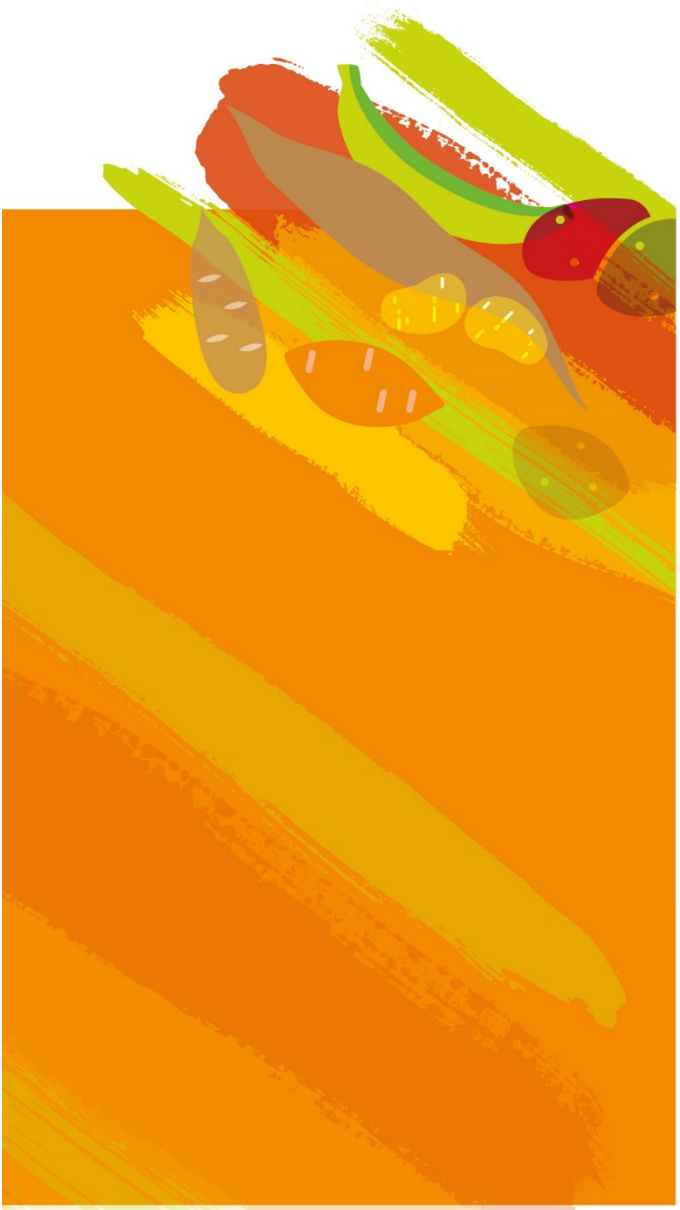

RTB Workshop Report

Proceedings for 3.3 Banana Wilts Cluster Planning meeting, 30th August-2nd September 2017, Kampala, Uganda.

Eldad Karamura, Elias Oyesigye and William Tinzaara

CGIAR RESEARCH PROGRAM ON Roots, Tubers and Bananas

LED BY CIP INTERNATIONAL POTATO CENTER A CGIAR RESEARCH CENTER · Bioversity International · CIAT Centro Internacional de Agricultura Tropical International Center for Tropical Agriculture · cirad AGRICULTURAL RESEARCH FOR DEVELOPMENT · IITA Research to Nourish Africa

Table of Contents

Acronyms

BAPNET	Banana Asia Pacific Network
BARNESA	Banana Research Network for Eastern and southern Africa
BXW	Banana Xanthomonas Wilt
CGIAR	Consultative Group for international Agricultural Research
EAHB	East African Highland Bananas
FAO	Food and Agricultural Organization
Foc TR4	*Fusarium oxysporum* f. sp. *cubense* tropical race 4
GMO	Genetically Modified Organism
IITA	International Institute of Tropical Agriculture
INISAV	Instituto de Investigacion de Sanidad Vegetal
LAC	Latin America and Caribbean
NARO	National Agricultural Research Organization
NPPO	National Plant Protection Organization
PCR	Polymerase Chain Reaction
R&D	Research and Development
SDSR	Single Diseased Stem Removal
VCG	Vegetative Compatibility Group
KARLO	Kenya Agricultural & Livestock Research Organization
ISABU	Institut des Sciences Agronomiques du Burundi
RTB	Root Tubers and Banana
NBRP	National Banana Research Program
TR4	Tropical Race 4
WBF	World Banana Forum
INREF	Interdisciplinary Research and Education Fund
qPCR,	Quantitative Polymerase Chain Reaction
LAMP	Loop Mediated Isothermal Amplification
KULueven	Katholieke Universiteit Leuven
CIRAD	Centre de coopération internationale en recherche agronomique pour le développement
NEPPO	Near East Plant Protection Organisation
APPPC	Asia and Pacific Plant Protection Commission

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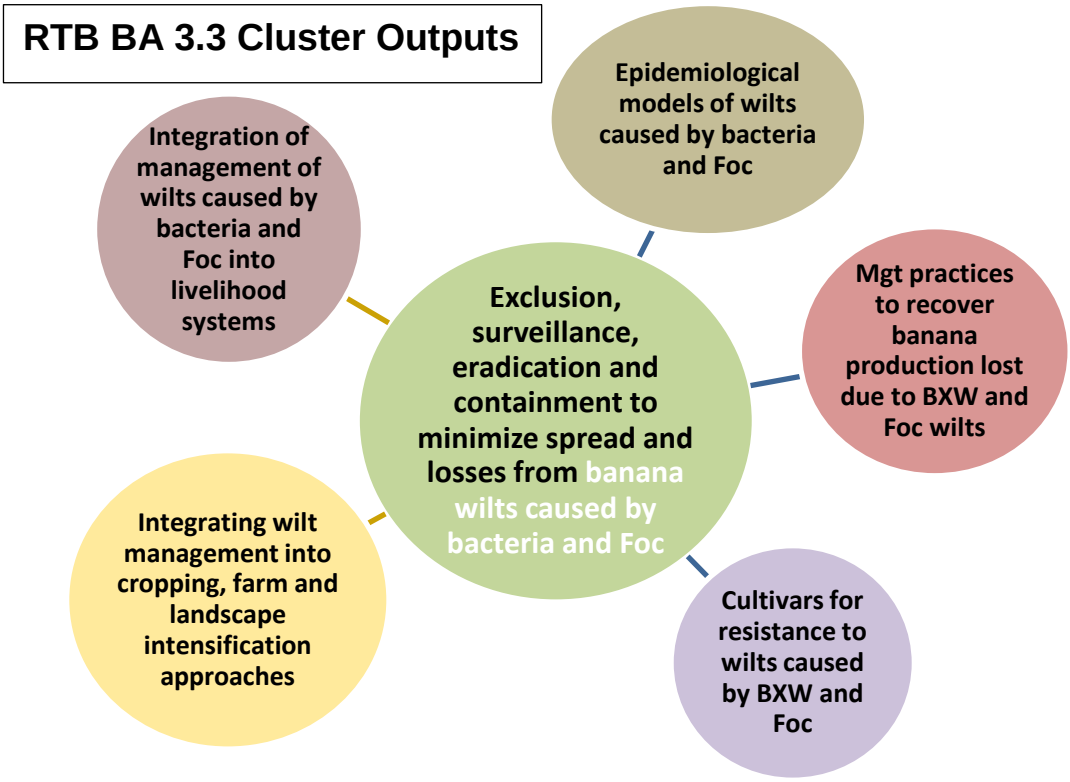
RTB Cluster BA 3.3 Banana Wilts Workshop, September 2017, Kampala, Uganda.

RTB Cluster BA 3.3 Banana Wilts

Cluster Title: Regional strategies and tools to arrest the spread of key fungal and bacterial wilts into new areas and recover banana productivity in endemic areas.



Diverse bacterial and fungal wilt diseases of banana threaten community livelihoods and national economies around the world. Production regions are variably, affected with differing degrees of risk. For example, Fusarium wilt Races 1 and 2 are widely distributed in Latin America, Asia and Africa, while Tropical race 4 is found in some countries in Asia, Africa and the Middle East. The bacterial wilts are regional in distribution with *Xanthomonas* in East and Central Africa but spreading; Moko *Ralstonia (Pseudomonas) solanacearum* in Latin America and the Caribbean; and, blood disease (*Pseudomonas spp.*)/Bugtok-moko (*Ralstonia* sp) in Asia. This cluster aims to marshal cutting edge and applied science in the fields of molecular biology, ecosystems modelling and socio-economics to exclude the wilts from wilt-free areas and contain and sustainably manage them in endemic areas to recover banana production. The collaboration will enhance cross-region learning technically and benefit millions of farm households and consumers on the ground. A global alliance of advanced research partners in the framework of RTB CG led by Bioversity, IITA, CIAT, and CIRAD and collaborating with national and regional organizations that work on various aspects of banana value chains in Asia, Africa and Latin America will collaborate to deliver the cluster outputs.

REPORT SUMMARY

Globally, the RTB conference on the Strategic Assessment of Banana Research Priorities, two wilt diseases (*Fusarium oxysporum f.sp. cubense (Foc)* and *Xanthomonas campestris musacearum*) of bananas came out globally as priorities, because of their impacts on smallholder production systems in key banana-dependent countries (D. Pemsl and C. Staver, 2014). At the regional level, the banana research network in east and southern Africa (BARNESA) at its annual meeting 2015 prioritized the two diseases as the most important threats to the smallholder systems in the region. Likewise, the banana networks in Asia (BAPNET) and Latin America (LACNET) have both prioritized Foc TR4 as the greatest threat to the banana industry in the respective regions. *Ralstonia* bacterial wilt has also gained increasing attention throughout South America and South-East Asia.

At the beginning of September 2017, Bioversity international-Uganda through RTB program hosted scientists from the three tropical continents (Africa, Latin America and Caribbean-LAC and Asia) for a review and planning meeting on Banana wilts (Banana Xanthomonas wilt-BXW and Fusarium wilt). The meeting objectives were to: (1) review past and current research on banana wilts in the three continents (LAC, Africa and Asia), (2) Identify research gaps and set up platforms on priority research directions including strategies for mobilizing resources. During the meeting, scientists made presentations; group and plenary discussions were held. The following were the succinct outputs achieved:

Current and past research on banana wilts was reviewed to reveal what has been done, the results obtained and the remaining gaps for each continent. The meeting observed that **especially so in Africa**:

- **i.** currently for both bacterial and fungal wilts, there are no elaborate actions to be undertaken before the disease arrives **(Pre-border activities);**
- **ii.** when the disease has arrived at the border **(On-border activities);**
- **iii.** after the disease has crossed the border but before it spreads out **(Post-border activities);**
- **iv.** no effective institutional arrangements that will support disease management actions across the board **(Off-farm activities),** and
- **v.** no measures to be undertaken when the disease has arrived on farm (**On-Farm activities)** to guide the respective practitioners to take timely and effective actions against the diseases.

In the issuing discussions, it emerged that there is no effective and strong political will, commitment and proper investment in plant biosecurity and phytosanitary actions required to deal with banana wilts. This may be linked to the lack of strategies for awareness-raising as well as the lack of proper risk and impact assessments to determine the threat of banana wilt diseases to countries and regions. In addition, especially for Foc TR4 there a lack of field detection capacity especially for latent infection, which means containment and eradication measures are not timely applied and the movement of planting materials, soil and water from Foc TR4-affected farms is not monitored.

The workshop finally agreed on the tentative priorities to be validated by the regional platforms:

Asia-Pacific

Blood disease & Bugtok

1. *Surveillance, early warning systems & mapping*. Survey of bacterial diseases in other countries in Asia and assessment of vulnerability according to cultivars' susceptibility and cropping systems.

Foc TR4

1. *Surveillance, early warning systems & mapping*. Survey of FW disease in other countries in Asia-Pacific (other than Philippines, China and Australia); development and adoption of disease management measures in new countries of occurrence
2. *Population characterization, linked to cultivar susceptibility and resistance maps*. Assessment of vulnerability according to cultivars' susceptibility and cropping systems

3. *Plant / soil health systems to suppress disease*. Study for deeper understanding factors that affect host pathogen interaction in the rhizosphere (suppressive soils), and understanding to operationalize it under field condition (biological controls).
4. *Assessment of risks and impacts.* Quantitative analysis of risk & impact of TR4 on different cropping systems (i.e. monoculture Cavendish vs cultivar and cropping system diversity by small farms); adoption and impact assessment on the use of new disease manage strategies & options (especially resistant soma-clonal varieties).
5. *Capacity building and raising awareness*. Promoting to small banana growers the use of the existing IPM strategies for improved adoption; awareness of stakeholders to prevent incursion; Enhanced regional and national information sharing on TR4 management and newly developed technologies.

Africa

Bacterial Wilts (BXW)

1. *Assessment of risks and impacts* as a basis for the development of national/regional/Africa-wide strategic plan/action plan (early reporting, management, investigation).
2. *Breeding for resistance in cultivated bananas.* Conventionally using resistant wild genotypes and genetic engineering for different production objectives.
3. *Fine tuning IPDM packages to meet the needs of different farming objectives*

Foc TR4

1. *Awareness creation and knowledge communication* linked to policy and investment at national and regional levels
2. *Surveillance, early warning systems & mappin*g to guide intervention applications
3. *Detection / Diagnosis (VCG determination)* linked to surveillance and capacity building for plant protection teams
4. *Cultivar characterization (cultivar susceptibility and resistance mapping)* linked to production systems
5. *Plant / soil health systems analysis to suppress disease incidence* linked microbial roles and interspecific exudate communication in the rhizosphere
6. *Assessment of risks and impacts.* Quantitative analysis of risk & impact of TR4 on different cropping systems (i.e. monoculture Cavendish vs cultivar and cropping system diversity by small farms); adoption and impact assessment on the use of new disease manage strategies & options
7. *Strengthening collaboration with policy makers and enforcers*: It was agreed that without intervention of policy makers, even with the best management package, little will be achieved in curbing the spread of banana wilts. It was unanimously agreed that once the report is ready and agreed upon, a committee will be set to bring on board policy makers around the three continents

LAC

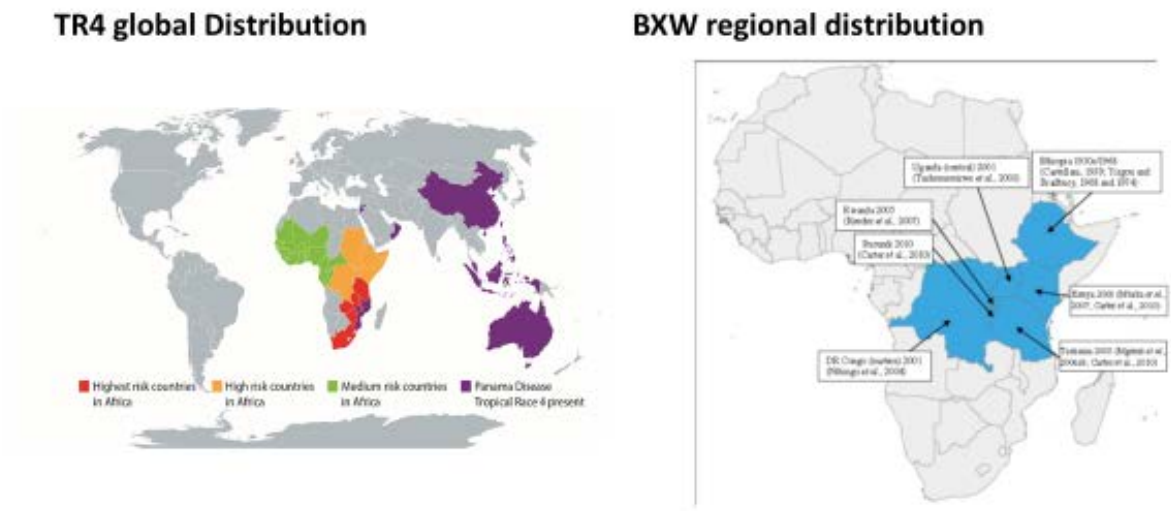
Foc TR4

1. *Strengthening Detection Capacity, especially Non-intrusive tools*. Regulatory bodies need to ALWAYS have well-trained Plant Pathologists and perform carefully analyses of the diagnostic process before making any inconvenient and groundless announcements. PCR, qPCR, LAMP, VCG analyses et al. are just techniques and do not replace plant pathologists.
2. *Raising the aware of Foc TR4, across the value chain stakeholders*. Using simulations will be carried out in quarantine services of OIRSA, in response to outbreaks, in diagnosis and in the management of phytosanitary emergency based on the Contingency Plan for Foc TR4 V2.0 and the Regional Action Plan for LAC
3. *Review/revision of the current PRA information*. In the light of the recent TR4 incursions in the Middle East, India and Africa. How was the disease transmitted in each case? Can it happen in LAC region and are there conditions in LAC that could enhance the introduction of Foc TR4 in that continent?

1. INTRODUCTION

Over the last 30 years, evasive and destructive wilts have attacked the crop and eliminated susceptible varieties and threatened banana-based livelihoods. In 2012, the RTB stakeholders meeting in Kampala prioritized Banana Xanthomonas wilt (*Xanthomonas campestris ssp musacearum*) and Fusarium wilt (*Fusarium oxysporum*, ssp *cubense*) largely because these diseases cause 100 % yield loss, especially in smallholder banana cropping systems and they are widely distributed (Fig 1). It is believed that successful management of these diseases is only possible through collaborative interventions including sharing knowledge and experience beyond national borders because when experience from different countries is shared, participants learn new innovations and the costs of practicing novel research are minimized. In this connection, a meeting was organized with the overall aim of strengthening banana research teams across Africa, Latin America and Caribbean (LAC) and Asia to combat threats posed by banana wilts. The meeting specifically reviewed past and current research on banana wilts in three continents (LAC, Africa and Asia), identified information gaps and set priority research directions including strategies for mobilizing resources. This report includes a summary of presentations, discussions and recommendations/way forward.

Fig 1. Wilts Distribution



1.1 Welcome remarks

The opening remarks were made by Eldad Karamura, the BA 3.3 Cluster team coordinator and Regional Representative for Bioversity International. He welcomed and thanked participants that honored the invitation to the meeting. Eldad underlined the threat to the banana industry in general and the potential plight of smallholder farmers if nothing is done to reverse the current rate of Foc TR4 spread. Other threats posed by bacterial wilts- BXW in Africa, Moko in Latin America and Blood Disease in South East Asia may be localized today but with the unpredictability due to climate change, their importance may elevate from being local to international threats. Apart from the threat to food and income security challenges, the banana wilts also threaten the environment- some wilts (like Foc) remain infective in the soil for decades while others tend to

weed out susceptible diversity which force affected farmers to change from banana cultivation (zero-tillage) usually to annual crops, requiring annual opening of land and leading to soil biodegradation and fertility loss. He stated that the current spread of these wilts mainly Fusarium is alarming- started in Asia in 1960s has now spread to the Middle East and Africa (Mozambique). He emphasized that the meeting should share experiences on the diseases and come up with strategies to curb the spread.

1.2 Workshop objectives

Eldad as one of conveners stated the overall objective of the workshop as- strengthening banana research teams collaborating within the RTB-BA 3.3 Cluster partnership who, since the Cluster was formed had not had an opportunity for a physical meeting and intra-team interactions. Moreover, the different regions had advanced variably regarding banana wilts research and now the aim is to facilitate researchers to discuss and share experiences in the quest to combat threats posed by the wilts and promote cross-region learning. This entailed:

- *the review of current and past R&D work, identification of information and technology gaps, and prioritization of the gaps at regional and global levels*. In this regard, the pioneering work carried out in Asia was shared, including the field evaluation of banana diversity in the Philippines as well as the genomics work in south China. From Africa, the discussions Focused on the Mozambique case for Foc TR4 and BXW in east and central Africa. Conversely the Latin American presentation discussed the biosecurity preparedness in anticipation of the arrival of Foc TR4;
- *the discussion and agreement on roles and responsibilities for addressing the identified gaps*; the issuing agreements and proposals on priorities and implementation plans to be reviewed by regional networks/platforms and adopted.;
- *the discussion on options for governance as well as strategies for funding*; both CIAT and CIRAD, core members of the Cluster team were not able to attend the meeting but there was overall consensus that the effectiveness of the Cluster team was dependent of availability of substantial funding and that the discussion of governance issues required presence of all core teams.

1.3 Expected output

- Shared current global experiences and research advances on key banana wilts.
- Priority intervention actions, roles/responsibilities and implementation and partnership plans
- Research gaps identified and organized into a competitive concept note
- Improved team spirit and common purpose.

1.4 Opening remarks (DG, NARO)

The Director General-NARO, Dr. Ambrose Agona, who officiated at the opening ceremony, welcomed participants from within and outside Uganda and underlined the importance of banana in Uganda. He recognized that Uganda as a country 'naturally gifted by God' to grow all RTB crops and more. He emphasized that Uganda should utilize the opportunities of having good climate and fertile soils to promote banana production. He added that Uganda is still lacking in terms of income per capita and value addition from banana but underlined the recent innovations in the banana industry, aimed at improving efficiencies and livelihoods. In this regard, he congratulated Dr. Jerome Kubiriba (Programme leader, NBRP) for facilitating the launching of the National Banana Cooperative Society, which will boost collective marketing and quality control of banana in Uganda. Regarding the management of banana bacterial wilt, he informed participants that the President of Uganda gave a directive to reduce prevalence of the disease to minimal levels; interestingly, this has been reduced to as low as 2%; the bad news of resurgence in some parts of the country as has been received recently will be resolved. He later added that the resurgence may give a justification that cultural practices may not sorely solve the problem; '…maybe it's time we unleash transgenic varieties now on shelf', he added. The DG was

eager to see NARO and other scientists in Uganda developing a "**super banana"** which can be high yielding, resistant to biotic and abiotic stress, and this variety would be able to create jobs, wealth and food security. Importantly participants were asked to work to bridge the gap between technology advancement on one hand and farmer adoption of new technologies, on the other because lots of technologies have been developed but have remained inaccessible to farmers who need them. He wished participants fruitful discussions and opened the meeting officially.

In the issuing discussion, the Program Leader, NBRP, responded to the DG about creating a super variety by highlighting that NABIO varieties are being developed to address the issue of super banana. Other diverse germplasm resistant to pests/diseases and tolerant to abiotic stresses are also being developed.

2. GROBAL OVERVIEW OF BANANA WILTS

Globally bacterial and fungal wilts occupy the same agroecologies but quite often different production systems. Bacterial wilts are more catholic in their infection modes, with all cultivated varieties succumbing to the disease, though high floral nectar-content cultivars (ABB), linked to insect transmission, appear to be most affected. These varieties are also grown in most regions as mixed cultivars in smallholder / subsistence systems. Conversely, fungal wilt spores are transmitted via soil and water. Both fungal and bacterial wilts are transmitted in planting materials. Hence there are similar management strategies for both groups of wilt diseases [surveillance and containment, use of resistant varieties (via classical breeding, somaclonal variation, genetic engineering and mutation breeding)] but there are also wilt-specific measures, based on cultural practices (debudding, decontamination of field tools, clean planting material, rouging of diseased plants). In all regions affected by these wilts, management measures have been prescribed/instituted to delay the arrival of the pathogens in disease free areas, arrest disease spread and recover productivity. The meeting provided an opportunity for cross-region learning- what has worked where and what has not worked where and why. All the regions were represented- Asia and Pacific provided the picture in the endemic region of Foc TR4; Africa shared the endemic case for BXW in east and central Africa and the epidemic situation for Foc TR4 in Mozambique. The Latin American team discussed the biosecurity preparedness in place in case Foc TR4 arrives in that region. In addition, there were presentations on the on-going strategic research in Chinese institutions. Below is the summary of the review papers presented at the workshop.

2.1 Foc TR4 in Bananas-successes, failures and lessons for strategic directions (Gus Molina)

The purpose of this presentation was to share successes, failures and lessons learnt for strategic directions in managing TR4. The presenter shared a brief history on Foc TR4 in Asia and Pacific region. He stated that the disease was first reported in Taiwan, 1967; Indonesia/Malaysia in 1990; in Australia in 1997 and in China and Philippines in 2000.

The disease symptoms that characterize Fusarium wilt included non-oozing brown spots within pseudo-stem and yellowing and sometimes collapse of leaves at the petiole (Plate 1)

Plate 1: Foc Pseudo-stem and foliar symptoms.

He stated that the current classification of Foc Races is limited based on differential responses (resistant/susceptible) of some varieties to certain Foc strain. In some cases, it can be misleading. For example, the literature stresses that TR4 affects all varieties susceptible to Race 1, but according to the study conducted in Philippines, many varieties susceptible to Race 1 were resistant to TR4 (Molina personal communication). This classification is widely used to describe Race 1 and should be revised.

Fusarium oxysporum* f.sp. *cubense affects many important cultivars; kills the plant completely and the pathogen survives in the soil for a long time, remaining infective even after decades of dormancy (based on circumstantial evidences). No cost-effective fungicide to eradicate the pathogen. In the Philippines, the first occurences of TR4 in Cavendish were observed in the highlands where Cavendishh was grown for sweet bananas. **Foc** TR4 spread to the traditional lowland Cavendish plantations via irrigation water sourced from a river coming from infested areas in the highland; subsequent spread thru movements of contaminated soils water irrigation-drainage, floods, equipment, and planting materials. **The strategies for the prevention of Foc TR4 incursion in disease-free areas** should include- raising awareness of the threat; effective quarantine policies; strengthening the capacity of plant protection teams to recognize the symptoms and take effective measures; and instituting effective surveillance and eradication systems. However, once the disease arrives, control measures to be undertaken include- early detection and eradication; intra-farm quarantine/disinfestation; varietal resistance and IPDM tactics (biological, cultural etc.)

The use of Cavendish resistant varieties has been sought for a long time through conventional breeding and genetic engineering. No successful result has so far been achieved. Selection from tissue-culture-somaclonal variation approach from Taiwan Banana Research Institute (TBRI) has resulted to some resistant varieties. Bioversity-Philippines office lead the evaluation and promotion of two somaclonal cultivars- GCTCV 218 and GCTCV 219 developed from (TBRI). These are now adopted in the Philippines and Mozambique and are very promising. The somaclonal cultivars are not immuned but resistant showing significantly lower disease incidence compared to the susceptible regular Cavendish. The resistance of the GCTCVs are stable with time.

Variety	No.Of plants	% PD Infected Plants			
		2012	2013	2014	2015
GCTCV 218	11,200	5.4	7.5	8.7	10.6
GCTCV 219	8,188	0.7	0.7	0.7	0.7
G Naine	100	87	NA	NA	NA

Table 1. Performance of of GCTCV 218 and GCTCV 219 in commercial plantation trials.

Most of the EAHB and plantains were deemed resistant to Foc TR4 but not immune- suffered less disease symptoms that could have been exacerbated by poor adaptation to sea level conditions (Table2). Cultivar Ibwi was later discovered to have been misidentified as EAHB when it is a Cavendish.

Variety Name	Genome	Sub-Group	% PD Incidence	
			52 weeks	72 weeks
Igitsiri (Intuntu)	AAA	Lujugira-Mutika	3	3
Mbwazirumi	AAA	Lujugira-Mutika	2	2
Ingagara	AAA	Lujugira-Mutika	5	5
Inkira	AAA	Lujugira-Mutika	4	4
Akpakpak	AAB	Plantain	1	1
Obubit Ntanga	AAB	Plantain	0	0
Enzirabahima	AAA	Lujugira-Mutika	1	3
Kazirakwe	AAA	Lujugira-Mutika	1	1
Ibwi	AAA	Lujugira-Mutika	23	32
Grand Naine	AAA	Lujugira-Mutika	58	77
Lakatan	AAA	Barangan	76	92

Table 2: Reaction of East African Highland Banana and Plantain cultivars to *Foc* TR4

The presentation concluded with sharing successes, failures and lessons learnt in managing TR4 in the Asia-Pacific region.

Successes:

- **A collaborative program to combat Foc TR4 in Philippines was successful** and this was attributed to: a). compelling and Focused developmental goal, a win- win goal for a collaboration, b). competent R&D players and support system, Focused towards impact rather than immediate research outputs, and c). presence of an effective and credible Focal coordination. The presenter emphasized the importance of these attributes for a successful collaboration towards impact.

- **Research studies have been successfully conducted**: a). evaluation of banana and plantain varieties against TR4, including banana of different genomic constitutions as well as local and commercial varieties in Philippines. b). Studying virulence of strains/race of Foc TR4 in the Philippines. c). Assessing the risk of East African Highland Banana and Plantain cultivars to *Fusarium oxysporum* f.sp. *cubense* (Foc) Tropical Race 4. Studies show that most African varieties are not susceptible to Foc TR4 (Table 1).

- Foc TR4 is a monoculture Cavendish issue. While TR4 has been in the Philippines since 2000, the production of local cultivars is not appreciably affected by the disease. In fact, BBTV and Bugtok are more important issue for small farmers. Indonesia, where TR4 is believed to have been naturally distributed in all islands, the banana production of the country had tripled since TR4 was reported to have severely affected new monoculture Cavendish in Sumatra province. The resilience of the local banana production is due to the use of diversity of cultivars and cropping system as well

- Foc TR4 is a serious threat to a monoculture Cavedish production system. However, it is doubtful if Foc TR4 will result to the prediction of total destruction of the Cavendish trade. IPM with the use of new technologies and knowledge that were not available during the Gros Michel era are now available: irrigation system that does not spread contaminated water, use of clean planting materials such as tissue culture, diagnostic tools for early detection and eradication, biological control and use of the concept of suppressive soil, and most importantly the use and development of resistant varieties such as GCTCVs, and rational regulatory measures that prevent incursions to new areas.

Lessons learned:

- Appropriate assessment on the vulnerability of various Musa cultivars and cropping systems, geo-agroclimatic locations is limited. There is need to conduct adequate assessment so that the current risk and impact assessment, including models of losses is accurate.
- Molecular studies/laboratory studies must be geared to developmental goal, practical use, not only for knowledge sake.
- Research is Focused on monoculture Cavendish, although often the small banana farmers are used as justification.

Failures

- Disconnect between laboratory research and practical impact.
- Focus on research outputs for publication, thus less on impact.
- Disjointed efforts of organizations/institutions working in the area

Discussions:

Qn 1: How long did it take for TR4 to spread from commercial to subsistent growers and medium scale growers that produce exclusively for local market (small holder farmers). And what is the current situation of TR4 in smallholder farmers in Asia-Pacific?

Response: Small holder farmers use diversified cultivars an a diversified cropping system, **thus TR4 is not an important issue.** The small growers are insignificantly affected; moreover, the production of local varieties has actually increased, in places like Indonesia and the Philippines. Thus TR4 is not very destructive to small holder farmers. On the other hand, Cavendish monoculture plantation system is composed of two types of growers: the big plantations which are mainly multinational companies whose farms run to the thousands of hectares. Small independent Cavendish growers are also growing bananas in monoculture but these growers till bananas from 5 to few hundreds of hectares. Both big Cavendish growers and small growers are vulnerable to FocTR4. But big growers are more resilient because they have the technology and logistical resources to cope up with the disease.

Qn 2: What is the experience of studying TR4 in screen-house and field conditions; are there cultivars showing resistance in screen house and the reverse is true?

Response: Yes. Some varieties have shown to be susceptible in screen house, but show resistance in field conditions. Thus, both laboratory and field evaluations are crucial during germplasm screening. For practical purposes, field evaluation is essential.

Qn 3: I was told to use glyphosate so that it will release the H^+ required to increase soil pH and have an additive effect on soil suppression, does this work?

Response: In TBRI research showed it was ineffective, Glyphosate kill microorganisms in soil reducing on their role to suppress Foc. Indeed, in Matanuska (Mozambique), when glyphosate was used, the incidence of TR4 was higher than non-glyphosate applied fields perhaps maybe due to reduction in microbial activity as well as reduced root growth.

Qn 4: It seems like seed sharing system in Philippines is rare yet it looks vital in BXW spread - wasn't critical what is your view on this?
Response: Seed sharing across borders is minimal in Asia but exchange is common within borders.

2.2 Effective management of Banana wilts is elusive, but remains a global priority (Altus Viljoen)

This presentation reviewed and shared underlying factors/reasons that have kept management of banana wilts elusive (difficult to achieve). An overview of banana wilts with emphasis on Fusarium and Bacterial wilt diseases was given. He emphasized that following the recent (2014) outbreak of Foc Tropical Race 4 (TR4) in Mozambique, its potential to spread across Africa is undoubted and most importantly, the human factor has majorly

contributed to its spread. He added that TR4 is mostly problematic in monoculture cropping systems and specifically for Cavendish varieties.

The presenter discussed the possible reasons that may be responsible for the limited success in managing banana wilts which have continued to spread both locally and globally. In his discussion, the following emerged as key considerations that could explain the ineffective control of the banana wilt diseases:

a) For most countries in Africa, there are no elaborate actions to be undertaken before the disease arrives **(Pre-border activities);** when the disease has arrived at the border **(On-border activities);** after the disease has crossed the border but before it spreads out **(Post-border activities); and, there are no** institutional arrangements that will support disease management actions across the board **(Off-farm activities)** and measures to be undertaken when the has arrived on farm (**On-Farm activities)** to guide the respective practitioners to take timely and effective actions against the diseases.

b) Lack of strong political will, commitment and proper investment in plant biosecurity and phytosanitary actions required to deal with banana wilts, usually linked to the lack of a proper risk and impact assessment to determine the threat of banana wilt diseases to countries and regions; limited awareness campaigns and information sharing for decision making at policy level.

c) Lack of early detection capacity under field conditions, especially for Foc TR4-affected latent infection, which means containment and eradication measures are not timely applied and the movement of planting materials, soil and water off Foc TR4-affected farms is not monitored to contain the disease.

The following were presented as some underlying reasons contributing to elusiveness of banana wilts**:**

For BXW:

- Cutting and uprooting of plants is labor-intensive regarding de-budding, rouging, safe removal of infected material
- Fears for food security if infected banana mats are rouged; in some cases, there are no alternatives food options
- Expensive disinfectants,
- Fears that new cultivars might spoil the soil,
- Fears that researchers want to kill traditional technologies,
- Contradicting messages on the technology and negative attitude on the technology.

For TR4:

- Limited practical options for small growers to deal with Foc TR4
- The perception that the containment of Foc TR4 has never worked
- Early detection and eradication of Foc TR4-affected plants is inefficient
- Introduction and implementation of regulations is weak
- Screening of African banana varieties is inconclusive because they were evaluated under stressful agroecologies.
- Screening of international breeding materials is limited; international banana breeding materials need to be screened against wilt diseases

The issuing conclusion highlighted political will, commitment and proper investment in plant biosecurity and phytosanitary actions as key requirements to deal with banana wilts. For new outbreaks, affected farms should be placed under quarantine and inspectors should be employed to ensure that quarantine regulations are implemented and met. The movement of planting materials should be regulated. Soil and water from Foc TR4-affected farms should be monitored and regulated to contain the disease. Continuous reassessment of regulations is required as more information becomes available. The spread of banana wilt disease should be monitored by means of regular surveillance and appropriate containment efforts. All suspected cases should be reported and investigated immediately. A proper risk and impact assessment should be performed to determine

the threat of banana wilt diseases to countries and regions and awareness campaigns and information sharing should be conducted.

Discussions:

Qn 1: Among suggested interventions, you are not thinking of Biotechnology, has it failed?
Response: The challenge with transgenic lines is about acceptance by communities. There are currently two varieties still under evaluation, however Africa and the Europe export market are not ready for these transgenes thus not being an immediate solution.

Qn 2: What management options are recommended for TR4 management in small holder farms?
R**esponse** The most logic intervention would be a resistant banana. Additionally, there is strong growing evidence that the matooke cooking banana are resistant.

Qn 3: What is the yield loss posed by TR4 when you leave infected field abandoned
Response: Yield loss is total if the field is weed-free. There is no penalty on yield, since abandoning the plantation creates a micro environment to reduce inoculum.

2.3 Research advances on FOC TR4 in Asia and the Pacific- (Yi Ganjun)

The purpose of this presentation was to elucidate research advances on Foc TR4 in Asia-Pacific. The presentation described advances in molecular breeding for Fusarium wilt resistance as indicated below.

Evaluation of Banana germplasm resistance to TR4: The evaluation included plantains and EAHBs. Results (Table 3) show that most East African highland bananas were resistant to TR4, with variety Mbwazirume (commonly grown in Uganda) registering the lowest disease incidence (19.9±2.4).

Breeding resistant varieties through mutational breeding: Through use of Ethyl Methanesulfonate (EMS), somaclonal selection and mutation breeding, resistant Cavendish cultivars (GCTCV-119, GCTCV -218, ZJ4 and ZJ 9) have been developed for tropical areas (Philippines, Hainan Island of China). Cultivar ZJ9 that is 100% resistant to TR4 is high yield (30Kgs per bunch), resistant to strong winds, tolerance to coldness and good fruit quality characters has also been developed for in subtropical area in China.

Plate 3. **Resistant cultivar: ZJ-04**

The GMO Approach: Ongoing research activities include gene silencing of TR4 and Race 1 in Gross Michel varieties and establishing a CRISPR/Cas9-mediated gene editing system in banana. The presentation highlighted the following setbacks underlying use of GMOs; 1) resistance is controlled by many genes and no efficient resistant genes has been discovered from bananas, 2) transgenic plants are always connected with bad traits and importantly Chinese are not willing to accept GMO's.

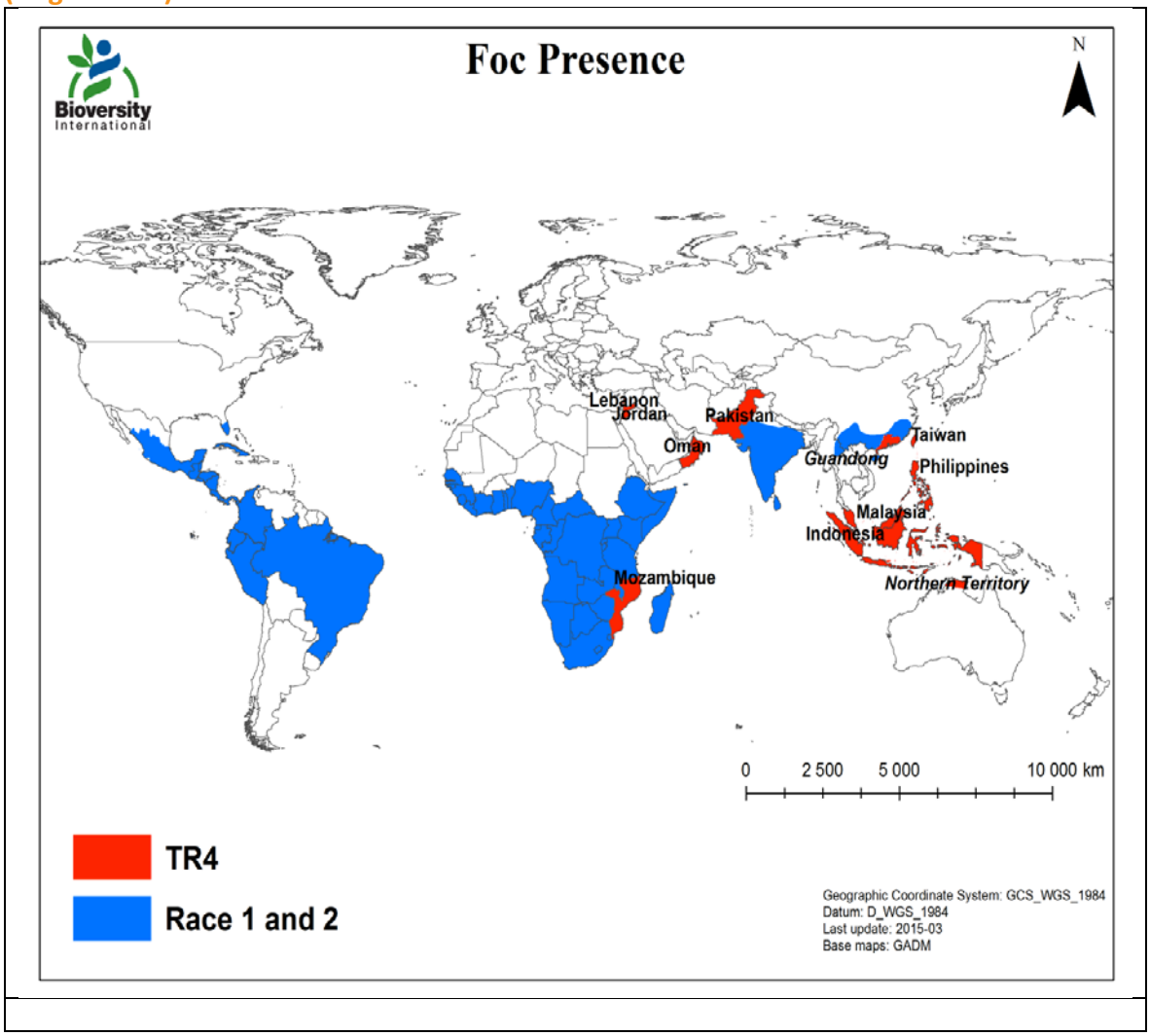
In conclusion, it was emphasized that during breeding, effort should not try to change the host (banana), but rather to let the host plant help to inhibit the fungi. This can be achieved by using HIGS (Host-induced gene silence technology). Conventional Breeding is still very important while molecular breeding show very good potential for developing resistant germplasm.

Table 3: Resistance of East African Highland Bananas (EAHBs) and Plantains to TR4 as screened in China.

Common Name	Subgroup	Genome Type	ID1	1D2
Ibwi	EAHBs	AAA	24.3±5.43	0
Igitsiri (Intuntu)	EAHBs	AAA	20.42±2.01	0
Ingagara Inkira	EAHBs	AAA	22.97±3.74	0
Inkira	EAHBs	AAA	21.67±3.82	0
Intokatoke	EAHBs	AAA	31.17±1.53	6.67±1.15
Kazirakwe	EAHBs	AAA	26.97±1.45	0
Mbwazirume	EAHBs	AAA	19.94±2.41	0
Akpakpak	Plantains	AAB	19.6±2.15	0
Curare enano	Plantains	AAB	33.2±1.59	0
Obino l'Ewai	Plantains	AAB	33.2±1.59	0
Obubit Ntanga green mutant	Plantains	AAB	28.08±0.95	5.33±3.06
Orishele False Horn	Plantains	AAB	18.72±3.75	0
Pisang Ceylan	Plantains	AAB	20.43±2.61	0
Pisang Rajah	Plantains	AAB	27.4±5.6	0

Clonal selection breeding in China has produced two varieties with good market qualities-
Zhongjiao No.4' ZJ- 4 (ZJ 4) has bunches of 21-24kg; good quality, soluble solid content 23.0%; titration acid content 0.256%. in China, it has growth circle of 380-400 days in 1st season. It shows high resistance to Fusarium wilts disease, but does not flower in cold seasons; fruit has good commercial quality
Zhongjiao No 9- ZJ 9 (ZJ 9) is high yielding and good fruit quality. 30kg per bunch; soluble solid content of **18.4%.**

2.4 Biosecurity preparedness in LAC to curb the entry of evasive pests and diseases (Miguel Dita)



The purpose of this presentation was to capture Biosecurity preparedness in LAC to curb the entry of evasive pests and diseases and facilitate cross-region learning. The presentation was made by David Brown on behalf of Miguel Dita. In Latin America and Caribbean (LAC), Brazil and Ecuador were presented as the highest producers of banana with much of the cultivation dominated by small holder farmers. The presenter stressed and envisaged the TR4 management strategy as based on an integrated approach which includes use of cultural practices coupled with genetic resistance, chemical use and biological, with legal control at the centre of all these practices. The following are practiced in LAC in preparation for TR4:

Exclusions; (Biosecurity) preparedness and research for solutions were prioritized as key strategies to curb evasive diseases. It was evidently presented that the strength of LAC to prevent entry of TR4 has been majorly in strengthening capacities. Risk and surveillance programs supported by MUSALAC, BIOVERSITY, NPPOs and INISAV have already been put in place.

Capacity building: The presenter stated that the strategy for strengthening diagnostic capacities has been seriously practiced. Scientists have been trained in diagnostic techniques including PCR, qPCR, LAMP and VCG analysis. Regional templates for national contingency plans for TR4 have been developed and disseminated, free online knowledge sources about the disease has also been availed; non-intrusive Inspection with Dog Units is in action by agricultural authorities in Mexico yet to expand in Guatemala, Belize, El Salvador, Honduras, Nicaragua, Panama, Costa Rica and the Dominican Republic should be strengthened. The need for regulatory bodies to

always have well-trained plant pathologists and perform carefully analyses of the diagnostic process before making any groundless announcement was emphasized.

He concluded by emphasizing the need to have information to answer the following questions:

- How did TR4 jump to Africa and Middle East and might it be disseminated by the same pathway to LAC or elsewhere?
- Did it hitch-hike on shoes, clothing and machinery?
- Were infected plants (banana or others) involved?
- What dissemination vehicles are most problematic?
- What besides people came from Asia?
- What is in place in Africa to avoid a fatal jump to LAC?

2.5 Mobilizing stakeholder platforms for prevention and management of FOC TR4 (Martin Emeu).

This presentation was to enlighten the role of Food and Agriculture Organization (FAO) in mobilizing stakeholder platforms for effective management of Foc TR4 and was shared by Martin on behalf of the organization. Martin made introductory remarks about the spread and challenges of TR4 management. He noted that TR4 is a soil-borne fungus spread through infected planting materials and soil particles / spores (tools, vehicles, shoes, water). Challenges encountered during TR4 management were shared and they included: chemicals use being less effective, breeding for resistance being difficult, monoculture cropping system being common and yet makes the spread of the disease easy.

He further stated that FAO being an international organization mandated to ensure sustainable crop production, increasing resilience of livelihoods to threats and crisis and to enhance efficient food systems, the threat posed by TR4 is crucial. In this regard, FAO has supported the following activities tailored to curbing TR4, including: 1) Increasing advocacy at global level through news releases, 2) Consultations, collaboration and dialogue including; African Consortium on Foc TR4 strategy for Africa (Cape Town workshop); WBF task force meetings; Events in Philippines (INREF, BAPNET).

He also mentioned that currently, the following FAO-supported activities are being conducted in three continents:

- **Latin America and Caribbean**: workshops (Trinidad and Tobago, Ecuador, Guatemala, Costa Rica) assessments, sensitization, contingency planning, diagnostics, regional collaboration, trainings.
- **Asia:** Participation in events in Philippines, China (BAPNET, INREF) awareness and regional collaboration.
- **Africa:** formation of the consortium on Foc TR4 strategy for Africa, regional projects, Emergency support to Mozambique.

The presentation emphasized continued collaboration of FAO with the following institutions: **Bioversity** International, **IITA** (International Institute of Tropical Agriculture), World Banana **Forum**, **International** organizations (e.g. IAEA), Advanced universities and agricultural **research** centres (e.g. Universities of Queensland, Stellenbosch, Wageningen, KULueven; CIRAD), Regional Plant Protection Organisations (**RPPO**'s), networks and initiatives, particularly from countries at risk (e.g. NEPPO, IAPSAC, APPPC), International and regional banana research, genetic resources and knowledge sharing **networks** (e.g. ProMusa, MusaNet, BAPNET, BARNESA, MUSALAC, Innovate Plantain, TFNet), **National** governments, Ministries of Agriculture, phytosanitary authorities (National Plant Protection Organisations - NPPOs), **National research** institutions, particularly from affected countries and Producer organizations, banana sector organisations, and industry and **NGOs.**

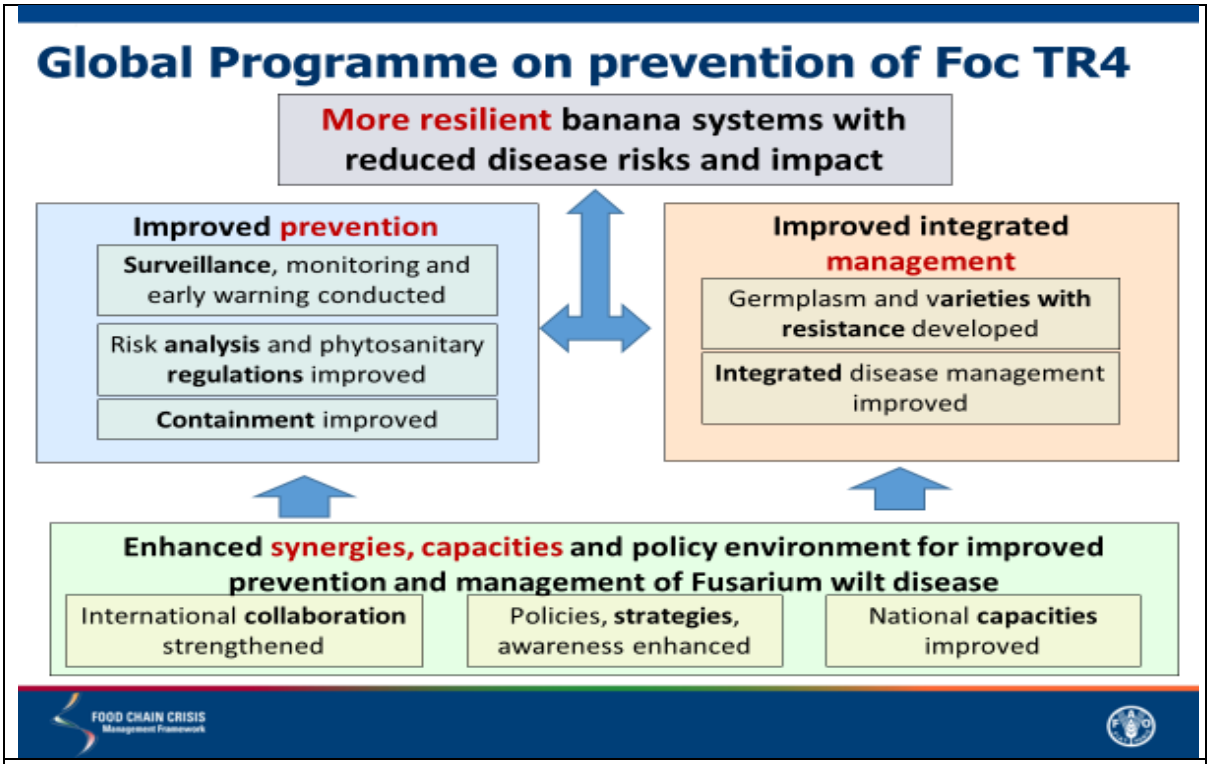


Figure 4. Global framework for addressing Foc TR4

Discussions:

Comment: One participant was not contented by including BAPNET as a partner. He stated that amidst several invitations by BAPNET, FAO has not come on board to support Asia. This would be a misrepresentation and BAPNET would not be comfortable with such display.

Comment: A participant was not contented to see just a few African organizations on the list. Surprisingly there was no country in the Middle East. Other organizations/institutions need to join the efforts.

2.6 BXW in East and Central Africa, an example of collaboration success (Jerome Kubiriba)

The purpose of this presentation was to share revised BXW management options based on piloting experience. The threat posed by BXW was emphasized and stated that early socioeconomic studies showed that 90% of Uganda's bananas would be cleared by BXW in 10 years if no control was effected (Figure 5). This would translate to a loss of US$ 4 billion worth of bananas.

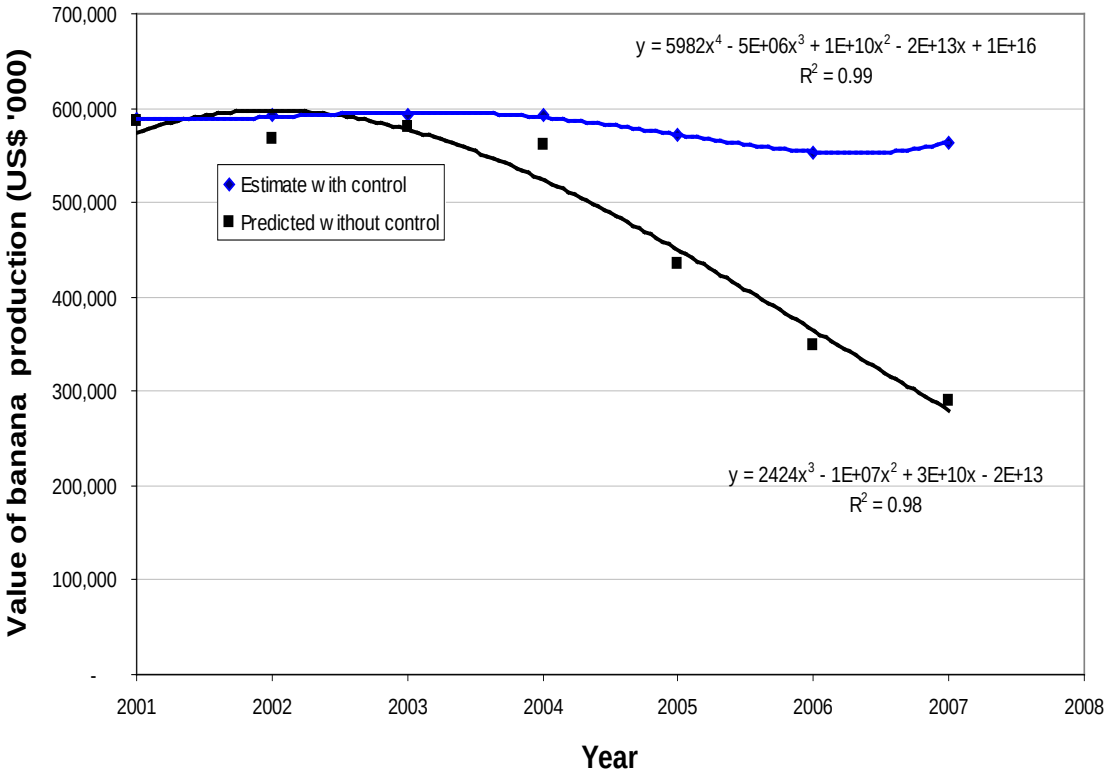


Figure 5: Projection of loss caused by BXW if no control measure is effected.

The presentation stated that in 2010, the dynamics of the spread of the disease changed. BXW prevalence in major banana growing region increased six-fold to about 34% in 2010, and increased further to about 45% in 2012 (Figure 6).

In response to this increment, a revised management strategy was launched in 2012 and included: validation of technologies for control of BXW, aggressive and wide disseminate information on BXW spread and control, mobilise communities for BXW control, support the development and implementation of a legal instrument, monitor and evaluate implementation of BXW control activities. It was documented that through concerted efforts, BXW incidence has remained below 5% for about 4 years in main banana growing areas of Uganda. Control of BXW was more successful where effective technologies were deployed together with institutional approaches that efficiently mobilise stakeholders.

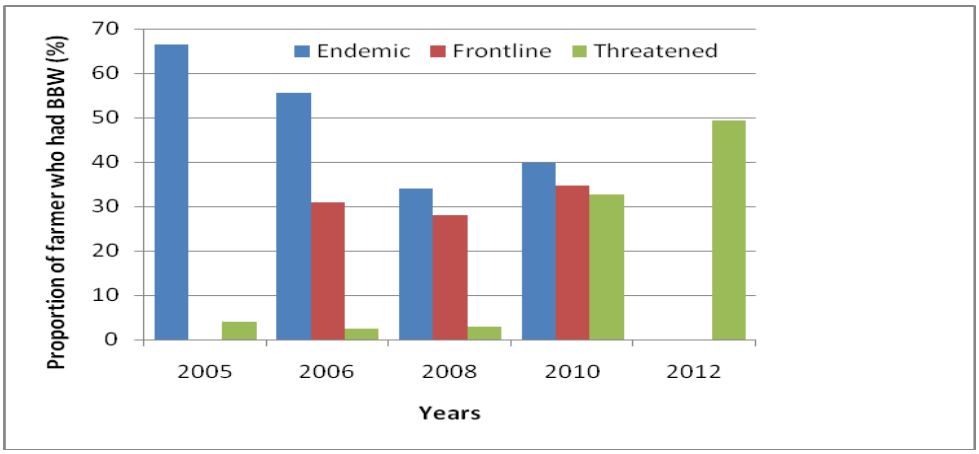


Figure 6: Dynamics of BXW spread from 2005 to 2012

In conclusion, it was emphasised that an effective banana wilt management package should include: frequent assessment of spread, understanding the epidemic dynamics and implications for the control, aggressive mobilization of technology uptake machinery involving farming communities, and mobilization of necessary government and other structures to support BXW control. Lastly, cultural control will not sustainably control BXW thus there is need for development and deployment of BXW transgenic resistant varieties.

Discussions:

Qn 1: How many transgenic BXW resistant varieties have been adopted?
Response: None, the Biosafety and Biosecurity bill that allows adoption of transgenic lines in Uganda has not yet been passed

Qn 2: Which year was BXW introduced in Uganda?
Response: 2001

Qn 3: BXW seems very serious, small scale farmers are more scared in Asia of it than TR4, how is its management possible?
Response: For effective management, government intervention is key, for example during the launch of revised BXW management package; the Minister himself was present and launched the strategy. Also, recently a banana farmer's cooperative was launched to facilitate easy flow of information in a coordinated manner.

Qn 4: Do you expect the GMO for fusarium resistance/BXW to be in the field soon?
Response: If the Biosafety and Biosecurity bill is passed, in next 4 years the GMOs will be in field. Moreover, the use of resistant varieties may reduce the disease inoculum in infected soils

3. DEVELOPING STRATEGIES FOR THE MANAGEMENT OF BANANA WILTS

Presentations in this section Focused on current strategies employed in managing and curbing the spread of banana wilts in Asia-Pacific and Africa. Lessons learnt and experiences shared are documented.

3.1 Current strategies for managing banana wilts in Asia and the Pacific- (Vida Grace Sinohin)

The aim of this presentation was to capture current strategies employed in Asia and the Pacific to manage banana wilts. In her presentation, three banana bacterial wilts were clarified: i) **Moko** (*Ralstonia solanacearum)*-a wilt disease in commercial Cavendish plantations in the Philippines (Plate 2), ii) **Bugtok Disease** (*Ralstonia solanacearum)*-a fruit rot disease on cooking bananas in the Philippines (Plate 3), and iii) **Blood Disease** (*Pseudomonas celebensis)* **-**wilt and fruit rot disease in Indonesia and Malaysia (Plate 4).

The presentation indicated that the three bacterial wilts of banana have been managed through regular survey and early detection, eradication of infected plants by burning with rice hull burning, disinfecting farm tools for leaf pruning and de-suckering as well as use of clean planting materials.

An insight about Fusarium wilt in Asia was shared. It was mentioned that Tropical race 4 is spreading very rapidly in the continent within countries and across country borders. The epidemic of Foc TR4 mostly affected the small growers, since they lack technical, financial and logistic resources to curb the spread which resulted to abandoned area of approximately 3,000 ha.

Plate 2: Moko disease

Plate 3: Bugtok disease

Plate 4: Blood disease

The current strategies to curb TR4 practiced in Asia include: 1) Early detection and prevention of spread by fencing off the affected area, setting up footbaths filled with disinfectants, quarantine with infected farms; 2) Reducing inoculum by chopping down all plant parts of infected plant on the mat lined with rice hull of about 30 Kgs and burnt, eradicating all banana plants within 5m radius of the infected mat; 3) use of resistant somaclones to rehabilitate affected Cavendish farms and use of diverse local banana varieties as opposed to monoculture that has facilitated the spread.

In conclusion, it was indicated that in all countries where the banana wilts, especially Foc TR 4 is still absent, efforts should be put to prevent entry of the pathogen. In areas where the disease is already an epidemic, managing is essential for production sustainability and sustaining livelihoods. There is need for R&D support to promote all available disease management tactics. Somaclonal variation selection is a practical and efficient banana improvement approach, and the use of diverse local banana varieties will make banana production resilient in every country.

Discussion:

Qn: It is documented that microbes play a vital role in suppression of Foc, what is the effect of burning infected plant materials with rice hulls on these microbes?

Response: Burning is a method of eliminating the plant not to kill the fungus and no study has been conducted to assess the effect of burning on microbes.

3.2 Managing Banana Wilts in Africa; experiences and lessons *(Guy Blomme)*

The purpose of this presentation was to share experiences and lessons learnt in managing bacterial wilts in Africa. The scientist informed members that research results on the effect of soil fertility levels on plant response to *Xcm* were inconclusive. While the application of potassium, calcium and nitrogen to *in vitro* banana plantlets resulted in significantly reduced susceptibility to *Xcm* (Atim et al., 2013), the application of nitrogen, phosphorus and potassium in controlled pot experiments did not (Ochola et al., 2014). He further argued that observed differences could be attributed to the interaction of physical and chemical factors in pot trials, factors that were lacking in the *in vitro* studies. Thus, field studies are still needed to further elucidate the interaction between soil nutrients and the disease.

The following methods were mentioned as current control methods for BXW: early removal of male buds, sterilisation of garden tools, use of clean planting material, complete uprooting of diseased mats (CMU), Single Disease Stem Removal (SDSR), use of symptomless shoots in disease endemic areas, CMU plus fallowing for 3-6 months. It was observed that use of endophytes as biological control agents were promising in the laboratory but results were not replicated in field conditions.

The presenter shared the concept of incomplete systemicity. He argued that *Xcm* does not invade all physically attached shoots in a mat when mother shoot gets infected. According to the study conducted, 5 -25% of the attached symptomless suckers had latent infections, while 75-95% stayed free of *Xcm* – the concept of incomplete systemicity. In another study results (Figure 7) indicate that timely symptom identification and removal of infected shoots prevented the infection from reaching the corm in florally infected plants.
Knowledge on alternative hosts was also shared. It was noted that *Musa zebrina*, *Musa ornata* and *Canna indica*, maize, beans and sweet potato, sorghum, wild Sorghum and millet were all hosts under in artificial inoculation (Ssekiwoko et al., 2006; Rutikanga et al., 2016)

This presentation identified knowledge gaps including:

- Need to clearly pin-point the genes of resistance in *M. balbisiana* and its mechanism for potential use in molecular breeding
- Conventional breeding to segregate for resistance to BXW could be explored with *M. balbisiana* as a parent.

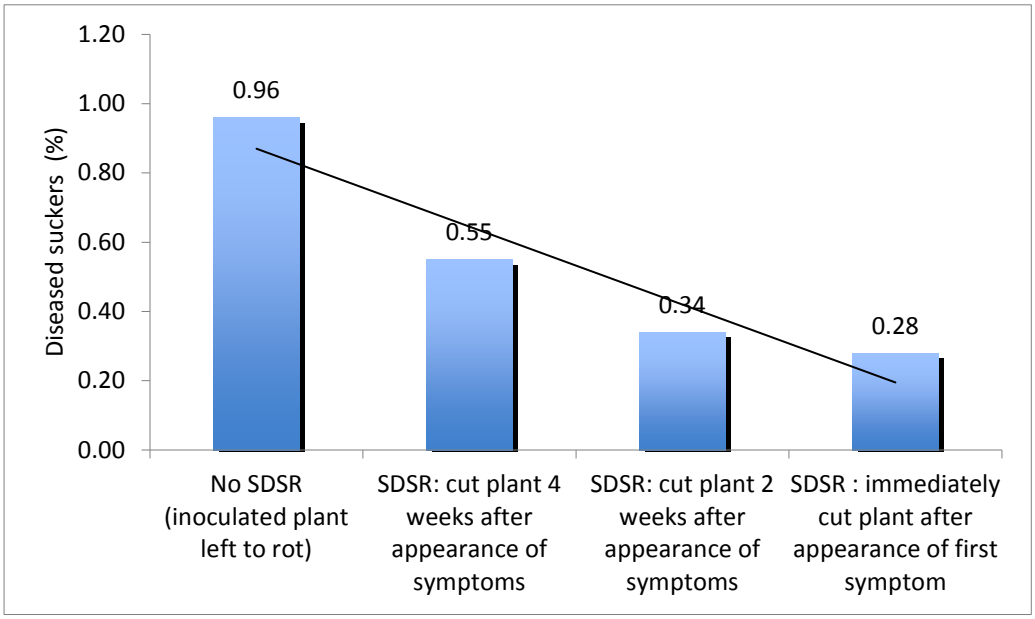


Figure 3: Effect of timely application of SDSR on BXW incidence.

Discussions:

Qn: When and where is single stem removal applied and why is there incomplete systemicity?

Response: Applicable when the rate of infection is still low, but not applicable in case the disease incidence is beyond 80%. Single disease stem removal (SDSR), is based on idea that in the mat there may be suckers not sick due to incomplete systemicity, thus it's possible that we have 'daughters' not infected. However, it must be appreciated that under SDSR, the aim is to maintain disease inoculum below threshold and not eradication. This makes SDSR a clear tool where subsistence farming is the key objective. In farming systems where the objective is commercial, eradication is preferred and complete mat removal (CMR) is employed.

3.3 Strategies for Curbing Foc TR4 spread In Mozambique (Joao Augusto & George Mahuku)

In 2013, Tropical race 4 was confirmed in Mozambique. The purpose of this presentation was to share strategies devised to curb Foc TR4 spread in Africa. The presenter urged for urgent need to stop the disease spreading to other countries on the continent. He mentioned that the disease is rapidly spreading within affected farms (Plate

5) and losses are accumulating. So far more than 1 million plants have been killed by Foc TR4 accounting to almost $30 million loss. In one of the heavily affected farm in Matanuska, employees have been downscaled from 3,000 to 1000. It is beleived that the disease has been in large scale plantations, but the recent discovery of about 50 suspected Foc TR4 positive samples in smallholder farmers is worrying. There are growing fears that the disease may even spread across national borders given the Nacala corridor that links Mozambique, Malawi and Zambia and the the porous border that is not adequately controlled. Thus East Africa and Indian Ocean islands are all at risk.

The following were mentioned as current interventions to curb the disease in affected fields of Mozambique:

- destroying and burning infected plants and plants around them,
- application of lime; limiting workers movement in infected blocks disinfection of cars, farm equipment and use of foot baths
- use of drip irrigation and somaclones

Status in 2013

Status in 2014

Status in 2015: 570,000 infested out of > 2.5 million plants

Status in 2016: > 1 million plants killed by Foc TR4; ~ $30 million

In conclusion, the presenter stated that failure to contain the spread of the disease will have not only economic but also environmental consequences in the banana producing regions of Africa. In these regions, 50% of arable land is under banana cultivation with positive effects on the environment. If the bananas are destroyed by Foc TR4, the environmental impact would be catastrophic.

Discussions:

Qn 1: The collected suspected samples in smallholder farmers are far away from initial infected farm, is there any evidence to why the fungus is spreading fast?
Response: The evidence is not very clear, but these are suspected samples subjected to confirmation.

Comment: According to the rate of spread, a participant was very cautious and asked the member from NPPO Mozambique (in attendance) to approach the government and ensure the disease spread is stopped.

Qn 2: What is the border regulation at Mozambique? Is it business as usual?

Response: Not business as usual, after a sensitization there is initiative mostly on limiting movement of planting materials. The issue is still on trucks carrying rails from Nacala to Malawi, these may carry soil on tyres and are rarely disinfected.

3.4 Data needs for mapping Pests and Diseases in small holder systems (David Brown)

The presenter shared the roadmap for data mapping. He stated that a crop mapper has been developed to enable easy browsing and mapping. It can be accessed on www.crop-mapper.org. He stressed that the current data source is from official reports e.g CABi, expert knowledge (unofficial reports) and is challenged with low accuracy, sometimes incomplete and may create confusion. Thus, there is need to have reliable sources of data. He also shared with participants on how to improve data and make it accurate by using crowd sourcing with mobile devices and using remote sensing images (RSI) to map affected areas or under risk. The presenter's next steps include 1) prototyping Fusarium sample collection based on Viljoen et al. (2017), and, 2) Prototyping Fusarium sample collection.

In conclusion, the presenter stated that there is need to agree on a common methodology, considering regional and local characteristics during mapping and to take advantage of leading edge technologies, supported by expert knowledge on plant pathology.

Discussions:
Qn 1: what type of data is needed for complete and effective mapping?
Response: River, pathways, spatial analysis to give an epidemiology approach.

Qn 2: Have you done modeling work on banana?
Response: Not particularly on the project work, but did on spatial distribution and auto correlation on my Master's Degree

GENERAL DISCUSSIONS

This was an interactive moment for participants basing on all the presentations, general comments and questions were shared as documented below.

Qn 1: How long can banana farmers keep TR4 infected plantations.
Response: Ideally it is difficult for a farmer to abandon the entire plantation thus strategies devised should help farmers manage the disease as opposed to abandonment.

Qn 2: Is it possible to get a simulation of TR4 for experiment in Uganda where the disease is absent?
Response: It can only be possible in a laboratory not in any field including CFTs.

Qn 3: There was a suggestion of evaluating cultivar for TR4 resistance. Where would this be done?
Response: In Mozambique but Phillipine would be considered if the altitude is favorable.

Qn 4: LAC produces a lot of Cavendish, are there any surveys regularly carried out to look out for TR4? And how are country members of MUSALAC prepared for TR4?
Response: Personnel have been trained on diagnosis of TR4; surveillance systems are in play; however, the trained individuals are still few.

3.5 Group and Plenary Discussions

Participants were divided into three groups and requested to review current and past research by region (Asia, Africa and LAC) and indicate research activities with their expected outputs, collaborating partners as well as

existing information and technology gaps. For each region, participants selected and used either Foc TR4 or Foc Race 1 for endemic country and one disease-free country. Where BXW is not present, Moko/Bugtok was used. Below are the results from discussions according to regions:

Country	Disease	Research activities (projects)	Key outputs	Collaborating partners	Remaining gaps
Mozambique	TR4	Disease distribution and disease incidence/disease mapping/surveillance; identification	Disease distribution map	FAO, Bioversity, RTB, IITA, Stellenbosch, NPPOs	Further surveillance; characterization of mechanisms of spread; cultivar maps, biosecurity awareness raising
	TR4	Somaclonal screening,	Good tolerance		Screening germplasm for resistance including African varieties
		VCG Analysis	On-going		
	Integrated Pest and Disease Management	Disinfecting tools/sanitizers	Good products for cleaning		Risk and impact assessment at national and regional levels
		Systems analysis and agroecological intensification	Planned		Effect of intercropping/cultivar diversity on disease dynamics Feasibility of biosecurity measures on spread of disease (policy research)
Tanzania	BXW, TR4 free	Epidemiological studies; impact analysis	Fine-tuning control measures		Awareness, Policy research, Biosafety, Training, surveillance
Uganda	BXW	Host ranges and alternative hosts; soil-pathogen interactions; systemicity; detection tools; host plant resistance,	Fine-tuned IPDM options		Screening more germplasm for resistance, Microbial analysis,
Malawi	TR4/BXW free	Biosecurity measures	Planned		

The Asian group came up with the following ideas

Country	Research activities (projects)	Key outputs	Collaborating partners	Remaining gaps
Philippines/ China	Strain & Race Distribution Studies in Asia	Distribution map of VCGs in Asia	BAPNET, Stellenbosch, GDAAS, UPLB, DA-BPI	Survey & collection in more countries - Laos, Cambodia, Myanmar, Vietnam, India Thailand
	Variety evaluations (TR4)- screenhouse & field evaluations	Identified resistant and susceptible banana varieties from Asia and Africa	GDAAS, UPLB, DA-BPI	Evaluation of more useful local varieties from BAPNET countries for identification of vulnerability to Foc TR4
	Mitigation studies/ disease management studies on cropping systems (biocontrol, Ground covers, crop rotation)	Established suggested management practices to mitigate FW	GDAAS, Aus, UPLB, DA-BPI, USEP, commercial banana companies	understanding the enabling mechanism of biocontrol from screenhouse to field conditions
	Molecular studies on host pathogen interaction (proteomics), transgenics, mutation breeding (somaclonal selection induced by TC)	New somaclonal selections, resistant genes identified, transgenics developed	GDAAS, UPLB, DA-BPI, Commercial Banana Companies, USEP	nature of genes for resistance to Foc TR4 and incorporating it to commercially acceptable phenotypes
India/ Indonesia/ China	Conventional Breeding for TR4 resistance	Foc TR4 Resistant banana varieties	ITFRI, GDAAS, NRCB	nature of genes for resistance to Foc TR4 and incorporating it to commercially acceptable phenotypes
Philippines	Field resistance mechanism	an understanding of the host pathogen interaction	UPLB	Understanding the contribution of resistant variety (biological and physical specifics) on resistance in the rhizosphere
Philippines, Australia	Soil Suppression	an understanding of the host, pathogen soil microorganism interaction	Aus, USEP, DA-Phil	Understanding the biological, epidemiological and physical mechanism of host pathogen interaction

	Asia pacific has a strong regional network - promoting research collaboration		BAPNET	
	Risk and impact assessment		BAPNET	scientifically designed study on actual risk based on cultivar agro-ecological and cropping system vulnerabilities
	BAPNET is an effective platform of regional collaboration		BAPNET	the need for new leadership & revitalized platform

The Latin America and Caribbean (LAC) where TR4 doesn't exist, Foc race 1 was used and the following ideas were generated.

Research Action	**Key output**	**Collaborating partners**	**Key gaps**
Soil suppression in Foc Race 1	Clear relationship between PH and soil health with disease suppression	University of Costa Rica Bioversity international CORBANA EMBRAPA MUSALAC	-Results obtained are from laboratory, small field trials, needs to upscale -Identify specific microorganisms which are responsible for suppression- interactions
Restricted movement of materials within the farm and among neighbors	Farmer initiative and concern		-Not reinforced
Host resistance	Still under trial for resistance cultivars		Need evidence

4: DEVELOPING BB 3.3 CLUSTER AGENDA (2018-2020)

In this section plenary discussion of cluster ongoing activities, ranking identified research gaps per continent according to urgency as well as way forward for the next agenda were documented.

4.1 Ranking identified gaps according to priority

Participants were asked to prioritize the identified gaps with the most priority activity ranked 1 and the least priority activity ranked 3. Below is a summary on most priority areas (ranked 1) and a detailed summary is presented in Appendix.

The African group had the following priorities for BXW; surveillance, early warning systems & mapping in DR Congo and Uganda for resurgence. For TR4, priorities are detection / diagnosis (VCG determination), TR4, surveillance, early warning systems & mapping TR4, assessment of risks and impacts, awareness creation and knowledge communication, cultivar evaluation, national/regional/Africa-wide strategic plan/action plan (early reporting, management, investigation).

The Asian team, in the framework of BAPNET had already set regional priorities Focusing Foc TR4 and the research thus far carried out. Their priorities therefore were more about consolidation of their achievements, including resistant cultivar development, including molecular breeding; VCG analysis and mapping in countries that recently reported the disease; impact assessment and plant / soil health systems.

The LAC region remains Foc TR4 disease free; the priority actions are thus centred around biosecurity within and between sub-regions and countries and the attendant capacity building needs. **The meeting agreed that the priorities set were only tentative until they are validated by the regional platforms**

Region	Wilt Type	Priorities	Description
Asia-Pacific	**Blood disease & Bugtok**	***Surveillance, early warning systems & mapping***	Survey of bacterial diseases in other countries in Asia and assessment of vulnerability according to cultivars' susceptibility and cropping systems
	Foc TR4	***Surveillance, early warning systems & mapping***.	Survey of FW disease in other countries in Asia; development and adoption of disease management measures in new countries of occurrence
		`Population characterization, linked to cultivar susceptibility and resistance maps	Assessment of vulnerability according to cultivars' susceptibility and cropping systems
		`Plant / soil health systems to suppress disease.	Study for deeper understanding factors that affect host pathogen interaction in the rhizosphere (suppressive soils), and understanding to operationalize it under field condition (biological controls).
		Assessment of risks and impacts.	Quantitative analysis of risk & impact of TR4 on different cropping systems (i.e. monoculture Cavendish vs cultivar and cropping system diversity by small farms); adoption and impact assessment on the use of new disease manage strategies & options;
		Capacity building and raising awareness.	***Capacity building and raising awareness***. Promoting to small banana growers the use of the existing IPM strategies for improved adoption; awareness of stakeholders to prevent incursion; Enhanced regional and national information sharing on TR4 management and newly developed technologies.
Africa	**Bacterial Wilts (**BXW**)**	***Assessment of risks and impacts***	as a basis for the development of national/regional/Africa-wide strategic plan/action plan (early reporting, management, investigation)

		Breeding for resistance in cultivated bananas	Conventionally using resistant wild genotypes and genetic engineering for different production objectives
		Fine tuning IPDM packages to meet the needs of different farming objectives	LEAFF in semi-commercial systems and SDSR in subsistence systems
	Foc TR4	***Awareness creation and knowledge communication***	linked to policy and investment at national and regional levels
		Surveillance, early warning systems & mapping	to guide intervention applications
		Detection / Diagnosis (VCG determination)	linked to surveillance and capacity building for plant protection teams
		Cultivar characterization (cultivar susceptibility and resistance mapping)	linked to production systems
		Plant / soil health systems analysis to suppress disease incidence	linked microbial roles and interspecific exudate communication in the rhizosphere
		Assessment of risks and impacts.	Quantitative analysis of risk & impact of TR4 on different cropping systems (i.e. monoculture cavendish vs cultivar and cropping system diversity by small farms); adoption and impact assessment on the use of new disease manage strategies & options

4.2 Discussion from Plenary

Qn 1: Ex-Ante Impact assessment for TR4 would come first before any interventions are instituted in east and central Africa; why is impact assessment not a priority?
Response: We need to know the susceptibility of EAHBs before we talk about impact assessment.
Response: Contrary another member stressed that Impact assessment should be priority so that you have proof to argue out with policy makers to recognize the seriousness of the disease.

Qn 2: As Africa, are we trying boost capacity building like training of students e.g. for like six months about these techniques? Could we look into possibility e.g. a partner university emphasizing this into their curriculum?
Response: Stellenbosch is already doing this, probably there is need to add on more collaborating universities.

Qn 3: Are we not including legal enforcements by policy makers and task forces
Response: we need to identify an authoritative body in Africa like FAO, (BARNESA?) to emphasize that these wilts are a problem. This would give us a listening ear, but without policy we may not do much. A participant complemented on the same policy issue stressing that policy intervention voice has been low, and we need to show collective actions (approach as a group and present collective efforts to policy makers). This was concluded by suggesting that when the report is ready, a technical group will be selected to pack the information specifically targeting policy makers.

Comment: A participant identified the need to conduct an impact assessment even at regional level to get the figures and impact factor necessary to convince policy makers and this should be done in collaboration with socioeconomic team in Uganda and the whole region.

Response: A Mozambican participant representing NPPO noted that NPPO of Mozambique is willing to help, but challenged with financial limitations and suggested that there is need to specify which data is needed. It was agreed that the NPPO representative from Mozambique will liaise with socioe-conomist of Bioversity-Uganda to conduct an impact assessment of TR4 in the region.

The **LAC group** prioritized the following for Foc TR4: 1) Impact assessment to raise awareness, 2) Surveillance, early warning system, 3) Detection/Diagnosis; andfor Moko: 1) Impact assessment to raise awareness, 2) Management options, development of best options for IDM.

Reactions from plenary discussions:

Qn: The production system in LAC is very vulnerable, how prepared are you? We need to predict where will it come from and how?
Response: It is indeed very vulnerable, and that's why we included surveillance system as a priority area

The **Asian group** prioritized **two areas** namely; 1) Survey of bacterial diseases in other countries in Asia and assessment of vulnerability according to cultivars' susceptibility and cropping system and 2) Survey of fusarium wilt disease in other countries in Asia.

4.3. Conclusions

The following conclusions were made in line with presentations and discussions held:

1. **Strengthening collaboration with policy makers and enforcers**: Members agreed that without intervention of policy makers, even with the best management package, little will be achieved in curbing the spread of banana wilts. It was unanimously agreed that once the report is ready and agreed upon, a committee will be set to bring on board policy makers around the three continents.
2. **Conducting an impact assessment for TR4**: The impact of TR4 in Africa is not documented, it was agreed that the Mozambique representative will work together with socio-economist of Bioversity-Uganda to conduct this study.
3. **Curbing the spread of TR4 in Mozambique**: With preliminary results in Mozambique showing that Foc TR4 was identified in about 50 small holder farmers, the rate of disease spread is high. It was agreed that the NPPO representative (in attendance) alongside other collaborators in Mozambique devise interventions to stop the disease spread.
4. **Containment and reducing further spread of Foc TR4:** It was agreed that in all countries where the banana wilts, especially Foc TR 4 is still absent, all efforts should be done to prevent entry of the pathogen, areas where the disease is already epidemic, managing epidemic is essential for production sustainability and sustaining livelihoods.
5. **Need for more support from other collaborating organizations in Africa**: It was recognized that management of banana wilts is a collaborative intervention and there is need for more organizations to join this collaboration especially countries from the Middle East Africa.
6. **Research for development:** It was agreed on that the future proposals tailored for research, should include the development model to enable applicability of research in real life problem solving.
7. **Need to Focus on use of resistant varieties:** With resurgence cases of BXW reported, it depicts that cultural management practices may not sorely manage banana wilts, but rather the need for using resistant varieties as well as screening more varieties with farmer preferred traits is paramount.

8. The generalization that TR4 affects all varieties susceptible to Race 1 doesn't hold true, since in a study conducted in Philippines indicated that many varieties susceptible to Race 1 were resistant to TR4. This classification is widely used to describe Race 1 and should be revised.
9. There is evidence that most African varieties are not susceptible to TR4, however, there is need for an expanded variety evaluation that can confirm this finding.

4.4 Closing Remarks and way forward

The closing remarks were given by Dr. Eldad Karamura. He mentioned that the workshop report will be ready in a couple of weeks, probably at end of October. Each of the participants will take responsibility to share information with others for review. When the meeting report is agreed upon, a concept note will be developed. Four people were selected to develop the concept note for Africa. They included; Prof. Altus Viljoen, Dr. Joao Augusto (in collaboration with Dr. Mahuku), Enoch Kikulwe and Guy Blomme. Prof. Yi Ganjun will work with Vida Sinohin Grace to develop a concept note for Asia group. Miguel Dita was tasked to nominate 2-3 people from LAC to develop the concept note. Members agreed that all concept notes should be ready by end of November. Another group targeting policy enforcement was to be selected when the final report is ready. Dr. Eldad Karamura closed the workshop and wished participants a safe travel back home.

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Appendix

Appendix 1: Workshop Program

Day 1 Wednesday August 30, 2017

SESSION 1.	**Opening Ceremony**
0800	Registration
0900	Welcome Remarks and Meeting Objectives
0915	Foc TR4 in bananas- successes, failures and lessons for strategic directions-**Gus Molina**
0945	Effective mnagement of Banana Wilts has remained elusive but a global priority-Altus Viljoen
1015	**Opening Remarks (Group Photo)**
1030	**Coffee/Tea Break**
1100	Research Advances on Foc TR4 in Asia and the Pacific- Yi Ganjun
1130	Biosecurity preparedness in LAC to curb the entry of evasive pests and diseases- Miguel Dita
1200	Mobilizing stakeholder platforms for effective management of Foc TR4-Fazil Dusunceli
1230	BXW in east and central Africa, an example of collaboration success. Jerome Kubiriba
1245	General Discussion of the presentations
1300	**Lunch Break**
1400	Working Group
1530	**Coffee/Tea Break**
1600	Working Group continued
1630	Plenary Discussion
1830	Workshop Dinner

Day 2 Thursday August31, 2017

SESSION C	**Developing Strategies for the management of banana wilts**
0900	Current strategies for managing banana wilts in Asia and the Pacific- Vida Sinohin
0930	Managing banana wilts in Africa; experiences and lessons- Guy Blomme
1000	Strategies for curbing Foc TR4 spread in Africa. Joao Augusto & George Mahuku
1030	**Coffee/Tea Break**
1100	Data needs for mapping pests and diseases in smallholder systems- David Brown.
1200	Plenary discussion
1230	**Lunch Break**
1400	Working Groups
1530	**Coffee/Tea Break**
1600	Plenary Discussion
1830	Cocktail
2000	End of Day 2

Day 3 Friday September 1, 2017

SESSION E. Developing BB 3.3 Cluster Agenda (2018-20)

0830	Working Group
1030	Pleanary
1030	**Break Coffee/Tea**
1100	Plenary discussion of Cluster on-going and planned activities 2018-20, resource mobilization and governance
1230	Closing Remarks
1300	Lunch and Departure

Appendix 2: List of participants

Participant	Location/Address	Email address
Celestin Niyongere	NARS Burundi	cniyongere@yahoo.fr
Johnson Kwach	KARLO - Kenya (Kisumu)	kwachjk@gmail.com
Jerome Kubiriba	NARO - Uganda	jkubiriba2012@gmail.com
Georgina Mwaka	NARO - Student	g.mwaka@cgiar.org
Guy Blomme	Bioversity - Ethiopia	g.blomme@cgiar.org
Oduor Bonaventure Omondi Aman	Bioversity Benin	b.a.omondi@cgiar.org
Eldad Karamura	Bioversity -Uganda	e.karamura@cgiar.org
Debora Karamura	Bioversity -Uganda	d.karamura@cgiar.org
Enoch Kikulwe	Bioversity - Uganda	e.kikulwe@cgiar.org
William Tinzaara	Bioversity - Uganda	w.tinzaara@cgiar.org
Rose Taremwa	Bioversity - Uganda	r.taremwa@cgiar.org
Elias Oyesigye	Bioversity - Uganda	e.oyesigye@cgiar.org
Moureen Nansamba	Bioversity - Uganda	m.nansamba@cgiar.org
Anna Nowembabazi	Bioversity - Uganda	a.nowembabazi@cgiar.org
Celea Naluburwa Abaasa	Bioversity - Uganda	c.naluburwa@cgiar.org
Miracle Arikiza	Bioversity - Uganda	m.arikiza@cgiar.org
Ambrose Atuhaire	Bioversity - Uganda	a.atuhaire@cgiar.org
Agustin Molina	Bioversity - Philippines	a.molina@cgiar.org
Vida Sinohin Grace	Bioversity - Philippines	v.sinohin@cgiar.org
Yi Ganjun	China	yiganjun@vip.163.com
Joao Augusto	IITA - Mozambique	j.augusto@cgiar.org
Martin Ameu	FAO	Martin.Ameu@fao.org
Geofrey Arinaitwe	NARO	aggarinaitwe@gmail.com
David Brown	Bioversity Costa- Rica	d.brown@cgiar.org
Misheck Soko	NARS - Malawi	misheck_soko@yahoo.com
Albertus Viljoen	University of Stellenbosch	altus@sun.ac.za
Custodio Daniel Mendes	Mozambique	customendes@gmail.com

Appendix 3: Asia Group Plenary Discussion Results

Disease	Partners	Theme	Activity description	Priority No.
Blood disease & Bugtok	Asia & Pacific Countries, Bioversity and NARs	Surveillance, early warning systems & mapping	Survey of bacterial diseases in other countries in Asia and assessment of vulnerability according to cultivars' susceptibility and cropping system	**1**
TR4	Asian Countries with Foc TR4, Bioversity and NARs	Surveillance, early warning systems & mapping	Survey of FW disease in other countries in Asia	**1**
Blood disease & Bugtok	Asia & Pacific Countries, Bioversity and NARs	Mg't options & devt of best options for IDM	Improving the adoption of proven disease management strategies (fine tuning the adoption IPM)	2
TR4	Asian Countries with Foc TR4, Bioversity and NARs	Mg't options & devt of best options for IDM	Development and adoption of disease management measures in new countries of occurrence	2
		Mg't options & devt of best options for IDM	Role of resistant varieties and crop rotation on reducing inoculum potential	2
		Mg't options & devt of best options for IDM	Variety improvement through somaclonal selection and selections from natural Musa clonal cultivar diversity	2
		Mg't options & devt of best options for IDM	Development of new varieties using conventional and molecular breeding (CRISPR Cas9 and Host induced gene silencing (HIGS) - CHINA	2
Blood disease & Bugtok	Asia & Pacific Countries, Bioversity and NARs	Capacity building and raising awareness	Promoting to small banana growers the use of the existing IPM strategies for improved adoption	2
TR4	Asian Countries with Foc TR4, Bioversity and NARs	Population characterization cultivar susceptibility and resistance maps	Assessment of vulnerability according to cultivars' susceptibility and cropping system	2
		Plant / soil health systems to suppress disease	Study for deeper understanding factors that affect host pathogen interaction in the rhizosphere (suppressive soils), and understanding to operationalize it under field condition (biological controls)	2
		Assessment of risks and impacts	Quantitative analysis of risk & impact of TR4 on different cropping systems (i.e. monoculture Cavendish vs cultivar and cropping system diversity by small farms)	2
		Assessment of risks and impacts	Adoption and impact assessment on the use of new disease manage strategies & options	2
Blood disease & Bugtok	Asia & Pacific Countries, Bioversity and NARs	Capacity building and raising awareness	Promoting to small banana growers the use of the existing IPM strategies for improved adoption	2

TR4	Asian Countries with Foc TR4, Bioversity and NARs	Capacity building and raising awareness	Capacity building & awareness of stakeholders to prevent incursion	2
TR4			Enhance and develop Regional and National information sharing on TR4 management and newly developed technologies	2

Appendix 4: Africa Group Plenary Discussion Results

Wilt	**Themes**							**Remarks**	
	Surveillance, early warning systems & mapping	**Detection / Diagnosis (VCG determination)**	**Cultivar characterization (cultivar susceptibility and resistance mapping)**	**Cultivar evaluation**	**Plant / soil health systems to suppress disease**	**Mg't options & devt of best options for IDM**	**Assessment of risks and impacts**	**Awareness creation and knowledge communication**	**National/regional/Africa-wide strategic plan/action plan (early reporting, management, investigation)**
BXW	1 (DR Congo; Uganda as resurgence)	East DR Congo (2), rest 3	3	3	3	3	2	ranges from 1 to 3	2
BXW	DR Congo and Uganda (1)					3 (including clean seed system, use of escape varieties)	4	2..	5
TR4	1	1	2	1	3	2	1	1	1
TR4	1 (including detection)			2		3 (including prevention of spread/quarantine and clean seed systems, plant improvement)	6	5	4

1=Very urgent & important 2=important 3=medium importance