REMOVING INFECTED BANANA MATS TO CONTAIN XANTHOMONAS WILT:

Experiences in Uganda, Rwanda and the Democratic Republic of Congo

A brief prepared for the Crop Crisis Control Project

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Introduction

Bananas are extremely important for food security and income in East and Central Africa (ECA) with over 20 million people depending on the crop for their livelihood. Income is mainly generated from brewing and sale of both cooking and dessert bananas in local and export markets. In addition to fruits, other banana plant parts have important uses as construction material, fodder, and medicinal value and in numerous socio-cultural functions. Bananas also protect soil against erosion and leaching. This important crop is under serious threat from the *Xanthomonas* wilt pandemic spreading in the Great lakes region of East and Central Africa.

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 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 diseased mats are severely diseased and inevitably wilt before producing any bunches. The disease attacks all banana varieties.

Disease management

Xanthomonas can infect banana plants through various ways, and disease management strategies are most effective when based on knowledge of the mechanism of disease spread. 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 in higher populations[1] .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. When farmers consistently remove the male flowers the importance of insect vectors is reduced drastically, even when ecological conditions are favorable.

The other main pathway of disease spread is through human activity. Human spread is mainly through tools that get contaminated when they come into contact with infected plants. The disease also spreads if farmers use infected suckers to establish new banana plantations in distant locations. Tools are important 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

[1] Mwangi et al., 2006**.** Comparative study of banana *Xanthomonas* wilt spread in mid and high altitudes of the Great Lakes region of Africa. Tropentag symposium 2006, Bonn, Germany.

knife using pesticides or fire after working on each different mat, while use of suckers from sources certified to be healthy reduces further spread.

Rationale for removing infected mats

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 can not be planted immediately after uprooting removing infected mats since pathogen cells released into the soil can survive for a while pitting to risk the replanted suckers. After uprooting infected mats it is recommended to leave the field under fallow or grow a crop that is not closely related to banana, and thus can not be infected by the Xanthomonas wilt pathogen.

Removing infected mats leads to reduced food, income and employment opportunities along the banana value chain as well as reduced taxation base for government. Exposed soils are also vulnerable to degradation through leaching and increased erosion risk. The specific measures taken to prevent and/or manage BXW depend on the intensity or threat of the disease in the target area. Generally areas in which less than 50% of the farms are infected with each farm having less than 50% mats infected would be categorised as epidemic expansion phase. Areas with more than 75% of the farms infected, each farm having more than 75% mats infected would be categorised as post-epidemic phase. A critical transition phase could be defined to describe an area where more than 50% of farms are affected but each farm having less than 50% mats infected.

In fields where disease incidence is below 50% (Fig 1A), removing infected mats is recommended so as to reduce the inoculum load and thereby prevent disease transmission from the few diseased mats to the majority healthy mats. In this case mat removal has an underlying urgency since delays are likely to result in more mats getting infected, depending on the mechanisms of disease spread. Where conditions are favorable and insect vectors are abundant the disease primarily spreads sporadically but continuously from the infected mats to new plants as soon as they flower (Figure 2A). In secondary infection events the newly infected plants provide the inoculum that is spread to more plants, and the cycle continues. Where insect vectors are important disease spread can be contained by removing the male flowers and bunch of the infected plant to reduce sources of inoculum through which the insects get contaminated. Eventually, it is absolutely necessary to remove the entire mat that was infected to ensure no infected sucker will reach flowering stage as it might again provide a source of inoculum for insect vectors. Where contaminated tools are the main mechanism of pathogen dissemination, disease will most likely spread in a systematic manner starting from the infected mat and expanding outwards (Figure 2B). Unless tools are disinfected after working on each mat the number of infected mats increases rapidly, to a great extent depending on the frequency of use of tools within the farm.

In areas where disease incidence exceeds 70% (post-epidemic phase) there is very little chance of harvesting anything from any few remaining mats (Figure 1B). For farmers with small pieces of land it becomes necessary to remove the infected mats so the land is available for other enterprises, either alternative crop or livestock integration. Removing mats also starts the process of pathogen reduction in the soil, which is an essential thing to do if one intends to replant banana in the same field in future.

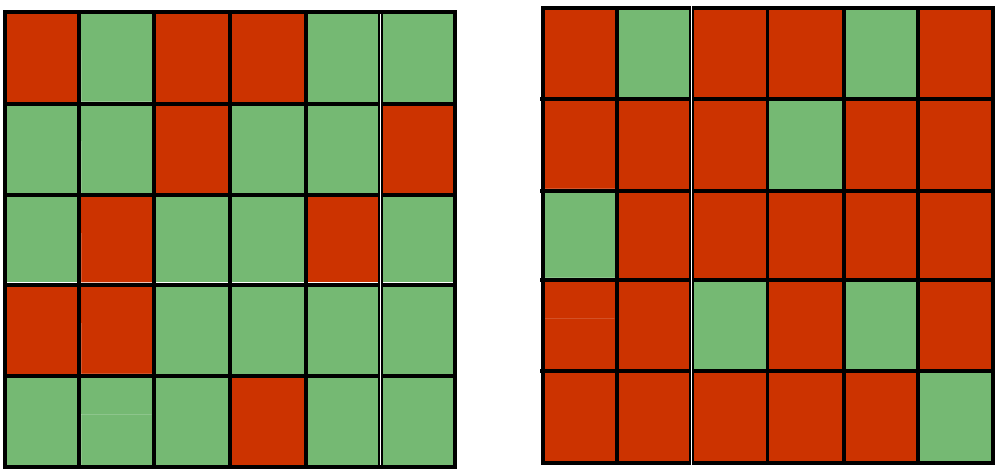

Figure 1 A&B. Hypothetical layout of a field in a pandemic expansion phase with 33% infected mats (left), and post epidemic phase (right) with 75% of mats infected. Red boxes represent infected mats while green boxes represent healthy mats.

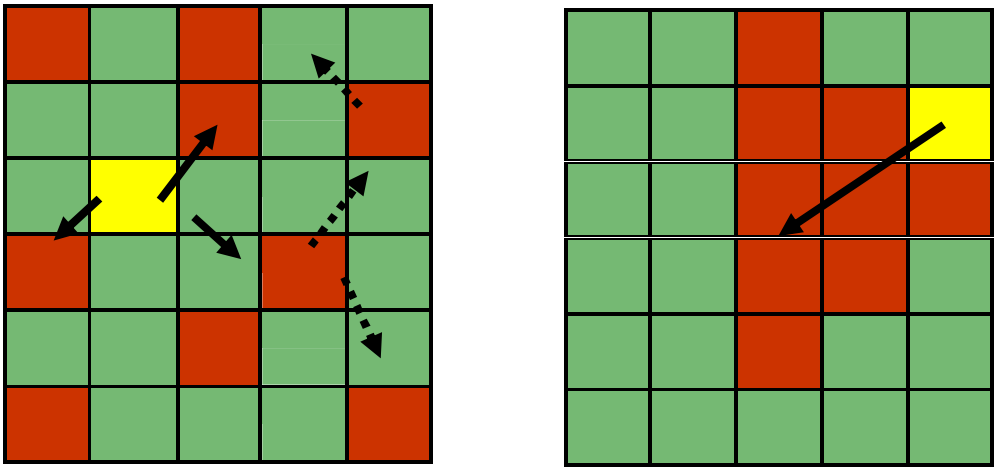

Figure 2A&B. Diagram on the left shows hypothetical disease spread by insect vectors when one infected mat (yellow box) is not uprooted and farmers are not removing male flowers. The solid arrow [⟶] represents primary spread from the infected plant to other flowered plants (red boxes), while broken arrow [▪▪▪▶] represents typical secondary spread from newly infected plants to other plants as they continue to flower. Diagram on the right shows hypothetical spread through tools when one infected mat (yellow box) is not removed. The disease usually spreads in a continuous pattern regardless of whether the plants have flowered or not.

Experince in Uganda

In Uganda the bacterial wilt pandemic commenced in September 2001 in Mukono[2] and Kayunga districts. These districts are located in the central region of the country where brewing bananas were dominant. Although bananas have been an important source of income and food in the central region, relatively less attention and management input was committed to plantations in this region, as compared to the south western districts of the country where most of the cooking Matooke bananas are produced. In the south western districts bananas are of the highest economic importance, and farmers pay great attention to maintain productivity at peak levels. The importance associated with banana in different regions is seen as an important factor in how farmers and other stakeholders respond to apply management measures recommended.

After the outbreak was reported in Mukono one of the immediate responses was formation of five teams in each affected village to carry out destruction of infected mats. Each team consisted of ten strong men and women (Kanyamas). Thus a total of 90 teams were formed in all the 18 villages that were affected by the disease. Within ten months after the outbreak was reported the teams had uprooted 94,000 mats, at a total cost of Uganda shillings 138 million (about 80,000 USD at current exchange rate). This would translate to 0.86USD per mat. Within the same period 85 000 newly infected mats were identified that awaited destruction. This quick measure reduced disease incidence below 10%, but could not be sustained due to the high cost of implementation[3]. The disease was at the same time found present in 13 districts as opposed to the original two target districts and spreading fast, thus necessitating a change of goal from eradication to contain the spread and manage the disease[4].

A new strategy was developed that put emphasis on protecting unaffected key banana growing areas, e.g. the south western districts. This strategy would be based on implementation of disease preventive measures (removal of male flowers, disinfecting tools and eliminating disease outbreaks in the zone. The last aspect of this strategy, eliminating disease spots in the zone depended entirely on effective removal of all infected plants as soon as they were spotted. Although herbicides have been demonstrated to be effective in killing banana stems, farmers in the south western districts appeared to opt for uprooting of the entire infected plant and burying in a hole. It is notable this could be done relatively easily because in this region there were few mats infected. Taskforces were formed starting from village level that would collectively contribute the required labor for monitoring and removing any infected plants. The task forces have in some cases been facilitated with provision of tools for uprooting and seeds provided to affected farmers to plant where banana have been uprooted. This community action approach based on zero BXW tolerance policy is still being pursued and being effected through prompt total removal of infected mats. The approach has largely contributed to the success achieved in eradicating the occasional outbreaks that have been reported in the south western districts. As a preventive measure total removal of mats has

[2] Progress report on banana bacterial wilt control. National Banana Research Program, Uganda. 26 July 2002.

[3] Tushemereirwe et al., 2006. Status of banana bacterial wilt in Uganda. African crop Science Journal, 14 (2): 73-82.

[4] Tushemerirwe, W.K, 2006. Implementation of the banana bacterial wilt control strategy: progress update. National Banana Research program, Uganda. June 2006.

worked well in western Uganda where the disease has not established, but as the experience of central Uganda shows mat removal would not be appropriate as the first response preventive measure in areas where disease is spreading fast. In such areas it is considered more valuable to remove mats in fields that are in post-epidemic phase in preparation for rehabilitation.

Experience in Rwanda

In the north western districts of Rwanda that are affected by BXW bananas are regarded with great importance and there is intense management of the crop to increase and sustain productivity. The disease has been present in the area since 2005 and has considerably spread with incidence (number of farms infected in the district) surpassing 50%. To manage the disease a local NGO (BAIR) organized the community to uproot and remove all infected mats in eight sectors of Rubavu district that are affected by the disease. A total of 1291 households were identified that had diseased fields with mats requiring removal. Each household was required to contribute one person to join others in forming teams that would move around the villages uprooting the affected farms. A total of 43 teams, each comprising 30 people were formed. According to this strategy farmers did not have to necessarily work in their farms, so any team could be allocated to any area. Each person contributing to the uprooting effort was provided with food assistance through Food for Work program. At the beginning of the uprooting initiative there was a total of 400 ha estimated area requiring mat removal and it had been estimated that each person could uproot and bury five mats per day. After two months of uprooting, and with the resources allocated already spent, only 256 ha had been uprooted. The residues of all uprooted mats were buried in holes. The major challenges encountered and lessons learnt from this strategy were:

1. One person could only effectively remove two mats per day, as compared to the originally estimated five mats per day, thus slowing progress. There were difficulties in some areas digging up holes due to volcanic rocks, while sometimes the operation time was affected by rainfall.
2. Quality of uprooting was affected because farmers were neither responsible nor always present in the teams removing mats in their own farms. BAIR has proposed to revise this strategy in future to ensure the owner of the farm is present and will be responsible for quality of the work done in his/ her farm.
3. There was no adequate mechanism provided to join the team initiative for farmers whose farms got infected after the uprooting had started. This might have led to a perception of farmers belonging more or less to the joint team initiative, depending on whether they were in or out. The key lesson here is that any strategy that appears to divide the community should be avoided at all costs since everyone has to act together for success to be achieved.
4. The motivation method (Food-for-Work) was not sustainable as the uprooting work came to a halt when the Food for Work support resources allocated got exhausted. However it is apparently difficult to organize the community to carry on the uprooting together if there is no motivation.
5. The presence of intercropped beans and other crops was a major challenge since these needed to be protected as they are a major source of food and income when bananas have been lost. To avoid damaging intercrops, farms with such crops can

be identified to be worked in later once the crops have been harvested. Farmers with diseased mats could also be discouraged from putting in intercrops, though this might be difficult as many farmers may not have access to alternative land. There is need to have a protocol for guiding the process of identifying the mats to be uprooted. In Rubavu, many mats that appeared healthy were left, though adjacent to infected plants, only to show symptoms after a short time, which demoralized farmers as it indicated that uprooting is not effective in stopping disease spread. Farmers need to be sensitized on the rationale of removing all plants around the infected mat, so as to reduce potential resistance.

Experience in DR Congo

When the BXW pandemic was confirmed present in DR Congo FAO and the World food program responded by initiating a campaign to cut down and uproot all infected plants. The FAO initiative was built on a strategy of organizing teams that would move through different farms uprooting all infected mats. The initiative was supported through cash for work while the WFP initiative was supported through Food for work. Since 2004 an estimated 100ha of infected banana mats have been removed by uprooting, though a much larger area was cleared but by simply cutting down the stems without removing the corms. As was the case in central Uganda it was quickly realized the disease had spread too far and resources would not be sufficient to sustain an eradication campaign. The strategy thus changed into supporting farmers to cope with the adverse impact of the disease, partly by providing planting materials of other crops (maize, cassava, beans, sorghum) to put in the areas where bananas had been destroyed and continued provision of food aid. In 2006 FAO supported uprooting of an additional 18 ha of land, but the residues were heaped on the surface without burying as done by BAIR in Rwanda. All the areas where bananas were removed have been under other crops, except few remnants or re-sprouted banana plants. Recent observations show that farmers are eager and are making their own effort to remove infected banana mats so they can utilize the land to grow alternative crops. A recent visit to the area where bananas were totally removed showed that:

1. Where mats were systematically removed and land put under non host crops for over one year, there is a possibility of returning bananas. A protocol is needed to guide certification of the land as being disease free before replanting can be done.
2. Labor for mat removal can be significantly reduced by heaping the residues instead of burying them. Heaping equally effective as burying and both methods require regular monitoring of the heaping or burying site to cut off any re-sprouting suckers.
3. The approach used to motivate/compensate the community to remove mats needs careful consideration for sustainability. As in Rwanda, community efforts to remove mats largely stopped after the cash and food for work programs ended.
4. In DR Congo bananas are important but the farms are not very well managed. In such case, as in central Uganda, mat removal is likely to pay off when done in post epidemic areas, to help farmers to cope and prepare for rehabilitation. Mat removal is unlikely to be effective or sustainable as a strategy for preventing disease spread.

Experience in Tanzania

In Tanzania BXW was confirmed present in January 2006. In Kagera region where the disease has attacked bananas are of absolute importance and most farmers pay significant attention with good management of plantations to maintain productivity. After the disease was reported the government institutions mobilized the community and embarked on a widespread campaign to remove the infected mats. Over 80,000 infected mats were removed in a relatively short time, though the disease continued to spread with outbreaks being observed in new villages. Farmers started by organizing themselves into groups and jointly removed mats in farms within a village. Subsequent efforts were driven by farmers own initiative. Compared to other countries, the experience in Tanzania is different in that there was no compensation paid or motivation provided to facilitate mat removal as was done in other countries. The strategy utilized here was to convince farmers of the need to remove infected mats to save bananas, which are of great economic importance to them. Except in some cases where government intervention was required farmers worked freely and made their own schedule for removing mats, with local leaders, researchers and agriculture extension staffs monitoring the work. Important lessons were:

1. It is very important to convince local leaders on the need to remove infected plants, as farmers pay more attention when the message is communicated through their own leaders.
2. Persuasion methods can include use of byelaws but more so should demonstrate the disaster facing farmers if they do not remove the infected banana mats.
3. The process should be participatory and farmers should be given room to appreciate the effectiveness of their chosen course of action, being facilitated to draw lessons from the actions they take. In Tanzania, a majority of the farmers who resisted removal of plants without symptoms ended up removing uprooting the entire fields later when plants thought to be healthy later showed symptoms.
4. Local task forces remain a critical component of any initiative to bring BXW under control. The success in Uganda and Tanzania could not have been achieved without formation and involvement of local task forces that find ways to carry on the effort. Lack of effective local taskforces is seen as one of the reasons for the stalling of mat removal efforts in Rwanda and DR Congo when external compensation support ends.

Methods for removing mats

Infected mats can be removed using one of various methods, with differing outcomes. To an extent the method chosen for removing the mats will depend on the acreage and the resources available for the task. Experience in Rwanda has shown BAIR had targeted to remove 400 ha with an initial estimation that one person could that one person can only effectively uproot and bury two mats per day. In DR Congo, where mats are much larger, each having over 25 stems and occupying areas of upto $4m^{2,}$ it is estimated that one person can only effectively uproot and bury one mat in one day.

Partial removal of mats

Due to difficulties faced in physically uprooting the mats, farmers in DR Congo have taken to trying out a method whereby the mat is partially removed. They only cut down the infected stems, place soil on top of the stumps (without uprooting) and plant beans or sorghum. This way the space available for growing other crops is increased without having to uproot the infected mats. This method has a major drawback in that the stumps continue to sprout infected banana suckers. Observations in DR Congo show that some crops e.g. sorghum when sown in high density can be quite effective in suppressing re-sprouting of the banana suckers. The main disadvantage of not uprooting mats is that bacterial inoculum persists in the soil and in the corms, making it impossible to grow bananas in the same field.

Mechanical removal of mats

The most effective method of getting rid of infected banana mats is by uprooting and burying or heaping the residues in one section of the farm. Comparing the experience in Rwanda and DR Congo, it is clear that burying has no major advantage over heaping the residues. The common problem associated with both methods is re-sprouting of suckers which require regular monitoring to remove them (Fig 3). Unnecessary difficulties in digging holes as experienced in Rwanda can be avoided by heaping. In Uganda, over 94, 000 mats were uprooted and buried in the initial wave of response to the pandemic. Due to the labour involved many farmers were reluctant to bury and instead preferred to heap the residues on the edges of the farm to rot gradually. No adverse effect was associated with heaping, and the only measures required are to prevent animals from disturbing/scattering the heaped residues, and if on a slope, measures would be needed to prevent the residues from being washed downhill by rainfall. These experiences tend to indicate there is no clear benefit in burying residues as compared to heaping them.

As mentioned above, a positive outcome of early removal of diseased mats was recently observed on the Bwere hills in Masisi, DR Congo. Here the farmers uprooted all diseased bananas with the support of FAO in partnership with WFP in 2004/2005 and they have been growing sorghum, sugarcane, cassava, beans or maize for the last two years. Since bananas are almost eradicated on these fields, it seems quite possible to replant bananas but with proper training to avoid re-infection. This is of course assuming there will be sources of clean planting material. In addition to helping the Bwere farmers re-establish their banana farms, provision of planting material might also encourage and motivate those lagging behind in neighbouring villages to follow suit and remove infected mats.

Experience in Rwanda shows total removal of mats can be hindered by the presence of intercrops. Following this experience, it would seem advisable that uprooting should be planned to commence after the intercrops have been harvested, which should also reduce conflict with farmers who may resist uprooting to protect their food crops. An alternative would be to identify farms with mats to be uprooted before the planting season commences, and notify their owners so that they do not plant intercrops.

Figure 3: Re-sprouting of suckers from banana residues. Figure on the left shows re-sprouting from residues buried in a hole while on the right re-sprouts are from residues heaped on the soil surface. In both case regular monitoring of the burying or heaping sites is necessary to remove the re-sprouts.

Using herbicides

Two herbicides have been evaluated and found to be suitable and cost-effective for killing diseased banana mats. The most effective chemical is 2, 4 D-Amine which causes stems to topple over quite rapidly, while Glyphosate acts gradually causing plants to wither and wilt after several weeks. However there have been concerns regarding the toxic nature and eventual fate of 2,4 D once it gets into the environment and its effect on non-target organism. In farms where bananas are heavily intercropped with Colocassiae, e.g. East DR Congo, experiments have shown use of 2, 4 D is inappropriate as it can kill this root crop. Although most of the experimentation with herbicides has been done in Uganda, there is as yet no documented widespread use of these herbicides in the country. In 2006, experiments were carried out with Glyphosate in Masisi, DR Congo. After six months results showed the chemical to have killed mats, but the results varied depending on competence of applicants. The key conclusion from the trial was that the effectiveness of herbicides would to some extent depend on the expertise of the applying teams. Evidence from published research data shows that use of herbicides can be cost-effective and less laborious as compared to physical uprooting of mats, and a small well trained team can eradicate large acreage in a relatively short time. An often mentioned advantage of using herbicides is that they reduce disturbance of the soil and hence minimise risks of erosion especially on hillsides. This may be true only to an extent since the banana mats treated with herbicides eventually die-off and the soil is left exposed to rainfall and erosion, unless other protective measures are taken.

Where land is scarce as in Rwanda and some parts of east DR Congo, herbicides are unlikely to be adopted since farmers would like to quickly utilise the space occupied by bananas, which would not be possible when using herbicides as mats take awhile to rot. . In some countries herbicides would also not be easily available nor affordable to small

scale farmers in rural areas where they have little application in ordinary farming operations.

Managing environmental degradation risk

A major concern associated with removal of infected mats is that it disturbs and exposes the soil to erosion risk on hillsides. This risk can be little if mats are removed sporadically from within a plantation (Fig 4A), or totally on flat land (Fig 4B) but could be significantly high where all bananas are removed on hillsides (Fig 4C). Recent experience from Rwanda where 256 ha of bananas were uprooted showed that the risk is further increased if uprooting is done during the rainy season. As a result of this concern there have been suggestions to declare a moratorium on further uprooting and possibly consider more benign methods such as use of herbicides, and these concerns need to be taken into account when deciding on mat removal.

However, going by the experience in DR Congo, it seems that farmers are determined to remove infected bananas and quickly start using the land. In both Rwanda and DR Congo farmers seem to be well aware of the risk of erosion and are also fairly familiar with the protective measures that would be required, more so in Rwanda where they are accustomed to farming on steep hills. In Rwanda farmers are willing to put in place measures to protect the soil from erosion, rather than leave the infected mats standing on their farms. The most commonly practiced measures for preventing erosion are digging trenches along the ridge and planting *Pennisetum* spp in rows 20 m apart along the ridge. There are also increasing numbers of farmers planting *Caliandra* sp and *Leucaena* sp, which increase soil fertility through N-fixation and are also used as fodder. Substitution crops could also be selected to include those that can provide good soil cover and protection to the soil e.g. sweet potato or sugarcane.

Environmental protection needs to be taken seriously and it is recommended to have extra resources for protective measures before actual removal of mats commences. The possibility of uprooting mats only during the dry season has been considered but it seems not practical given that dry seasons can be unpredictable and very short in some countries. In addition, recent experience in Rwanda has shown that the soil gets hard when dry, making uprooting much more difficult.

Figure 4A: sporadic removal of infected mats (only one or few mats removed) presents less risks to environment.

Figure 4B: Total removal of mats on flat land presents less environment degradation risks.

Figure 4C: Total removal of mats on hillsides presents greatest risk to environment degradation. Measures must be taken to protect soil before banana mats are removed.

Conclusion

Banana Xanthomonas wilt disease has presented a new challenge to farmers in East and Central Africa, to which there is no readily available effective solution. To combat the disease different communities in different countries have come up with various strategies depending on economic importance of banana locally, capacity of local institutions to respond and support disease management initiatives and resource availability. Removal of infected mats is a painful process, equated to the death of a child in many communities. It should only be considered as a measure of the last resort when all else has been attempted and failed.

As demonstrated through the hypothetical scenarios presented in this paper, where disease has not taken hold it is necessary to remove the few infected mats and hope to save the many more healthy plants. When disease incidence is extreme, it is necessary to remove all infected mats to free the land for use with other enterprises and as well commence the process of reducing pathogen inoculum in preparation for rehabilitation in future. As shown by experience from different countries, there is no one good method for removing infected mats. Across the region removing mats is recognized to be a most frustrating and labor demanding task, not least since there is no immediate reward for the effort invested. Yet if bananas are to be grown again in the region, it is imperative that farmers understand the need to invest the effort today, so that they may be able to replant bananas in future.

The challenges facing affected communities are largely similar. These include compensating for labor spent when removing mats, organizing community to act together, finding alternative sources of income and food and the frustration of not knowing if they will ever grow bananas again. The Crop Crisis Control Project has created an excellent opportunity for experiences from different countries and communities to be shared and exchanged. This opportunity should be utilized to also encourage farmers and restore their hope that if the right measures are taken today, BXW can be effectively managed and the possibility exists to grow bananas again.