C3P

Crop Crisis Control Project

RESPONDING TO BANANA XANTHOMONAS WILT AMIDST MULTIPLE PATHOGENS AND PESTS

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Brief 6

Abstract

Banana Xanthomonas wilt (BXW) is the most serious threat to sustainable banana production in East and Central Africa. Before the advent of BXW major biotic constraints were black leaf streak (Sigatoka), Fusarium wilt, bunchy top and streak viruses, weevils and nematodes. The rapid spread of BXW has diverted attention from the other biotic constraints, which, unlike BXW, rarely cause total yield loss. In addition, there are resistant varieties for most biotic constraints of banana, but not for BXW. Although in the Crop Crisis Control Project (C3P) the focus is on BXW, the multiple pathogens and pests in the region cannot be overlooked, as they are on the same crop and system. There are interactive effects between pests and pathogens that must be managed for successful rehabilitation of banana production, while extension messages need to be well developed to communicate clearly on numerous biotic constraints. The multiplicity of pests also demands increased investments in technical capacity to improve diagnosis and to ensure responses are timely and appropriate. With little extra effort, measures targeting BXW can also contribute to management of other biotic constraints. For example, the provision of clean planting material would in one stroke limit spread of several pathogens and pests that are potentially transmitted through infected suckers. This brief highlights areas of convergence for the management of BXW and other key biotic constraints facing farmers in East and Central Africa.

Introduction

Bananas have sustained livelihoods in the Great Lakes region for well over two centuries. Over that period productivity has faced numerous constraints, the major ones being declining soil fertility, pests and poorly

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developed seed production and product marketing systems. Bananas are grown in diverse farming systems that face a multitude of pests. There are no single pest/disease situations in sub-Saharan African banana systems, but a complex pest/disease system whose distribution is greatly influenced by the broad range of agroecological and socioeconomic factors (Frison et al. 1999). The most serious threat currently is Banana Xanthomonas wilt (BXW). Previously, the major biotic constraints were black leaf streak *(Mycosphaerella fijiensis)*, Fusarium wilt *(Fusarium oxysporum* f.sp. *cubense)*, nematodes (e.g. *Radopholus similis*), weevils (*Cosmopolites sordidus*), and in a few areas, viruses – see Ramirez et al. 2005. Most efforts are currently focused on managing BXW, but the other pests still need attention as they continue to present serious challenges.

Managing multiple pests and diseases simultaneously has several unique challenges that must be taken into consideration when developing integrated pest management (IPM) strategies. More resources and technical competence are needed, e.g. diagnostic manuals/guides, equipment and trained personnel for proper diagnosis and responses. Interactive effects between pathogens and pests often exacerbate disease severity and increase the proportion of yield lost. For breeders, pest and disease complexes have special implications, as each new variety needs to be screened for resistance to different pests likely to be encountered. For extension work, multiple messages may need to be developed and communicated, which could confuse farmers.

On the other hand, multiple pathogens and pests present unique opportunities for developing, testing and implementing solutions with multiple targets. For example, eradication of mats infected by BXW also knocks off all pests that depended on such mats for survival, while planting healthy seed prevents spread of all pests that are transmitted through suckers. Regional coordination efforts targeting one pest, e.g. BXW, could also be broadened to include policies for all pests with a transboundary character. Therefore, in the Crop Crisis Control Project, management strategies for BXW need to be conscious of the other pests and diseases, and where possible, activities should be integrated to address holistically the maximum number of constraints from this single investment. Some of the key diseases and pests in the Great Lakes region are highlighted below.

Figure 1. *Farmer debudding male flower.*

Banana Xanthomonas Wilt

Banana Xanthomonas wilt (BXW) is caused by the bacterium *Xanthomonas campestris* pv. *musacearum (Xcm)*. BXW was first observed on a close relative of banana, *Ensete ventricosum*, about 90 years ago in Ethiopia. In 1974, it was reported for the first time on bananas, also in Ethiopia. The pandemic currently spreading in East and Central Africa began in central Uganda in 2001 and has since then spread to the DR Congo, Rwanda, Tanzania, Kenya and Burundi.

BXW causes early ripening and rotting of fruits, with rapid wilting and eventual death of the entire mat. Suckers produced by contaminated mats are severely diseased and inevitably wilt before producing any bunches. The disease attacks all banana varieties.

The *Xanthomonas* pathogen can infect banana plants through various ways, and disease management strategies are most effective when based on knowledge of the mechanism of disease spread.

Figure 2A: *sporadic removal of infected mats (only one or few mats removed) presents less risks to environment.*

Figure 2B: *total removal of mats on flat land presents little environmental degradation risk.*

Figure 2C: *total removal of mats on hillsides presents the greatest risk for environmental degradation. Measures must be taken to protect the soil before banana mats are removed.*

The most efficient natural pathway of disease spread is through insect vectors that pick the pathogen when visiting plants to collect nectar or pollen. Insect vectors are of highest importance in mid-altitude agroecological conditions (1100 - 1600 m above sea level), where vectors are thought to be more active and to occur more abundantly (Mwangi et al. 2006). To reduce insect-transmitted infections, farmers are advised to remove the male flower immediately after the last cluster of fruits has formed. Removing the male flower, a process called "debudding", ensures there is no nectar or pollen to attract insects and also no entry points for the bacteria into the plant (see Figure 1). When farmers consistently remove the male flowers the impact of insect vectors is reduced drastically, even when ecological conditions are favorable.

The other main pathway of disease spread is through human activity: mainly through the use of tools that are contaminated by contact with infected plants and by utilizing infected suckers to establish new banana plantations in distant locations. Contamination through tools is an important factor where banana farms are more intensely managed, e.g. where farmers regularly remove excess suckers, dry fibers or green leaves. The risk of tools spreading disease can be minimized by disinfecting the knife (e.g. by dipping in bleach), using pesticides or fire after working on each different mat, while the use of suckers from sources certified to be healthy reduces further spread.

The tragedy associated with BXW is that once plants have been infected there is no remedy other than to uproot them since they will eventually die off. A new banana crop cannot be planted immediately after uprooting and removing infected mats because pathogen cells released into the soil can survive for up to 6 months. If there are any remaining plant parts in the soil the pathogen can survive for up to a year. After uprooting infected mats it is recommended to leave the field fallow or grow a crop that is not closely related to banana, and thus cannot be infected by the Xanthomonas pathogen.

Removing infected mats leads to a reduction in food, income and employment opportunities along the banana value chain as well as a reduced taxation base for the government. Exposed soils are also vulnerable to degradation through leaching and increased erosion risk (see Figure 2A, 2B, 2C). The specific measures taken to prevent and/or manage BXW depend on the intensity or threat of the disease in the target area.

Fusarium Wilt

Fusarium wilt is caused by a soilborne fungus (*Fusarium oxysporum* f.sp. *cubense*) and the disease occurs wherever bananas are grown. In East Africa (Ploetz RC 1990), Fusarium wilt was first reported in the early 1950s in Kenya, Tanzania and Uganda and is now widely spread in the region. All the affected cultivars

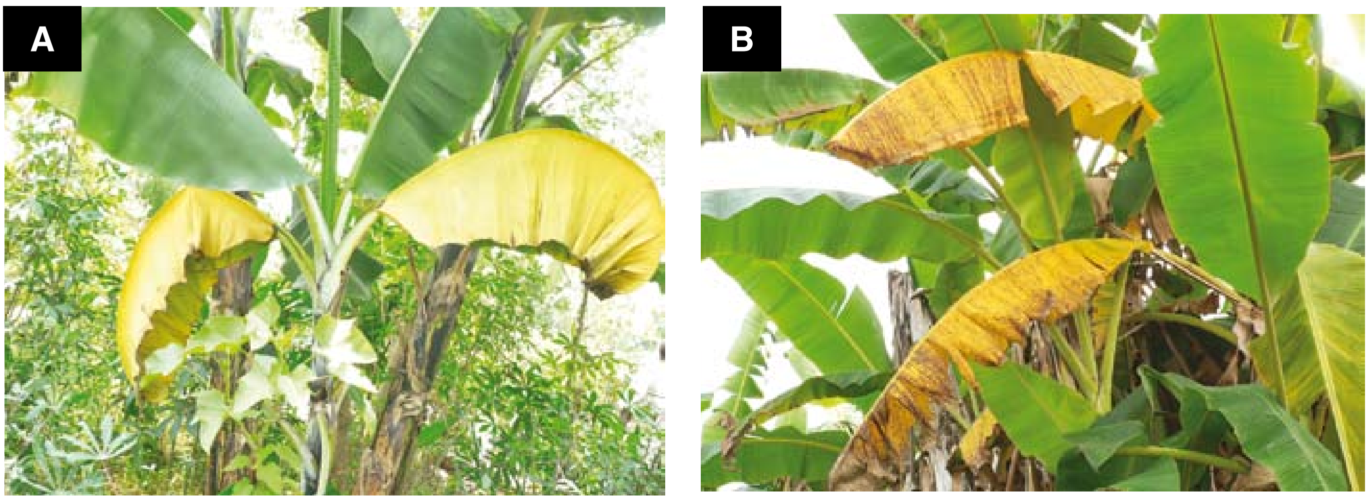

Figure 3: *Yellowing symptoms caused by Xanthomonas [A] and Fusarium [B] infection. Some of the similarities can complicate visual diagnosis and delay initiation of management measures. There is a need to develop robust diagnostic capacity in all the countries affected to ensure immediate and appropriate responses to diseases.*

were widely planted in the last century, e.g. cv Pisang Awak (*Kayinja* - genome ABB) and Ney Poovan (*Sukari ndizi*). The East African highland bananas (Matooke - genome AAA) are reported to be resistant to Fusarium, but there have been reports of infected mats in Mbarara, in the Kivu region, and recently from a young Mbwazirume sucker infected in Rwanda[1]. Traditionally four races of the pathogen are recognized, but there are reports of new pathogen populations.

Fusarium wilt mainly reduces bunch size but in rare severe cases it can cause 100% yield loss (Tushemreirwe and Bagabe 1999). Recent surveys in western Kenya (Mwangi et al. 2007) and Burundi found Fusarium wilt in 71 and 63.6% of the surveyed fields, respectively. The disease spreads mostly through infected suckers and rhizomes, but also in soil, water and on tools. The most effective management method is planting healthy suckers and starting on virgin land. Crop rotation is ineffective since Fusarium propagules can survive in soil for 30 years. In commercial plantations, soil fumigation has previously been effective but cost, environmental considerations and banning of methyl bromide has eliminated this option.

In relation to BXW management, Fusarium wilt presents challenges due to some similarities of leaf yellowing symptoms caused by the two diseases (Figure 3). However, there is an urgent need to develop robust diagnostic capacity in all the countries affected to ensure immediate and appropriate responses to both diseases.

Where Fusarium wilt is confused with BXW, farmers have been slow to respond appropriately to halt disease spread, since traditionally farmers have not been taking measures for Fusarium wilt management as it rarely manifests drastic yield reductions. Extension messages on disease recognition and management need to stress on the key differences between BXW and Fusarium wilt, and to insist on the need to take immediate measures when BXW is diagnosed. Importantly, the efforts being made through C3P to increase availability of clean planting suckers through macropropagation will prevent spread of Fusarium wilt as well.

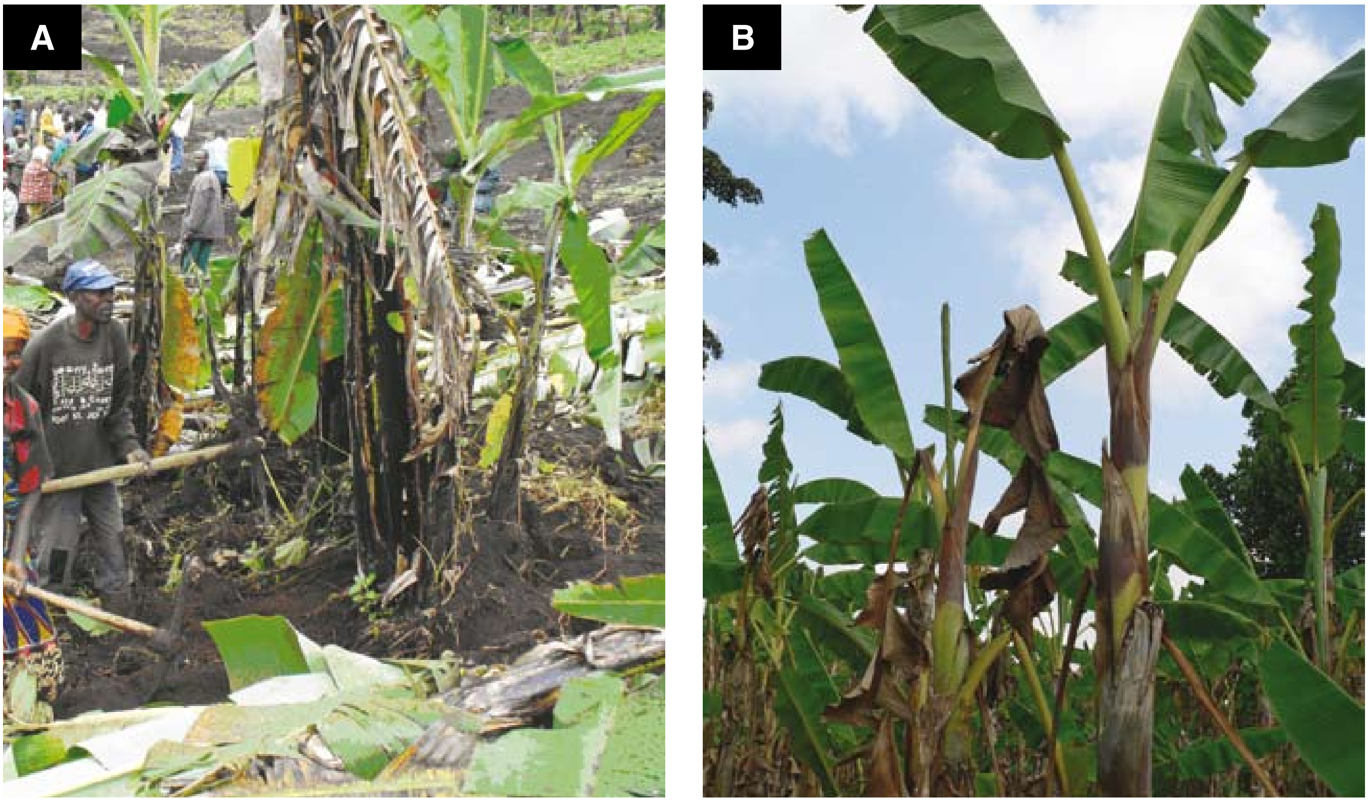

Figure 4: *Leaves infected with Black leaf streak (Sigatoka) [A] should be removed regularly to reduce inoculum sources and shading which creates suitable microclimates. Precautions should be taken to avoid spreading Xanthomonas wilt through tools when removing leaves [B].*

1 Samples delivered by Murekezi Charles (ISAR), isolated by Maina Mwangi (IITA). 2007.

Black Sigatoka Leaf Spot

Black Sigatoka leaf spot, also known as the "black leaf streak disease" (BLSD), is caused by a fungus, *Mycosphaerella fijiensis*. It is the most aggressive form of the *Mycosphaerella* leaf spot disease complex and causes up to 37% yield loss (Tushemereirwe and Bagabe 1999). BLSD was first noticed in Fiji in 1963 and was confirmed in all countries in East Africa between 1986 and 1990. Unlike BXW, black Sigatoka does not kill plants immediately, but loss increases with time and as the plantation ages. The disease destroys leaves, reducing functional leaf area. Infected fruit ripens prematurely and does not fill properly. Plants in the ratoon crop are much weaker and could sustain higher losses of up to 75%. Disease severity and incidence is high where plant density is high, since shading leaves create favorable microclimates for the pathogen. BSLD is managed by regular removal of leaves (every 7–9 days): those with fungal lesions in order to reduce inoculum production, and the abundant ones to reduce shading.

- Where farmers remove leaves intensively to manage BLSD (e.g. in the western Uganda matooke systems), the regular use of tools could greatly increase spread of BXW (Figure 4). Farmers in such areas must disinfect tools rigorously to avoid BXW spread.
- A careful assessment of BLSD incidence is required before recommendations touching on leaf removal are given. In most matooke systems, once BXW presence is noted farmers are advised to stop immediately the use of tools, including for leaf removal, for up to three months. This allows latently infected mats to express BXW symptoms and to be removed subsequently, without further disease spread. However, keeping leaves on the plants increases BLSD inoculum, which can significantly affect yield.
- BLSD can be effectively managed using resistant hybrids, but *M. fijiensis* has a high level of pathogen variability and therefore could easily break newly introduced resistance. Breeding for resistance to BXW thus needs to consider resistance to BLSD as well.
- In commercial plantations, BLSD is managed through fungicides, but this is expensive, requiring up to 36 spray cycles per year, and representing about 27% of the total production costs.

Cigar End Rot

Cigar end rot (CER) is caused by one of two fungi, either *Verticillium theobromae* or *Trachysphaera fructigena*. Both pathogens exist in Central Africa with the latter being more common. In recent surveys, CER was common in northwestern Rwanda, some areas in Burundi and eastern DR Congo. The disease causes a black necrosis spreading from the perinth into the tip of immature fingers, and the pulp undergoes a dry rot. The infected tissues are covered with fungal mycelia that resemble the grayish ash of a cigar end. The rot spreads slowly and rarely affects more than the first 2 cm of the fingertip. Incidence is highest during the rainy season. The pathogen colonizes banana leaf trash and flowers, from where spores are disseminated in air currents to other drying flower parts (Figure 5B). *T. fructigena* causes premature ripening of fruits, and

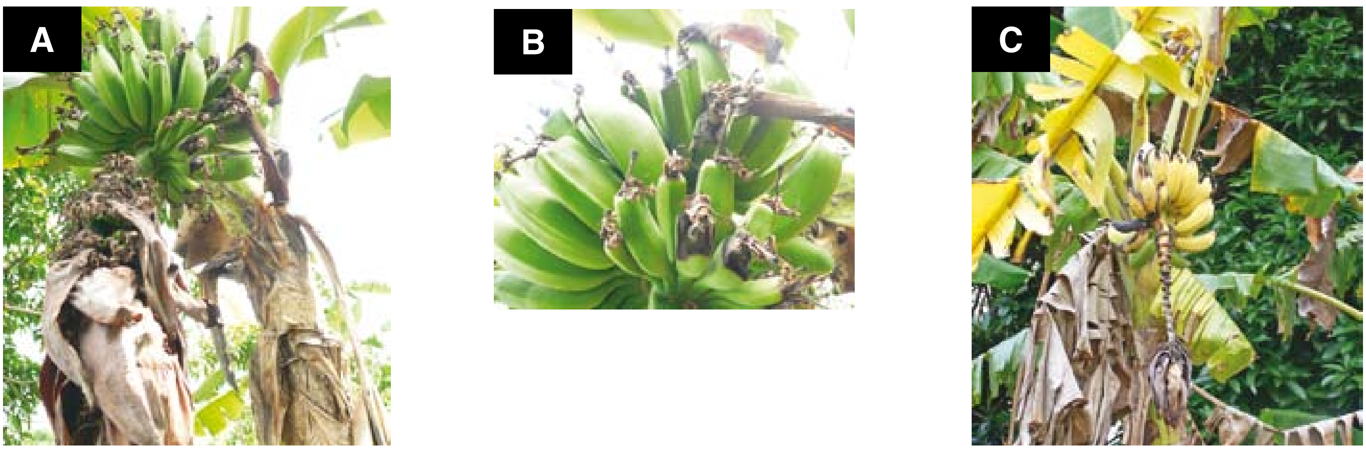

Figure 5: *Failure to remove dead flowers and male bud [A] provides incubation sites for pathogen causing cigar end rot [B] and entry sites for Xanthomonas wilt [C]. Early removal of male bud can provide a solution to both BXW and cigar end rot diseases.*

can attack fruits after harvest, invading freshly cut crown surfaces and wounds in the peel caused by improper handling.

Disease control is by:

- Early removal of dead leaves and flowers to eliminate inoculum before it reaches developing fruits. Infected fingers should be cut off before harvesting and packaging.
- With improved packaging, fruits can be washed in disinfectant, such as bleach, to remove *T. fructigena* or *V. theobromae*, and at the same time kill any Xanthomonas cells that may be smeared on the surface of fruits.
- In Rwanda, a common practice for CER control is to put a string on the male buds so that the bracts remain tightly held as the bud emerges and elongates. Bracts held in place could prevent spread of BXW by restricting insect vectors from accessing male cushions.
- Early removal of the male bud (after formation of last fruit cluster) should be promoted as it prevents spread of both BXW and cigar end rot, although through different mechanisms.

Banana Streak Virus

Banana streak virus (BSV) has been confirmed in Kenya (1993), Rwanda (1988), Tanzania (1988), Uganda (1990) and recently in the D.R. Congo near Goma (Mwangi 2006). Where BSV is severe, (Figure 6) mats have to be replaced after every three years due to rapid decline in productivity. Symptom expression is temperature dependent and the effect on yield depends on whether flowering and bunch initiation coincide with temperatures that increase virus replication within the plant. If temperatures are unfavorable, bunches would be normal, even though the leaves show symptoms. BSV infection can reduce plant stem girth by 6–53% and reduce yield by 6–7%. This virus is globally spread and it is the most commonly detected virus at banana indexing centers, presenting a major hindrance to movement of germplasm around the world. BSV spreads primarily through infected suckers. Mealybugs, e.g. *Planococus citri* and *Pseudococus* sp., can transmit the virus but under field conditions, this is limited. The disease has so far not been successfully transmitted by mechanical methods, thus cannot be passed on through cutting tools. Disease management is by:

- Using healthy suckers (e.g. through macropropagation targeting for BXW management).
- Destruction of infected plants to reduce sources of inoculum for mealybugs. (There are no methods at present to eliminate BSV from infected material, even through tissue culture, thus all infected material should be destroyed.)

Banana Bunchy Top Disease

Bunchy top disease is caused by the banana bunchy top virus (BBTV), and is one of the most serious diseases affecting banana (Dale 1987). The disease was first reported in Fiji in 1889 and has been confirmed in Burundi and Rwanda (1988) and the D.R. Congo (1982). Other reports are in Angola, the Central African Republic, Congo, Egypt, Gabon and Malawi (Pillay 2005). Plants can be infected at any stage of growth. Symptoms include rosetted and small leaves that are more erect than normal, giving the plant a "bunchy top" (Figure 6). Infected plants rarely produce a bunch though plants infected late in the season may fruit

Figure 6: *Banana bunchy top [A] and streak virus infection [B]. Both diseases can be effectively contained through use of healthy planting suckers.*

once, but the stalk and fruit are small and distorted. As with BXW, all suckers on a stool infected with BBTV are eventually infected. The virus is transmitted through infected suckers and can be transmitted by the banana aphid *Pentalonia nigronervosa*, but not mechanically. In studies on BBTV outbreaks, the average distance of aphid spread was 15–17 m and nearly two-thirds of new infections were within 20 m of the nearest source of infection. As with BXW, there are no known resistant cultivars to BBTV.

- Disease management is by using healthy suckers (thus will benefit from ongoing macropropagation efforts) and enforcing eradication of infected mats to remove sources of inoculum for aphids.

Banana Weevil

The weevil, *Cosmopolites sordidus* is the most important insect pest of banana and plantain. The weevil has a narrow host range and attacks only plants in the genera *Musa* and *Ensete*. Damage is caused by larvae feeding within the corm and pseudostem, causing galleries that weaken the plant and provide entry points for ants and other pests (e.g. BXW) (Figure 7). Damage eventually leads to plant toppling after snapping at the base. Affected plants suffer retarded and stunted growth, leaf drop and reduced bunch size; also the number and vigor of suckers is reduced. Eggs are laid at the base of the plant and emerging larvae tunnel into the corm and the pseudostem. The larvae are the only damaging stage of the insect but adults can live for two to four years. Many weevils reside in residues, or are burrowed in the soil, near mats.

Weevils are mostly spread through planting suckers containing eggs, larvae, pupae or adults. The adults can also walk over short distances. Weevil attacks are often severe and important in newly planted fields, but become unimportant after crop establishment and thereafter for several crop cycles. Weevil problems build up slowly and are more visible in ratoon crops, generally more during the rainy season and in mulched fields. Weevil management measures include:

- Using clean planting suckers (thus will benefit from ongoing macropropagation effort).
- Deep planting (60 cm) prevents weevils from locating the corm to lay eggs. This practice will benefit BXW management since tools cannot injure deep roots easily.
- Removal and chopping down of residues, exposing them to dry to reduce weevil-breeding sites. This practice benefits BXW management since bacteria in residues would die as residues dry. Removing mats for BXW management will thus reduce weevil populations.
- Crop sanitation and placement of mulches further away from the base of a banana mat is important for management as it reduces suitable habitat from close to the plant.
- Paring and hot water treatment of corms before planting.
    1. However, paring injuries can increase BXW incidence if corms are planted in soil infested with *Xanthomonas*. Farmers need to cure pared corms for 2–3 days. After paring (removal of roots and the entire outer surface of corms) the corm is exposed to air under shade for 2–3 days. Immediately after paring the surface is fresh and moist. After two days a hardened covering forms over the healed surface, which can not be easily penetrated by pests/pathogens.
    2. Weevil management also requires regular weeding and trash removal, which could increase BXW spread due to intense use of tools. This increases the need for disinfection.

Nematodes

Nematodes parasitize the banana root system and can reduce yield by up to 80% (Moens 2006; Dochez 2005). Root damage is induced directly and indirectly by facilitating the entry of fungi (e.g. *Fusarium*) and bacteria (e.g. *Xanthomonas*). It results in lower nutrient uptake, extends the harvest-to-harvest interval and increases plant toppling (Figure 7). The major nematodes include *Radopholus similis*, *Pratylenchus goodeyi*, *Pratylenchus coffeae*, *Helicotylenchus multicinctus* and *Meloidogyne* spp. In Uganda, production losses of over 50% have been observed on banana cultivar Nakitemebe and 37% for cultivar Mbwazirume. The nematode *R. similis* contributes to most plant toppling, but generally, the extent of losses that are inflicted depends on the banana genotype. A strong interaction between nematode and weevil damage has been reported in Kenya. Banana nematodes are generally difficult to manage as they live well protected in the root and rhizomes.

Management measures include:

- Planting healthy suckers (Figure 8). Starting with healthy suckers will lengthen plantation life from

Figure 7: *Weevils damage to roots and corm [A] can facilitate spread of Xanthomonas wilt [B]. Nematodes damage roots and cause toppling of plants prematurely [C]. Nematodes and weevils are effectively managed by use of healthy planting suckers and crop rotation.*

Figure 8: *Planting healthy suckers [A] produced by tissue culture [B] or macropropagation [photos C, D & E] is one of the most efficient ways of preventing spread of pests and diseases.*

two to over five cycles and increase production by 30–50% for each cycle for a period of at least three cycles due to reduced nematode effects.

- Using resistant varieties. Most breeding efforts have had considerable success finding resistance; the major challenge is identifying resistance to several nematode species.
- Crop rotation, break cropping and fallowing. This aims to starve the nematode and reduce the population so the next crop starts with a lower population. However, the perennial nature of banana production does not provide opportunities for crop rotation. Some opportunities are coming up where banana mats infected by BXW are being removed, and periods of at least six months are recommended before replanting banana. Rotation crops should be selected carefully since some nematode species have a wide host range. For example, cassava, sweet potato and pineapple are good rotation crops to suppress *R. similis* and *H. multicinctus*.
- Application of nematicides. In relation to BXW management, nematicides would be more helpful if applied at the time of planting when young suckers are more fragile and vulnerable to attack by pests. Research has shown some pesticides may have adverse effect on *Xanthomonas* populations in the soil. However, cost, availability and environmental concerns are some factors that do not favor use of nematicides.

Conclusion

While the focus in C3P is on management of Xanthomonas wilt, a variety of biotic constraints will continue giving major challenges to production of banana and plantains in East and Central Africa. Helping farmers to produce and use healthy planting suckers will have far-reaching effects beyond the management of BXW. Thus, the single investment made to promote macropropagation can have a multiplier effect with regard to management of biotic constraints. Considering the evolving nature of biotic constraints and their variability within regions and agro-ecologies, extension messages must be tailor made for the target audience and extension practitioners require regularly updated information on pests and disease threats. Governments in the region also need to continuously invest in technology and development of human capacity to ensure rapid and appropriate diagnosis of pests within their territories.

Removal of diseased banana crop

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