short lifespan in the soil, which could enable farmers to replant bananas after a rotation cycle with a non host substitute crop lasting at least six months long (Mwebaze *et al.*, 2006). When considering replanting farmers need to be adequately trained on measures to avoid re-infection of their plantations. Although all banana varieties that have been screened were found to be susceptible when artificially inoculated, some cultivars have been identified in DRC and Uganda that are tolerant to Xcm (Mwangi *et al.*, 2006c). Most of these cultivars are cooking types including Mbwarzirume, Nakitengu, and Gonja. The cultivars have persistent flowers and bracts, which make them less vulnerable to insect transmitted Xcm, and thus potentially valuable in the efforts to contain BXW and ensure adequate food supply.

BXW has also affected farmers' access to healthy planting suckers which they have traditionally obtained from their own farms or from neighbors. Infected suckers can be a major BXW transmission pathway and thus availability of planting material needs to be addressed as a component of BXW management efforts. The recently introduced macropropagation technology is proven to be cost effective and should be utilized to address scarcity of planting material (Tenkouano and Swennen, 2004). Macropropagation is especially appropriate for

eastern DRC where tissue culture technology is difficult to implement due to lack of infrastructure.

#### Preventing BXW spread to Central and West Africa

Based on the observed sporadic nature of BXW spread in the Great lakes region, it would be prudent to anticipate, and therefore prevent, disease spreading to western parts of DRC. There are several factors that could be exploited to delay the westward spread of disease. The large distance (almost 2000km) between east and west DRC might help in delaying spread of disease, and thus allow a window of opportunity that should be seized by authorities to organize response taskforces. It would also be prudent for other countries in the Congo Basin towards Central and West Africa to initiate disease surveillance programs as well as sensitizing and training research and extension agencies to respond should an outbreak occur.

The dense forests of the Congo basin might also present a natural barrier to disease spread, considering that human presence and density of bananas is less than in the East. The increasing density of plantains (relative to banana) as one moves westwards should also contribute to reducing disease spread since most plantain cultivars have persistent bracts and hermaphrodite flowers that restrict insect transmission of *Xcm*.

Although it is inimical to production, the generally low level of crop management in DRC would also help in reducing pathogen spread, since the incidence of disease transmission through tools is considerably reduced. However farmers need to be sensitized on the risks posed by intense intercropping practiced in DRC. In addition to the long distance between east and

west DRC, the rather difficult means of transport should also help to slow down disease spread. Notably, most transport between eastern and western regions of DRC is by air, which is easier to control and regulate the movement of potentially infected banana materials. This opportunity needs to be exploited to ensure regulation is enforced at major transport points, including boat transport along the river Congo. Transport along the river could present a particularly significant risk of spreading BXW due to the long journey along the river, traversing across regions with numerous stops at which bananas are likely to be loaded and offloaded. Awareness of the threat of BXW needs to be raised taking into consideration all stakeholders along the banana value chain in DRC. The taskforces that have been established in eastern parts of the country could be used as a base for establishing national taskforces for BXW management.

Importantly, strong partnerships have been formed between different organizations and agencies involved in BXW management in DRC and the region including local NARS and regional research and development organizations. The collaborative Crop Crisis Control Project has contributed significantly to dissemination of knowledge on BXW recognition and management. Such partnerships need to be strengthened and coordinated to facilitate training of farmers as well as efforts for technology development and transfer. There is no doubt concerted efforts will contribute to bringing BXW under control in the DRC. However, for the time being banana *Xanthomonas* wilt remains a devastating disease and a serious threat to food security in East, Central and West Africa.

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