FEASABILITY STUDY

Report of the workshop and field visits of the feasibility study on developing virus indexing capacity for banana planting materials in Malawi (STDF/PPG/404)

9-13 December 2013

Lilongwe, Salima and Blantyre, Malawi

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ACRONYMS

ACIAR-SIMLESA	Australian Centre for Agricultural Research's Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa program
AGRA	Alliance for a Green Revolution in Africa
ARC-PPRI	Agricultural Research Council - Plant Protection Research Institute
ARET	Agricultural Research and Extension Trust
ASWAp	AgricultureSector Wide Approach
BBrMV	Banana Bract Mosaic Virus
BBTD	Banana Bunchy Top Disease
BBTV	Banana Bunchy Top Virus
BMMV	Banana Mild Mosaic Virus
BSV	Banana Streak Virus
CABI	Centre for Agriculture and Biosciences International
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
CIMMYT	International Maize and Wheat Improvement Centre
CIP	International Potato Centre
CIRAD	Agricultural Research Centre for International Development
CMV	Cucumber Mosaic Virus
COMESA	Common Market for Eastern and Southern Africa
DARS	Department of Agricultural Services
ELISA	Enzyme-linked Immunosorbent Assay
FAO	Food and Agriculture Organization of the United Nations
FIDP	Farm Income Diversification Programme
FOC TR4	*Fusarium oxysporum* f.sp. *cubense* Tropical Race 4
GIZ	German Federal Enterprise for International Cooperation
ICRAF	International Centre for Agro Forestry
ICRISAT	International Crops Research Institute for the Semi-Arid-Tropics
IITA	International Institute of Tropical Agriculture
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
LPI	World Logistics Performance Index

LUANAR	Lilongwe University of Agriculture and Natural Resources
MCDA	Multi Criteria Decision Analysis
MGDS II	Malawi Growth and Development Strategy
MoIT	Ministry of Trade and Industry
NGO	Non-Governmental Organisation
NPPO	National Plant Protection Organisation
PCR	Polymerase Chain Reaction
PPG	Project Preparation Grant
RTB	Roots, Tubers and Bananas
SADC	Southern Africa Development Community
STDF	Standards and Trade Development Facility
SPS	Sanitary and Phytosanitary
TRF	Tea Research Foundation of Central Africa
USAID	United States Agency for International Development

1. Background information of the study

1.1. Mandate for this study

Previously, a study using a Multi Criteria Decision Analysis (MCDA) to identify and prioritize key sanitary and phytosanitary (SPS) capacity building options and needs for Malawi, was done in May 2012 (Gokah *et al*., 2012). An initial sifting process identified 16 capacity building options, one of which was virus indexing capacity for planting materials. The rationale for including virus indexing capacity for planting materials in the priority-setting analysis were described in the following way: Crops such as Irish potatoes, sweet potatoes and pineapples are propagated from live vegetative planting material. The risk here is that pests and diseases can be carried through to succeeding crops. In particular viruses and mycoplasma-like organisms are readily transmissible through vegetative planting material even if they go through a tissue culture phase. This option involves the development of capacity to test and certify live planting material in Malawi. In turn, this will facilitate the indexing of viruses in Irish and sweet potatoes, leading to improvements in productivity and also facilitating exports of indexed planting material (Gokah *et al*., 2012). The virus indexing capacity for planting material was ranked as high priority in this study (Gokah *et al*., 2012). Although the banana crop was not listed in this study, the importance of banana in Malawi and the importance of healthy planting materials for banana production cannot be ignored.

This feasibility study is based on a project preparation grant (PPG) entitled "Developing Virus Indexing Capacity for Planting Materials" approved by the STDF Working Group in March 2013. The PPG was requested by theDepartment of Agricultural Research Services (DARS) in the Ministry of Agriculture and Food Security in Malawi and supported by various government and private sector stakeholders.[1] It was approved subject to some conditions including a number of technical comments provided by the International Plant Protection Convention (IPPC) Secretariat (discussed below).

The objective of the PPG is to assess the feasibility of establishing capacity for the indexing and production of virus-free planting materials for bananas in Malawi and, depending on the findings and recommendations of this assessment, to develop a project proposal. The PPG is focused

[1] Including the Ministry of Industry and Trade, the Department of Crop Development in the Ministry of Agriculture, Malawi Mangoes Limited, World Vision Malawi.

on developing export potential (i.e. production of clean planting materials for local use and export to regional markets, and support to develop banana pulp exports).

Agriculture is a crucial component of the Malawian economy and contributes to more than 80% of the country's foreign earnings. Recognizing the potential of agriculture, the Malawi Growth and Development Strategy (MGDS II) focuses on the agricultural sector as a priority for export-led growth and trade diversification, in order to enhance food security and reduce poverty. Smallholders play the major role in agricultural production. In the context of the MGDS II, the Government is promoting the intensification of horticultural crop production (including fruit pulps that are in high demand in regional and global markets) for export.

Certain horticulture crops (e.g. bananas, Irish potatoes, sweet potatoes and pineapples) in Malawi are propagated through the use of live vegetative planting materials. A major problem with these materials is that pests and viral diseases can be carried through to succeeding crops. Some programmes to enhance agricultural productivity in Malawi, supported by donors (e.g. EU, Irish Aid, Scottish Aid, World Vision) and the government have reportedly been negatively affected by viral diseases to the point where they have abandoned certain crops (including bananas) or terminated early, despite the local suitability and economic potential of the crops concerned.

Bananas are an important crop for food security and household income in Malawi, and grown extensively by smallholders. However, production is negatively affected by the Banana Bunchy Top Virus (BBTV), with serious consequences for livelihoods, food security and efforts to diversify exports. BBTV is seen as a quarantine pest of very high importance given its destructive potential. The virus, which has no chemical treatment, is spreading rapidly in Malawi, and the region, through the use of infected planting materials, as well as via aphids. Effectively controlling this pest requires the use of pest-free planting materials, supported by strong complementary measures to avoid the presence of any source of infection. In practice, this means that contaminated materials need to be destroyed under the legal authority of the National Plant Protection Organization (NPPO)[2]. The NPPO also needs to enforce strict regulations on the movement of planting materials.

Access to clean planting materials is extremely limited in Malawi. While such materials are available from South Africa, the cost is prohibitive for small farmers, who account for most of

[2] The NPPO is hosted within DARS.

banana production. In addition, public sector capacity to implement international phytosanitary standards is weak with serious shortfalls in human resources, infrastructure capacity, lack of an up-to-date legal basis for phytosanitary services, etc.[3] At the same time, informal movement of people and infected planting materials (e.g. from Mozambique and Zambia) across the country's porous borders exacerbates the problems faced, and highlights the need for concerted regional action for pest control.

Virus indexing is one part of disease surveillance and treatment since it helps to monitor quality of materials coming into and going out of a country, and provides comprehensive management information on various diseases.[4] The purpose of virus indexing is to prevent the distribution or establishment of infected planting materials through the identification of previously characterized viruses and the testing of planting materials to confirm the presence or absence of transmissible viruses or diseases. Since viruses are difficult to eliminate without removing the host, infected plants or plant lots must be removed as early as possible before they get planted into the field. Developing virus indexing capacity generally focuses on building capacity to produce, test and certify disease free planting material. The basic requirements may include: (i) a functional laboratory including availability of relevant equipment such as Polymerase Chain Reaction (PCR) machines, associated accessories and enzyme-linked immunosorbent assay (ELISA) kits, as well as test reagents, and trained diagnostic staff; (ii) seed multiplication facilities and other associated facilities, such as screen houses, hardening sheds, etc. and trained staff to run these facilities); and (iii) robust virus indexing procedures

The outcomes and recommendations of the two main activities of the feasibility study will be discussed in this report. Firstly, results from the workshop held with different stakeholders in the banana industry will be discussed followed by; secondly, an analysis of field visits to different producers and research stations in Malawi.

[3] Capacity weaknesses were identified in 2009 through use of the IPPC's Phytosanitary Capacity Evaluation (PCE). In addition, FAO carried out a National Biosecurity Capacity Assessment in 2009, which reviewed food safety, plant and animal health.

[4] In 2012, the Ministry of Industry and Trade (MoIT) worked with other parts of government and the private sector to prioritize SPS-related investments using the Multi Criteria Decision Analysis Tool. This work ranked virus indexing capacity for planting materials as one of the top four priorities (out of 16 capacity-building options/investments) based on the expected positive impacts on poverty reduction, vulnerable groups, trade diversification and agricultural productivity.

1.2. Feasibility study

The feasibility study was tasked to include a systematic examination of the following:

- An assessment of the current situation of BBTV in Malawi, including its status as a quarantine pest, with particular focus on districts (e.g. Nkhata Bay, Nkota Kota, Salima, Thyolo and Mulanje districts) with greatest potential for banana production.
- An analysis of the existing capacity of the government, private sector and other relevant stakeholders to adequately contain BBTV in Malawi, as well as significant capacity gaps and priorities. This analysis should consider other necessary regulatory actions which should be undertaken by the NPPO to effectively control BBTV, as well as any other important complementary actions and measures (e.g. containment and/or destruction of old banana plantations/mats) which should be undertaken by other stakeholders (e.g. government, industry, small farmers).
- Human resource needs (including virus indexing and tissue culturing at professional and technical level), infrastructural requirements and costs (related to upfront investments and ongoing costs for laboratory equipment, seed multiplication facilities and associated facilities, etc.) related to the production and development of clean planting materials.
- Commercial opportunities to produce disease-free planting materials in Malawi for export to neighbouring countries (e.g. Zambia and Mozambique) based on market demand in the region, other financial aspects (e.g. production costs, transportation costs, market price for clean planting materials in Malawi and region, etc.), private sector interest, opportunities for public-private partnerships. This should include an analysis of selected, commercially-viable facilities for virus indexing and the production of disease-free planting materials in other parts of Africa.[5]
- Capacity of stakeholders in Malawi to meet regulatory requirements necessary to export banana planting materials within the region, including relevant SPS requirements, SPS export/import clearance procedures, etc.
- Linkages and complementarities to related (ongoing/planned) capacity building activities supported by donors and development partners in Malawi, such as support for virus indexing in potatoes and the rehabilitation of a small tissue culture facility.

[5]For instance, Agro-Genetic Technologies Ltd, Kampala, Uganda (Mr.Erostus W.N. Nsubuganerostus@gmail.com, www. agtafrica.com)

- Synergies to other ongoing/planned efforts in the region to address problems related to the use and spread of infected planting materials (see paragraph 8 above).
- Prospective interest of donors and development partners to fund or co-fund all or part of the project to be developed through this PPG (particularly given the likelihood that such a proposal would not meet STDF eligibility criteria given an expected focus on infrastructure and equipment). Preliminary discussions have taken place with some development partners and donors in Malawi including the Food and Agriculture Organization of the United Nations(FAO), the European Union and the United States Agency for International Development **(**USAID**)**. These discussions should be continued and consultations initiated with other possible donors (e.g. World Bank).

The above mentioned points were formulated to accommodate the inputs of stakeholders in the private sector (including producers), the public sector including officials from the National Plant Protection Organisation (NPPO) of Malawi in the Department of Agricultural Research Services (DARS) as well as research professionals. The methods used to obtain the information will be further discussed in section 2.3.

2. Workshop on developing virus indexing capacity for banana planting materials in Malawi

A two day workshop was held in the Pacific Hotel in Lilongwe on 9-10 December 2013 on developing virus indexing capacity for banana planting materials in Malawi. Day 1 of the workshop was attended by stakeholders in the private sector, including producers and researchers, and some public sector stakeholders from the Ministry of Trade and Industry (MoIT), DARS officials and a member of Parliament. Day 2 was attended by public sector stakeholders from the NPPO, MoIT and a Member of Parliament.

2.1. Participant Profiles

Front row: Hon L. Lowe, Dr. E. Jooste, D. Kamangira, M. Soko, Y. Nyaika, A.W. Phiri
Back row: I.B. Gokah, Dr. I. Benesi, M. Washoni, E. Chongwe, F. Washoni, S. Mng'omba, O.M. Chirwa

The following participants contributed to the workshop and a list with their contact details is available in Appendix 1:

Honourable Lobin Lowe: Member of Parliament- also a producer of banana and mango
Dr.Benesi: Chitedze Research Station, Commodity team leader for root crops, and leading biotechnology officer
Jacinta Nyaika: Lecturer at Bunda College – Post harvest, tissue culture and mushroom production. She obtained her MSc in tissue culture
Matthias Nkhoma: Department of Crop Development- Horticulture
E.D.L.Mazuma: Chitedze Research station – Dept of Agricultural Research – Plant Pathologist

D. Kamangira: DARS. Technology Management and Regulatory services. IPPC contact point
O.M.Chirwa: Lilongwe ADD. Divisional Crops officer
E. Chongwe: Coordinator of FIDP Horticulture project
Simon Mng'omba: ICRAF (International Centre for Agro forestry). Based at Chitedze.
Amon W. Phiri: Dept of Crop Development, Horticulture officer
Isaac B Gokah: Ministry of Trade and Industry (MoIT)
MisheckSoko: Chief Scientist at Bvumbwe Research Station
Frankie and Maurice Washoni: Producers in Lilongwe region
Solister M. Matchere: Mangoes Malawi (Operations) Ltd, Producers in Salima district

2.2. Objectives of the Workshop

According to the tasks stipulated in the terms of reference, we formulated the objectives of the workshop accordingly.

The questionnaires used to obtain the necessary information are listed in brackets. The results will be discussed according to the following objectives:

1.Banana pest profile and current situation on the spread of BBTV in Malawi (A, B- pest list)
2.The capacity in the private sector to contain BBTV in Malawi.(E-producers)
3. The commercial opportunities to produce disease-free planting materials for local and regional use.

3.1. Private sector interest and potential for public and private partnerships (F-tissue culture)

3.2. Assessment of existing or potential capacities of private sector (research and academia) and research within the NPPO e.g. location, infrastructure and Human Resources (C, D)

4. The capacity of stakeholders to meet regulatory requirements for exporting banana planting materials into the region (B, without pest list)
5. Synergies to other ongoing/planned efforts in the region to address problems related to the use and spread of infected planting materials and the potential of local and exporting markets for banana. (F,G)

2.3. Method used to facilitate the workshop

2.3.1. Workshop Agenda and Questionnaires

The agenda for the workshop was scheduled for two days. As mentioned previously, Day 1 (9 December 2013) of the workshop was attended by stakeholders in the private sector, including producers and researchers, as well as public sector stakeholders from the Ministry of Trade and Industry (MoIT), DARS officials and a member of Parliament. Day 2 (10 December 2013) was attended by public officials from the NPPO, MoIT and the Member of Parliament. The Agenda of the workshop is attached as Appendix 2 of the document. In total eight questionnaires were designed to obtain the information formulated in this report. The questionnaires are attached as Appendix 3 of this report.

2.3.2. Workshop Presentations

On day 1 of the workshop two introductory presentations were given. Mr. M. Soko presented on the most current spread of BBTV in Malawi and also reported on other important diseases of banana in Malawi. Dr. Jooste presented on the objectives of the workshop and other viruses that is a threat to bananas worldwide. The stakeholders were encouraged to participate in this important meeting.

2.3.3. Workshop Discussions

Discussion groups were formed and brainstorming opportunities were given to the participants to complete the questionnaires. After compiling the questionnaires, the answers were discussed in the group. All the answers from the groups were collated in one document that was used to produce a collective opinion, resulting in the results discussed in the next section.

2.4. Results from the workshop

The objectives (1 to 5 stipulated in section 2.2) will be discussed in this section.

2.4.1. Banana production in Malawi

The answers from Questionnaire A, the pest list in Questionnaire B and Questionnaire E for producers were used to compile answers to this section.

The major banana growing areas in Malawi include Chitipa and Karonga in the North, areas along Malawi Lake including parts of Rumphi, Nkata Bay, Nkhota Kota and parts of Salima as well as Mulanje, Thyolo and an adjacent area in Blantyre in the South. There are also production areas in the Lilongwe district. The production areas are marked in Figure 1.

Bananas are grown throughout the year. Farmers in the Northern regions traditionally cultivate cooking bananas (Bluggoe and Pisangawak, ABB) and plantains (AAB) for food. In contrast, Cavendish cultivars are popular in Thyolo and Mulanje districts, for fruit and to a minor extent for sucker production for the commercial market as planting material in Salima, Nkhota Kota and Nkata Bay where the demand for Cavendish is high (Kumar *et al*., 2011). The majority of banana production, over 97% of the total, is produced by smallholder/informal production on 83000 ha of land. Small holder farmers are individual farmers or they form cooperatives. The main component, over 95% has varying sizes of fields. The Cooperative, called Banana Association of Malawi, is based in the South and collectively they represent a commercial set up. Only 60ha of land are currently under commercial production. We define commercial production as having organised plantations. These commercial plantations can be found in Lilongwe, Mzuzu and Salima districts.

MOTIVATION FOR BANANA PRODUCTION AS PROFITABLE ENTERPRISE

- Cultivating banana ensures a very good source of income (an enterprise with a good gross margin)
- Income can be generated from both fruits and suckers e.g. 250MK=2.4 million
- It gives a profit of about 75% of the total revenue
- The demand for fresh fruit is high
- Pulp extraction and export opportunities exist

Two commercial producers in the Lilongwe and Salima regions, namely Hortnet (Washoni brothers) and Malawi Mangoes, completed Questionnaire E designed for producers. One small

scale farmer completed the same questionnaire. A summary of the feedback on cultivars mainly grown, origin of planting materials, hectares of land under banana production and income depending on the crop are summarised in Table 1.

	Maurice Mashoni (Hortnet)	**Frankie Mashoni (Hortnet)**	**Malawi Mangoes**	**Hon Lowe**
Cultivars grown	Williams & Grandnain	Williams & Grandnain	Grandnain	Williams & Grandnain
Where do you obtain plant material from?	Du Roi (SA) Amiran (Israel)	Du Roi (SA) Amiran (Israel)	Du Roi (SA) India (Jain)	Mangochi (initially from SA)
Hectares planted	5ha	3.5ha	49ha	0.2ha
Income depending on banana production	80%	70%	80%	5%
Is it profitable?	Yes	Yes	Yes	Yes

Table 1. A summary from producers on aspects of banana production

Producers indicated that they experience **constraints with banana production** that includes following:

- The high cost of labour is a constraint for small scale producers who must hire additional labour to assist with manual weeding
- The cost to combat aphids that spread BBTV is high and knowledge of pest management in the informal production system is inadequate
- The cost to import disease free planting material is high and in addition some quality problems have been experienced with imported plantlets from India and Israel

- Irrigation facilities are lacking and the cost to irrigate plants is high, especially when using diesel to pump water from the water source. Irrigation is therefore only feasible in a commercial set up at this stage
- Financial resources, i.e. quarantine facilities to establish mother blocks needed for a tissue culture facility are expensive to build and the availability of funds is a major constraint
- Soil fertility and soil degradation is a problem. Also, banana requires potassium fertilizers that are not readily available in Malawi.
- Malawi producers do not yet have market access to any potential export markets. However, the local demand is high.
- Economic concerns: Forex challenges exist when importing disease free planting material

Figure 1. A map of Malawi indicating the major banana production areas of the country in green

2.4.2. Banana pest profile and current spread of BBTV in Malawi

A summary of pests on banana is shown in Table 2. A number of pathogens have not yet been detected on banana in Malawi.

Pest Categories	Common name	Scientific name	Geographic distribution in Malawi Yes/No/not sure	Quarantine pest Yes/No
Nematodes	Spiral nematodes	*Helicotylenchus* spp	Yes	
	Burrowing nematodes	*Radppholus similis*	Yes	

	Rootknot nematodes	*Meloidogyne* spp.	Yes	
	Lesion nematode	*Pratylenchus* spp.	Yes	
	Reniform nematode	*Rotylenchus* spp.	Yes	
	Banana snail	*Urocyclus flavescens*		Yes
Arachnida	Citrus grey mite	*Calacarus citrifolii*		Yes
	Ornamental flat mite	*Brevipalpus obovatus*		Yes
	Reddish-back flat mite	*Brevipalpus phoenicis/ Tetranychus amicus*	Yes	
	Crimson spider mite	*Tetranychus lombardinii*		Yes
Orthoptera	Banana grasshopper	*Abisares viridipennis*		Yes
Hemiptera	Banana aphid	*Pentalonia nigronervosa*	Yes	
	Red scale	*Aonidiella aurantii*	Yes	
	Circular purple scale	*Chrysomphalus aonidum*	Yes	
	Banana white scale	*Aspidiotus alaeidis*		Yes
	Coconut scale	*Aspidiotus destructor*		Yes
Thysanoptera	Banana thrips	*Hercinothrips bicinctus*		Yes
	Flower thrips	*Thrips exilicornis*		Yes
Coleoptera	Common fruit chafer	*Pacnoda sinuate flaviventris*	Not sure	
	Banana weevil	*Cosmopolites sordidus*	Yes	
	Sugarcane snout beetle	*Ellimenistes laesicollis*		Yes
Lepidoptera		*Lobesia stericta*		Yes
		Cryptoblabes gnidiella		Yes
		Pyrodercus rileyi		Yes
	Tomato semi-looper	*Chrysodeixis acuta*	Yes	
	Bush pig	*Potamochoerus porcus*		Yes
Pest	**Common name**	**Scientific name**	**Geographic distribution in Malawi Yes/No/not sure**	**Quarantine pest Yes/No**
Fungal and bacterial infections	Fusarium wilt	*Fusarium oxysporum* f.sp. *Cubense*	Yes	
	Cordana leaf spot	*Cordana musae*		Yes
	Armillaria corn rot	*Armilaria* spp.		Yes
	Erwinia rhizome rot	*Erwinia chrysanthemi*		Yes
	Heart rot	*Erwinia musae*		Yes
	Black sigatoka	*Mycosphaerella fijiensis*	Yes	

	Yellow sigatoka	*Mycosphaerella musicola*	Yes	
	Leaf speckle	*Mycosphaerella musae*		Yes
	Deightoniella leaf spot	*Deightoniella torulosa*		Yes
	Bacterial wilt of banana	*Xanthomonas campestris* pv. *musacearum*		Yes
	Cigar-end rot	*Verticillium theobromae*	Yes	
	Moko disease	*Ralstonia solanacearum, race 2*	Yes	
	Banana blood disease	*Ralstonia solanacearum* phylotype IV		Yes
	Dreschlera leaf spot	*Drechslera siccans*		Yes
Viruses	Banana streak disease	*Banana streak virus(BSV)*	Yes	
	Banana mosaic	*Cucumber mosaic virus (CMV)*		Yes
	Banana bunchy top disease	*Banana bunchy top virus (BBTV)*	Yes	
	Banana bract	*Banana bract mosaic virus (BBrMV)*		Yes
	Banana mild mosaic	*Banana mild mosaic virus (BMMV)*		Yes

Table2.The pest list on banana in Malawi; indicating distribution of pests within Malawi and the quarantine pest status.

Banana bunchy top virus (BBTV), which causes banana bunchy top, is the most serious and destructive viral disease of banana and plantain in Africa. The first report of BBTV in Malawi was documented in 1997 in Cavendish plantations (Kenyon *et al*., 1997). Classical BBTV symptoms were observed to be widespread in the Thiwi Valley, Salima Agricultural Development division. The symptoms included marginal yellowing of the younger leaves, dark – green, dot-dash streaks along the veins, petioles, and midribs, and shortened internodes (Kenyon *et al*., 1997). The virus is transmitted by the aphid vector *Pentalonia nigronervosa* and in the report by Kenyon *et al* (1997) they recommended that all plants with symptoms be eradicated to reduce the economic damage caused by the virus and its vector. There are two distinct molecular groups of BBTV isolates based on nucleotide sequence differences: the 'Asian' and 'South Pacific' group (Karan *et al*., 1994). BBTV isolates from Malawi falls in the 'South Pacific' molecular group (Kumar *et al*., 2011).

A survey of BBTV was conducted in August 2008 to November 2009 in major banana production regions in Angola, Cameroon, Gabon, DRC and Malawi (Kumar *et al*., 2011). All the production regions in Cameroon and Malawi were included in this survey. Results from the survey showed that banana bunchy top disease (BBTD) was restricted to certain regions in Cameroon and Malawi, but widespread in all major banana growing regions in Angola, DRC and Gabon (Kumar *et al*., 2011). In a field in Malawi (Dedza Town, Dedza district) none of the plants collected showed BBTD symptoms, but 1 of the 5 plants collected tested positive for BBTV.

A map of surveyed locations in Malawi is shown in Fig 2 as described by Kumar *et al*. (2011). In Malawi, the virus was detected in Blantyre, Dedza, Lilongwe, Michingi, Mzimba, NkhotaKhota, Nkhata Bay, Ntchisi, Salima and Zomba. Infected banana plants were found in farmer's fields, research stations, backyard gardens and in the abandoned fields (Kumar *et al*., 2011). BBTV was detected at altitudes up to 1391 masl in Malawi (Ntchisi, Boma Center, Malawi). In Malawi, all 22 cultivars including banana, plantain and hybrids were found susceptible to BBTV showing differences in symptom severity in a field study conducted in 2004-2006 in Mkondezi, Nkhatabay (Mwenebanda *et al*., 2007).

The spread of the disease in Malawi is likely to have been through infected planting material. The disease was first reported in Thiwi area in Nkota Kota district and subsequently spread to Nkhata Bay and Salima which are remote from the source of the initial outbreak of BBTV in central Malawi (point 'a' in Fig 2) (Kumar *et al*., 2011). In Malawi the disease was also observed around major cities like Lilongwe and Blantyre, away from the epidemic areas of Salima, Nkhota Kota and Nkhata Bay. This spread can be explained by the fact that migrant workers and farmers take the infected planting material to the cities to be planted as a backyard crop (Kumar *et al*., 2011).

This survey showed that four major banana producing districts, Thyolo and Mulanje in the South, and Karonga and Chitipa in the North, remained free of BBTV (Kumar *et al*., 2011). Since this study, the regions in the South, Thyolo and Chikwawa districts adjacent to the disease-affected Blantyre, also became infected with BBTV. The impact of BBTD was most profound on cultivars with AAA genome, such as Cavendish Williams, Mulanje, Kafupi and Kabuthu, which are widely grown in Malawi (Kumar *et al*., 2011). To date, the BBTV outbreaks severely affected banana production in about 3500ha of banana in Malawi. In contrast, such a huge crop loss was not recorded and the disease was not very apparent in central African

countries including Democratic Republic of the Congo (DRC) and Gabon where plantains (AAB or ABB) or Gross Michel (AAA) predominate and are tolerant to disease (Kumar *et al*., 2011).

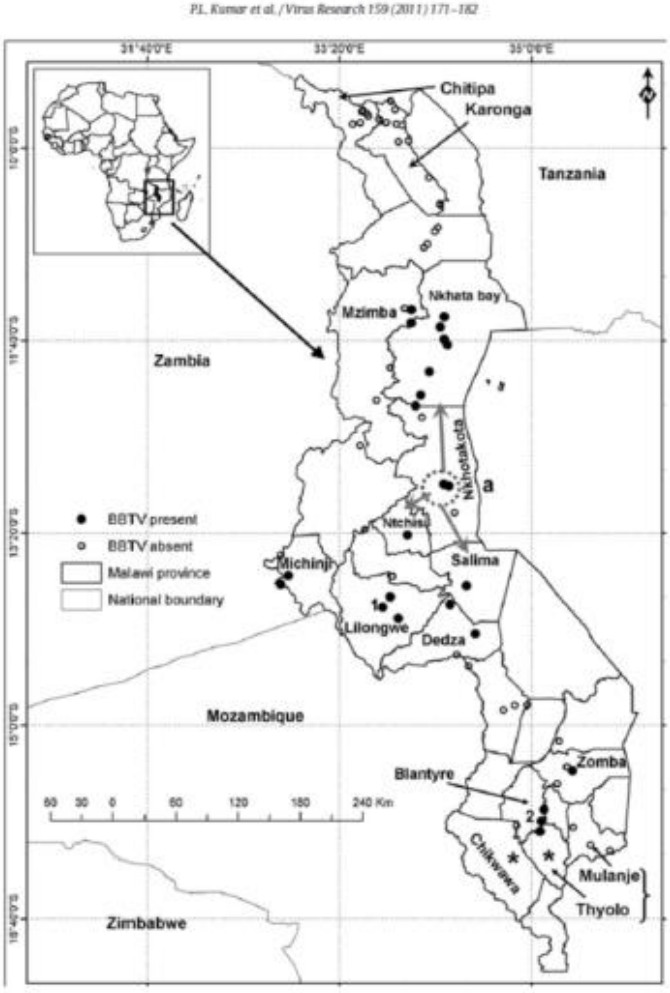


Figure 2. Map of surveyed locations in Malawi (indicated with circles). Region of first BBTD outbreak is indicated (a) and direction of disease spread indicated with arrow. 1=Lilongwe, and 2= Blantyre

2.4.2.1. Surveillance programs for BBTV

Currently, no detection surveys are being done for BBTV by either the public or private sector in Malawi. However, extension frontline staff is encouraged to be observant of the occurrence of the disease and they are trained in the identification and management of the disease. The public extension system reports on a monthly basis about the spread of diseases, including BBTV. Some private sector role-players do their own voluntary surveillance, for example Malawi Mangoes surveys in their production areas and uproot infected plants. Commercial producers are generally aware of the importance of the movement of banana suckers from one area to another. However, the lack of knowledge of the disease by informal/small scale farmers creates a challenge for control of BBTV.

CHALLENGES:

- Extension staff should be trained sufficiently. There is currently surveillance done by extension officers but the system can be streamlined to also include private sector inputs

RECOMMENDATIONS:

- Awareness should be encouraged through pamphlets/posters
- A more streamlined reporting system is necessary
- The Ministry of Agriculture should establish official movement controls for planting materials and may request assistance from the national police to implement such movement control points/ roadblocks.

2.4.2.2. Risk management practises to prevent the introduction and spread of BBTV

The following strategies and views were expressed in the meeting on the prevention of the spread of BBTV in production areas:

- Rouging and destroying if infected whole mats
- Use of disease free planting materials
- Creation of buffer zones by commercial producers through uprooting of banana plants
- Importation of disease free material (tissue culture)
- Posters on awareness of BBTV were produced but not widely circulated to the private sector and this is creating a knowledge gap. Disease awareness efforts should be strengthened
- The private sector, especially informal farmers, has inadequate knowledge of the management and control of BBTV

CHALLENGES:

- Inadequate human and financial resources
- Inadequate resources for monitoring

RECOMMENDATIONS:

- Collaboration on risk management should be applied on a broader range, more producers should be applying it to ensure clean banana materials
- Education and training of small scale farmers in risk management strategies is necessary

2.4.2.3. Management strategies implemented to control the spread of BBTV

The role of human transmission of BBTV by means of infected propagating material seems to be the main reason for its widespread distribution in Southern Africa but the role of the aphid vector is also significant. Using disease free planting material will not be sufficient but it is also important to protect source sites. The disease will have to be eradicated, or at best contained, to provide for pest free production areas/ places. This will mean that commercial and informal/ small scale banana producers will have to cooperate with the NPPO towards establishing pest free areas. A concern is the ability of current legislation to comply with the core requirements of the IPPC to ensure that the NPPO have appropriate mandates to implement phytosanitary regulatory services relating to pest containment and eradication.

CHALLENGES:

- Surveillance- very little is being done
- Movement control- no official movement controls are in place
- Containment – mostly practised by commercial farmers voluntarily
- Destruction- some farmers have been advised to destroy the infected plants however adherence to the practice is limited due to limited availability of certified disease free material

Legislative shortcomings to implement containment and eradication programmes for BBTV

RECOMMENDATIONS:

Responsibility for these management strategies should be taken by

- For surveillance: Research - surveillance through a streamlined extension system is necessary
- For containment: Research, Extension and private sector

The destruction of infected plantations should be a collective responsibility of all stakeholders involved but the physical destruction should be done by the farmer.

- The control of movement of planting material: Extension and education of informal farmers

The destruction of infected plants by commercial farmers (this is very minimal for small holder farmers) and creation of a buffer zone around new orchards, for example the case of Mangoes Malawi in the Salima district, is one example of an important management strategy implemented by commercial farms.

2.4.2.4. NPPO capacity that exists to do national surveillance of all production areas to confirm the spread of BBTV

This is an important capacity that the NPPO will need to strengthen in order to officially manage and verify the spread of BBTV (and other pests of quarantine concern), especially in support of

the pest risk analysis process for market access initiatives to develop potential markets for fruit in the region.

CHALLENGES:

- The trained experts available are inadequate
- The resources for monitoring are inadequate
- NPPO has limited inspection capacity due to shortage of staff
- Diagnostic services are available at molecular level at Chitedze and ELISA detection at Bvumbwe
- Inadequate human and financial capacity

RECOMMENDATION:

Increase NPPO capacity through human and infrastructural resources mobilization

2.4.2.5. Additional information on BBTV

Efforts have been made to sensitize people about the occurrence of BBTV in the country. Projects by non-governmental organisations (NGO's) have helped in producing leaflets/posters and other extension materials on the control of the disease. Some commercial producers are importing virus free material. The occurrence and management of BBTV has been given a Presidential priority and banana are recognized more and more as an important crop in Malawi.

2.4.3. The capacity in the private sector to contain BBTV in Malawi

Information gathered from Questionnaire E was used in this section.

The capacity of **commercial producers** participating in the workshop to implement IPM is available, except for the ability of virus-indexing that is still lacking. There is one supplier in the Lilongwe area that sells heavily infected suckers and this is an example of how knowledge gaps on BBTV mitigation exist. The availability of healthy plant materials locally is also restricting the expansion of the industry.

Results on how commercial producers implement Integrated Pest Management (IPM) are shown in Table 3. It is clear from Table 3 that the capacity of the private sector, referring to commercial producers, exists to contain BBTV in Malawi. The producers that attended the workshop all knew how to identify the symptoms of BBTV and were able to describe the symptoms.

	Hon Lowe (small scale farmer)	Hortnet (Commercial)	Mangoes Malawi (Commercial)
1. Planting healthy plant material	yes	yes	yes
2. Vector control	no	yes	yes
3. Removal of sources of infection, weeds, infected suckers	yes	yes	yes
4. Phytosanitation-virus indexing	no	no	no
5. Planting resistant cultivars	no	yes	yes
6. Geographical isolation	no	yes	yes

Table 3. A summary of the implementation of IPM by two commercial farmers and a small scale farmer

The capacity of **small scale producers** to contain BBTV is not well developed. In section 2.4.2.2.theconcern was raised that small scale producers have inadequate knowledge of the mitigation of BBTV. Education and training of small scale farmers in risk management strategies is therefore necessary and commercial producers may play an important role. Mangoes Malawi followed a procedure where they've provided training for small scale producers located in areas surrounding the Malawi Mangoes plantations. The small scale farmers were asked to remove and destroy all infected banana plants upon which they were reimbursed by Malawi Mangoes with disease free planting material. With this strategy Mangoes Malawi were able to create pest

free areas and/or areas of low pest prevalence surrounding for their places/ sites of production. The small scale producers also benefited from this strategy.

A question in Questionnaire E was formulated to test the viability of establishing pest-free areas for banana production in Malawi. Participants were asked if they would be willing to destroy infected plantations and replace them with healthy material from the newly established tissue culture and virus indexing centre. Commercial producers reacted positive on this question and indicated the following financial and infrastructural inputs will be required:

- Secure shade net facilities to maintain important plant material
- Disease free planting material of high yielding cultivars
- Technical expertise on banana production should be further developed
- Irrigation equipment and supply of water to plantations and shade net facilities
- Additional land required for production of banana
- Labour cost remains a concern and should be addressed

2.4.4. The commercial opportunities to produce disease-free planting materials for local and regional use.

In this section answers from Questionnaires F-tissue culture, C and D were analysed.

2.4.4.1. Market demand locally and in the region

There is a growing interest in banana production in Malawi with approximately 200 000 - 250 000 suckers annually being planted. Bananas are grown throughout the year and harvested in April until end of May. Less than 10% of locally produced banana fruit is sold to the consumer via retail or formal sector. The rest is traded in the informal sector with no local market requirements pertaining to labelling, packing and quality controls.

Commercial producers in Malawi have been importing disease free banana planting material from South Africa, Zambia, France, Israel and India. As mentioned before, some quality problems arose with imported material from Israel and India. So, current imports of disease free planting material focus on laboratories in the region namely Du Roi in South Africa at US$0.67 and Amiran in Zambia at US$2 per sucker. In Malawi, suckers are sold on the local market for

approximately US$0.83 and material derived from micro-propagation at US$1.18 each. The average domestic market price for desert bananas is 0.7 - 1US$/ kg.

The local demand for disease free banana planting material include smallholder farmers with well-established orchards, those with backyard mats and also large scale farmers which will justify the establishment of a tissue culture facility. The development of a processing plant for banana and mango in Malawi is considered to be a factor that will in time further increase the demand especially as the processing plant has indicated plans to incentivize farmers to produce more bananas for processing purposes.

Production areas that have been targeted for development for export markets include Salima, Lilongwe, Mangochi and Nkhota Khota. These areas have irrigation potential, a short rainfall season and generally high temperatures. It is expected that Mulanje, Thyolo, Nkota Kota and Karonga will continue to supply the local market and generally experience high rainfall and low to high temperatures.

Malawi would like to explore opportunities for export of disease free planting material to the northern regions of Mozambique. Mozambique imports various planting material including mango, citrus and forest trees. High demand for banana planting material has been demonstrated in the Villa Ulongwe/ Tete province. Mozambique imports most of its planting material from South Africa but mostly to the southern areas. Malawi shares a long northern border with Mozambique and would therefore be in a very good position to compete for the northern parts of the country as an export market.

During the Workshop on SPS Measures that was held in Malawi in 2008, poor infrastructure (e.g. lack of cold chain facilities and transport), weak market links, high inputs costs (e.g. fertilizers), lack of SPS training and awareness at grassroots level, and poor literacy levels were listed amongst the areas of concern affecting Malawian trade. Participants also listed poor awareness and lack of information of the market chain, international agricultural opportunities, world market prices and SPS requirements as some of the major challenges that prospective exporters face. Also, it is generally difficult for small scale farmers to access finance whilst access to incentives and available loans are further complicated by excessive administration. Improved access to export incentives and finance may give small scale farmers a better chance of producing for export markets.

2.4.4.2. Private sector interest and potential for public and private partnerships

In Malawi, research is mainly conducted in public sector research institutions. A few trained professionals are employed in the public sector that could be trained to work/ manage a virus indexing laboratory. The NPPO has been providing a virus indexing service for cassava, sweet potato and potato. Keeping this in mind it would have an advantage to use the existing laboratory facilities of the Research Institutions for potential virus-indexing centres. The potential for private/public interaction will depend on the potential investors in a tissue culture facility. Virus indexing for disease-free planting materials will be the main function of the tissue culture facility to ensure disease free plants are propagated. Commercial and small scale producers will make use of the virus indexing centres that are public entities, to test for other disease symptoms.

2.4.4.3. Assessment of existing or potential capacities of private sector (research and academia) and research within the NPPO e.g. location, infrastructure and HR NPPO capacities

The NPPO of Malawi is arranged within the National Research Coordinator for Plant Protection in the Ministry of Agriculture and Food Security. Inspectors are located at international airports and border posts and report to their respective Plant Protection offices. An updated version of the entry points is available on the IPPC website at http://www.ippc.int

DARS operates a network of nineteen service centres that are strategically located in all agro-ecological zones of Malawi. These cover a total land area of 2731 ha. Among the service centres there are 18 research stations which are categorized into the following four groups:

1. Agricultural Research Stations
    - Chitedze: Coordination of research activities in the following Commodity groups: Cereals, Legumes, Oilseeds, Soils and Agricultural engineering and Technical Services
    - Bvumbwe: Coordination of research services in Horticulture and Plant Protection
    - Lunyangwa: Coordination of research services in Livestock and Pastures

2. Agricultural Experimental Stations
    - Kasinthula: Coordination of Irrigation and Drainage Research
    - Makoka: Coordination of Cotton Research
    - Lifuwu: Coordination of Rice Research
    - Mkondezi: Coordination of research on Spices and Root and Tubers
3. Agricultural Experimental Sub-Stations: These stations are used as trail centres for testing promising technologies and are located in Citala, Mbawa and Baka
4. Agricultural Experimental Trial Sites: These sites are used to test promising technologies for the main research stations and are located in Ntchena-chena, Bolero, Meru, Ngabu, Bembeke and Tsangano.

Some diagnostic expertise exist in the NPPO of Malawi that could be trained to manage a tissue culture laboratory but it is expected that such a facility will be managed/ owned by the private sector though it is not yet clear as to what extent the private sector means to become involved in such a facility.

Some diagnostic expertise already exists in the NPPO of Malawi to do virus indexing for cassava, sweet potato and potato. Further training needs have been identified for banana virus indexing which include, quantification of pathogens, establishment of pest free areas and laboratory techniques using new methodologies. Professionals working with bacterial and fungal diseases listed further training requirements in taxonomy, developing laboratory standard operating procedures and molecular detection techniques. Entomologists working on bananas listed further training in taxonomy and bio-control of vectors. One nematologist is employed by the NPPO and he listed further training requirements in species identification and management strategies for nematodes. BBTV is regarded as the most important banana pest impacting negatively in the economy of Malawi and participants suggested that more students should be trained with a focus on BBTV management, especially in support of the establishment of a banana tissue culture facility.

The intention of Malawi is to have NPPO as the regulator doing the virus indexing whilst the tissue culture laboratory may be a private enterprise or a collaboration between the private and public sector.

Two laboratories are considered to have the capacity to be transformed into a tissue culture laboratory, namely the laboratories at Bvumbwe Research Station and Bunda College. A third laboratory at Lunyanga in the northern region was discussed but not considered to be suitable. In the case of Bvumbwe and Bunda it will mostly require increasing the laboratory in size but with Lunyanga laboratory it will mean completing the rehabilitation. The Lunyanga facilities were not visited during this study to give an opinion on the available infrastructure.

Two laboratories are considered to have the capacity to be transformed into a virus indexing laboratory, namely the ones at Chitedze Research Station and Bvumbwe Research Station. At Chitedze the laboratory has been newly renovated and will become operational soon. At Bvumbwe a laboratory exist but will need additional virology equipment, and specifically for molecular analysis. Responses from the entomology, nematology and bacteriology laboratories indicate that laboratory chemicals are generally not in sufficient supply.

The following banana pests were listed that can be detected with existing diagnostic capacities within the NPPO of Malawi: weevils, Elegant grasshoppers, Black Sigatoka, Panama disease, BBTV, *Rodopholus similis, Meloidogyne* spp, *Pratylenchus* spp and *Helicotylenchus* spp.

The University of Malawi and Bunda College of Agriculture (LUANAR) are the only research facilities in Malawi that is not affiliated with the NPPO that undertakes banana research focusing on nematode control, propagation techniques for banana production, macro- and micro propagation.

Contact details of the relevant specialists in the fields of Botany, Horticulture, Entomology, Nematology, Mycology, Virology, etc. within the NPPO:

- Botany: Prof Moses Kwapata (mkwapata@yyahoo.com)
- Horticulture: Felistus Chipungu (felichipungu@yahoo.com)
- Entomology: Donald Kachigamba (dkachigamba@gmail.com)
- Nematology: Donald Kachigamba (dkachigamba@gmail.com)
- Mycology: Elisa Mazuma (Elisamazuma@gmail.com)
- Virology: Misheck Soko (misheck_soko@yahoo.com)

Major donors of DARS, Malawi include World Bank and Kingdom of Norway (ASWAp), Irish Aid, Bill and Melinda Gates (AGRA), McKnight Foundation, Australian Centre for Agricultural Research's Sustainable Intensification of Maize-Legume cropping systems for food security in Eastern and Southern Africa program (ACIAR-SIMLESA), Scottish Government, Seed and Pesticides companies and various NGO's.

Collaborating Institutions include LUANAR, International Crops Research Institute for the Semi-Arid-Tropics(ICRISAT), International Institute of Tropical Agriculture (IITA), International Centre for Agro Forestry (ICRAF), International Potato Centre (CIP), Agricultural Research and Extension Trust (ARET),Tea Research Foundation of Central Africa(TRF), International Centre for Tropical Agriculture (CIAT) and the (CIMMYT).

2.4.5. The capacity of stakeholders to meet regulatory requirements for exporting banana planting materials into the region

Malawi is not exporting banana fruit or planting material to any other markets at this stage. There is an interest by commercial producers to explore market access opportunities, particularly in the Southern Africa Development Community (SADC) and Common Market for Eastern and Southern Africa (COMESA) regions but the immediate focus will be on providing disease free planting material to the local market.

Malawi's performance in more perishable and SPS sensitive agri-food exports, notably animals, fresh vegetables, cut flowers and animal products are suggestive that supply chain problems, logistics and seasonality remain the predominant constraints, especially in light of the country's landlocked status and poor ranking in the world logistics performance index (LPI). Malawi's major trading partners, particularly in the region, are not highly concerned about SPS requirements and anecdotal evidence suggests that traders circumvent these relatively easily, either through informal trade across borders or by certification/testing through international service providers.

Malawi NPPO will have to establish the appropriate pest risk management and diagnostic capacity to ensure that the production of tissue culture material and fruit would comply with regional phytosanitary requirements and testing standards. It is expected that BBTV and systemic diseases like *Fusarium* wilt race 1 and 2 will be major quarantine concerns for exports.

No official surveillance and/or certification schemes are currently applied to the crop and standard post-harvest processes are followed.

2.4.6. Synergies to other ongoing/planned efforts in the country to address problems related to the use and spread of infected planting materials and the potential of local and exporting markets for banana.

In Malawi, a number of other projects, supported by other donors, already exists that can complement the banana industry. These include the following:

- Biodiversity project/intervention- support small holder farmers to renovate the Cavendish banana plantation through clean seed systems
- A project funded by the Australian Government/ BMG Labtech - development of GMO banana for mitigating BBTV is being developed
- Mangoes Malawi project- importation of indexed planting materials used in their own production aimed at the banana pulp industry
- FIDP Horticultural project helps promote fruit production through the supply of clean elite planting material and technical information
- World Vision International's Food security project helps promote production through the supply of clean planting material and technical information
- CIP in collaboration with DARS, Malawi, funded by Irish Aid-Irish potato seed multiplication unit
- Presidential initiatives - focusing on the promotion of fruit production, including the revival of banana production in Malawi
- Cassava virus project- conducts surveillance and development of detection systems. The focus is on human resource capacity building
- Biotechnology project- focuses on developing capacity in biotechnology
- Bunda College has facilities for multiplication of seedlings
- The Centre for Agriculture and Biosciences International (CABI) and Malawi Government – Plant Wise Clinics: This is instrumental in building technical capacity in both farmers and extension agents in the identification of pests that farmers encounter and provision of relevant prescriptions.

- A regional project funded by the World Bank, that includes Zambia, Mozambique and Malawi, with the aim of establishing regional training centres for Biotechnology dissemination.

Propagation of disease free planting material for banana and setting up a banana virus indexing centre would link with other research opportunities at research institutes in Malawi in the following ways:

- The facilities at Bunda College that are used for tissue culture may benefit the banana industry. This facility will be discussed in the section on the field visits
- Training facilities available at training institutions, i.e. Chitedze and projects may assist in training staff, farmers in the propagation of clean planting materials for example, students from academia can be placed in different labs as part of the training and in this way enhance human resource capacity
- The certification of planting material will assist other projects (cassava, sweet potato project). Facilities for indexing will also be utilized for the production of virus-free potato and cassava planting materials.
- Technical expertise will be created that can be used in other projects
- Surveillances of other viruses in other crops would also be enhanced if a proper virus indexing centre can be established.

The workshop participants indicated that the establishment of a banana tissue culture and virus indexing centre will influence the other agricultural markets in Malawi in the following ways:

- It will emphasize the issue of quality based on the quality of produce from suckers
- It will reduce planting material imports
- The input uptake will increase
- A market for export will be created to export banana planting material and other vegetative propagating material
- It will bring back the ''lost glory'' of bananas
- The establishment of tissue culture and virus indexing centres will benefit other vegetatively propagated crops and this will expand the markets both internally and externally

There are currently existing facilities that can be used or transformed into banana tissue culture facilities. These options will be discussed in the following section on the field visits. Participants

indicated that LUANAR Bunda College, Bvumbwe Research Station and Lunyanga Research Station are possible places to start a tissue culture facility. Existing facilities that can be used and developed as a banana virus indexing centre, can also do testing for other diseases and pests of banana, and can possible be hosted at Bvumbweand Chitedze Research Stations. During the field visit Dr Jooste observed that it is possible to have pest free sites even within a diseased area with good sanitation and management strategies as exemplified by the Malawi Mangoes set-up.

2.4.7. Regional initiatives focusing on the management of BBTV

Biodiversity International is supporting some initiatives for the management of BBTV in Malawi, Burundi, and the DRC but a concern was raised that the grants are too small to have a significant impact. Grants allocations consist of US$25000 in the first year and then US$70000 in the second year for an area that covers at most two villages. The "Establishment of piloting sites for the strengthening of local seed systems and validation of strategies for eradication and replanting of banana plantations infected by BBTV" approach is believed to be feasible but further support is needed. Malawi NPPO has imported through this project plant material from France and South Africa due to an unavailability of such materials on the local market.

Recently there was an initiative launched where Roots, Tubers and Bananas (RTB) centres and partners joined forces to battle the Banana bunchy top disease across Sub-Saharan Africa. Malawi participates in this regional initiative.

2.4.7.1. Roots Tubers and Bananas Research Programme

The Roots, Tubers and Bananas (RTB) Research Programme was launched in January 2012, bringing together dozens of partners, including four Consultative Group on International Agricultural Research(CGIAR) research centres: Biodiversity International, the International Centre for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA) and the International Potato Centre (CIP), which coordinates the programme. Those organizations are working to improve the conservation of genetic resources, breeding programmes, pest and disease management, the supply of quality planting materials, cropping systems and postharvest options, in order to tap the full potential of RTB crops. The addition of the Agricultural Research Centre for International Development (CIRAD), with 800 researchers

in all disciplines and joint operations with more than 90 countries, will greatly enhance the programme's impact and international presence.

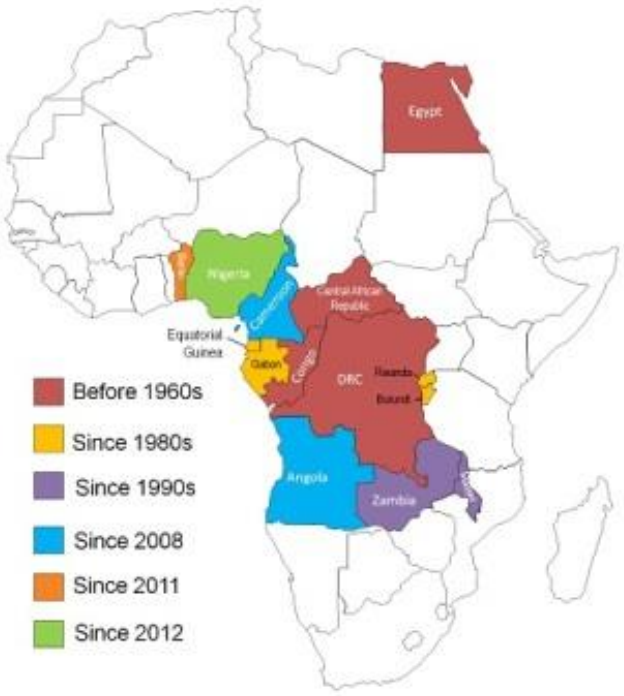
The CGIAR Research Programme on RTB is a broad alliance of research-for-development stakeholders and partners. Its purpose is to tap the under-utilized potential of root, tuber, and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity, especially amongst the world's poorest and most vulnerable populations. www.rtb.cgiar.org

The RTB programme has recently released its first two training manuals for extension personnel and applied scientists. One manual focuses on growing bananas using tissue culture plantlets and the other on running a banana tissue culture nursery. The manuals are based on training provided in Burundi, Kenya and Uganda that formed part of a project explore alternative ways of delivering tissue culture material to small-holder farmers.

Previous projects to encourage small scale farmers to switch to tissue culture plantlets have typically included the provision of subsidized plantlets but at the risk of supply chain collapse when donor support ends. An IITA coordinated project - in collaboration with the Volunteer Efforts for Development Concern and Jomo Kenyatta University of Agriculture and Technology, and funded by GIZ - includes not only technical training but also basics of business planning, record keeping and marketing in an attempt to provide nursery operators with the necessary marketing and business skills to turn a profit. As a result of this project 11 nurseries have been established in Kenya and Uganda. A cost-benefit analysis conducted on three of the Ugandan nurseries shows that they are making a profit of at least US$0.25. In Uganda, the availability of tissue culture plantlets from these nurseries have been reported to encourage commercial banana production in the surrounding areas.

The CGIAR is a global agriculture research partnership for a food secure future. Its science is carried out by the 15 research centres who are members of the CGIAR Consortium, in collaboration with hundreds of partner organizations. www.cgiar.org

BBTD disease spread in Africa during past decades:



2.4.7.2. Collective efforts of three international agricultural research centres

IITA, Biodiversity International and CIRAD are partnering in a BBTD control project titled “BBTD containment and recovery by building capacity and piloting field recovery approaches through a learning alliance”. The RTB program is funding the initiative.

On 20-25 January 2014, the project organized a workshop on “Recovering banana production in BBTD-affected areas: Community and farm household approaches”, during which researchers shaped out a framework for a participatory approach to eradicate infected plants and resuscitate banana production across nine pilot sites in Benin, Nigeria, Cameroon, Gabon, Congo, Brazzaville, DR Congo, Burundi, and Malawi. Approximately 50 experts from 20 countries gathered in Burundi for this workshop.

Lava Kumar, a virologist who heads the IITA’s Germplasm Health unit is co-leading this project and was involved in surveys for BBTV in Africa and Malawi. The tool that was developed is valuable for helping farmers to decide which control mechanism to implement for disease control. It also makes it much easier to raise awareness among farmers and to monitor disease development.

Mr M Soko, scientist from Malawi attended this workshop in Burundi and is part of this initiative. The mobilization of Farmers, scientists and stakeholders to support these initiatives in Malawi will enhance the successful expansion of the banana industry in Malawi. A collective task team should be formed, specifically in Malawi, to implement the efforts of the initiative of the RTB Research Programme in Malawi. It is recommended that the task team should consist of scientists, farmers, NPPO officials, private sector participants and academia.

3. Conclusions of Workshop information

The devastating effect of BBTV can be prevented by several factors including 1) awareness of the virus and its effects, 2) the planting of clean material and 3) good management practises in plantations. During the workshop we discussed several aspects of banana production and stakeholders with different backgrounds came together to give inputs on this important discussion. The objectives of the workshop were formulated to determine the feasibility of establishing the capacity for production of virus-free planting materials for banana in Malawi.

The commercial producers that participated in the workshop all indicated that the most important aspect of efficient banana production is the availability of clean planting materials. Currently producers have to import material from various places in the world. This contributes to one of the main constraints of banana production in Malawi because of the high cost of these imported materials. It automatically sidelines the smallholder farmers from the equation.

BBTV is prevalent in all the banana producing regions in Malawi and normal surveillance for BBTV is not done by the public or private sector. There are some extension services in the public sector but it was concluded that extension staff should be trained sufficiently. Extension personnel are empowered to impound any banana planting material that are moved from the south into the two northern disease free production areas. These districts produce as a staple the cooking and plantain varieties which have restricted/niche markets. Risk management practises are used by commercial producers, but education and training of small scale farmers in risk management strategies is necessary. NPPO capacity that exists to do national surveillance of all production areas to confirm the spread of BBTV is inadequate and it will be important to increase NPPO capacity through human and infrastructural resources.

The suggestion for the establishment of pest-free areas for banana production in Malawi was well received by commercial famers at the meeting. However, the challenge of financial and infrastructural inputs will be required to fulfil this objective and clean planting material was an important input that will be needed.

The existing or potential capacities of private sector (research and academia) and research within the NPPO was analysed.

In Malawi, a number of other projects, supported by other donors, already exists that can complement the banana industry and contribute to strengthen the capacities in the country. Propagation of clean material for banana and setting up a banana virus indexing centre will link with other research opportunities at research institutes in Malawi. Participants felt that the establishment of a banana tissue culture and virus indexing centre will influence the other agricultural markets in Malawi positively by reducing planting material imports and creating a market for export of banana material and other vegetative propagated plants and this will expand the markets both internally and externally.

The recent detection of *Fusarium oxysporum* f.sp *musae* in Mozambique is considered to underline the importance of the proposed project to establish a virus indexing facility and tissue culture laboratory in Malawi.

It was concluded that it is necessary to strengthen the capacity of clean planting materials locally to ensure that the demand for banana can be met without the interference of effects of viral diseases. To strengthen this capacity there is a need to 1) establish a virus indexing centre that are able to test for all banana viruses with established protocols and 2) establish a tissue culture facility with sufficient capacity to produce healthy material.

4. Field visits to different stakeholders in the banana industry in Malawi

4.1. Producers

4.1.1. Farm selling infected BBTV suckers

The first field visit was to a farm outside Lilongwe where banana are planted to supply suckers to other farmers. The plantations were severely infected with BBTV as seen in Figure 3.

This farm is an example of how a lack of knowledge of BBTV can cause an infection source for the surrounding banana growing areas. The producer is propagating diseased material and disease management practises does not exist. The plantations are also uneven and suckers from this farm are infected with BBTV and causes a risk for informal producers that are not educated in disease management. The NPPO representative indicated that they will go to the farm to inform the owner on the seriousness of BBTV.

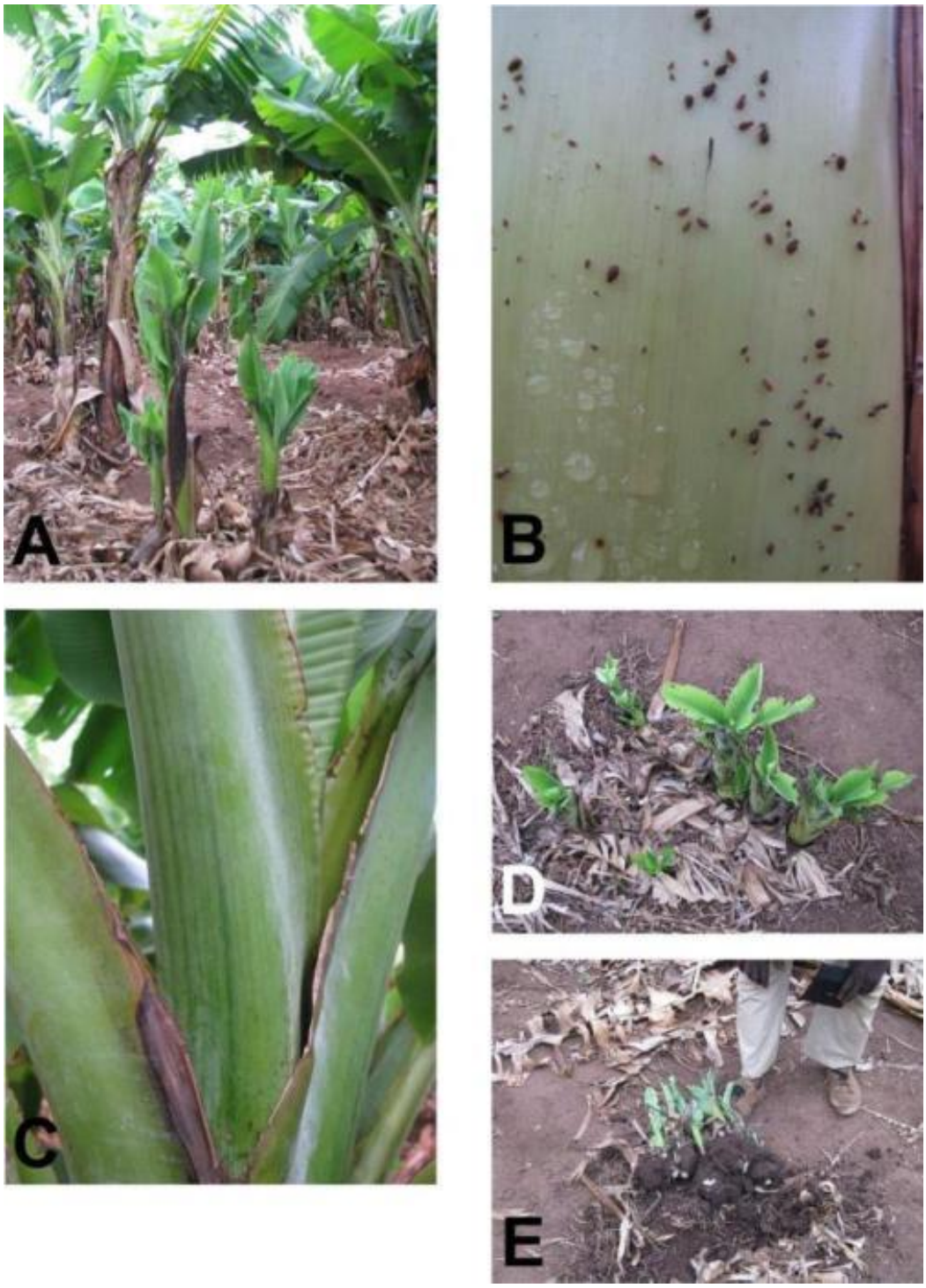


Figure 3. Typical BBTV symptoms seen in A) stunted plants, B) banana aphid transmitting the virus, C) streaks on pseudo-stem, D) immature banana suckers infected with BBTV and E) banana suckers infected with BBTV without rooting systems.

4.1.2. Commercial producers

4.1.2.1. Hortnet (Washoni brothers)

We visited the farm of the Washoni brothers and were impressed by the way they manage their banana plantations (Figure 4). They originally obtained their planting material from Du Roi in South Africa and Amiran in Israel. About 8 ha are planted and these producers have the ability to become a leading enterprise in banana production in Malawi. They use IPM practises that ensure disease free plantations and have invested in digging two dams to provide water to the plantations.

Strengths of the producers:

- They already established themselves as commercial producers in the Lilongwe area
- They installed irrigation from the dam to the plantations to ensure enough water for production
- They have knowledge on how to manage diseases
- They are producing for local demand currently but with more inputs have the capacity to move into the export market
- They are involved in the propagation of plants for local sales through macro-propagation techniques

Infrastructure capacity needs:

- They will need shade net facilities to keep plants for production
- There is no access to clean material locally and import costs of material from, eg, Du Roi is high
- Irrigation to new plantations

Challenges:

- They will need more land, more water and clean planting materials to expand and to provide in local demand and to move into the export market.
- They will need support in terms of virus-indexing services to ensure that the whatever plants they are multiplying and selling to farmers are disease-free

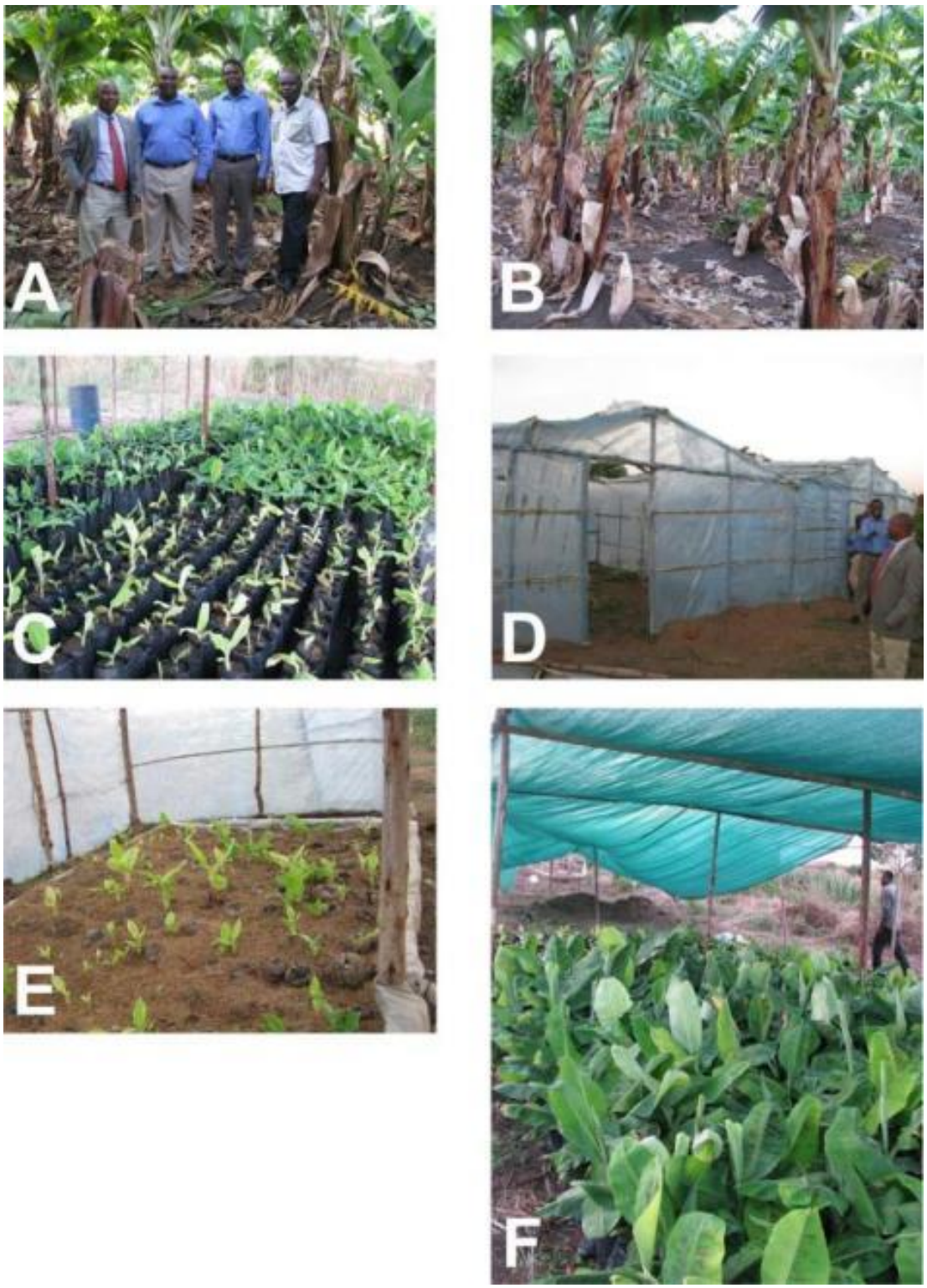


Figure 4. The farm of the Washoni brothers (A) brothers in blue shirts; (B) banana plantations; (C,F) current shade net facility; (D E) structure for growing suckers

4.1.2.2. Mangoes Malawi

Mangoes Malawi is the biggest commercial producer of banana in Malawi. The farm is situated in Salima district in the central region of Malawi.

Currently they have 49 ha of bananas planted and plans to expand their banana production to 60 ha in the near future. They obtained their planting material mainly from Du Roi Laboratories in South Africa. The Mangoes Malawi banana farm is an example of what the real potential for commercial banana production in Malawi can be.

They use IPM practises that ensure disease free plantations (Figure 5).

Strengths of Mangoes Malawi:

- They have established disease-free plantations with good management strategies
- They provide for the local market as well as the pulping factory in the same area
- They have the capacity to expand even more and move into export markets

Infrastructure capacity needs:

- Clean planting material produced locally will increase profits

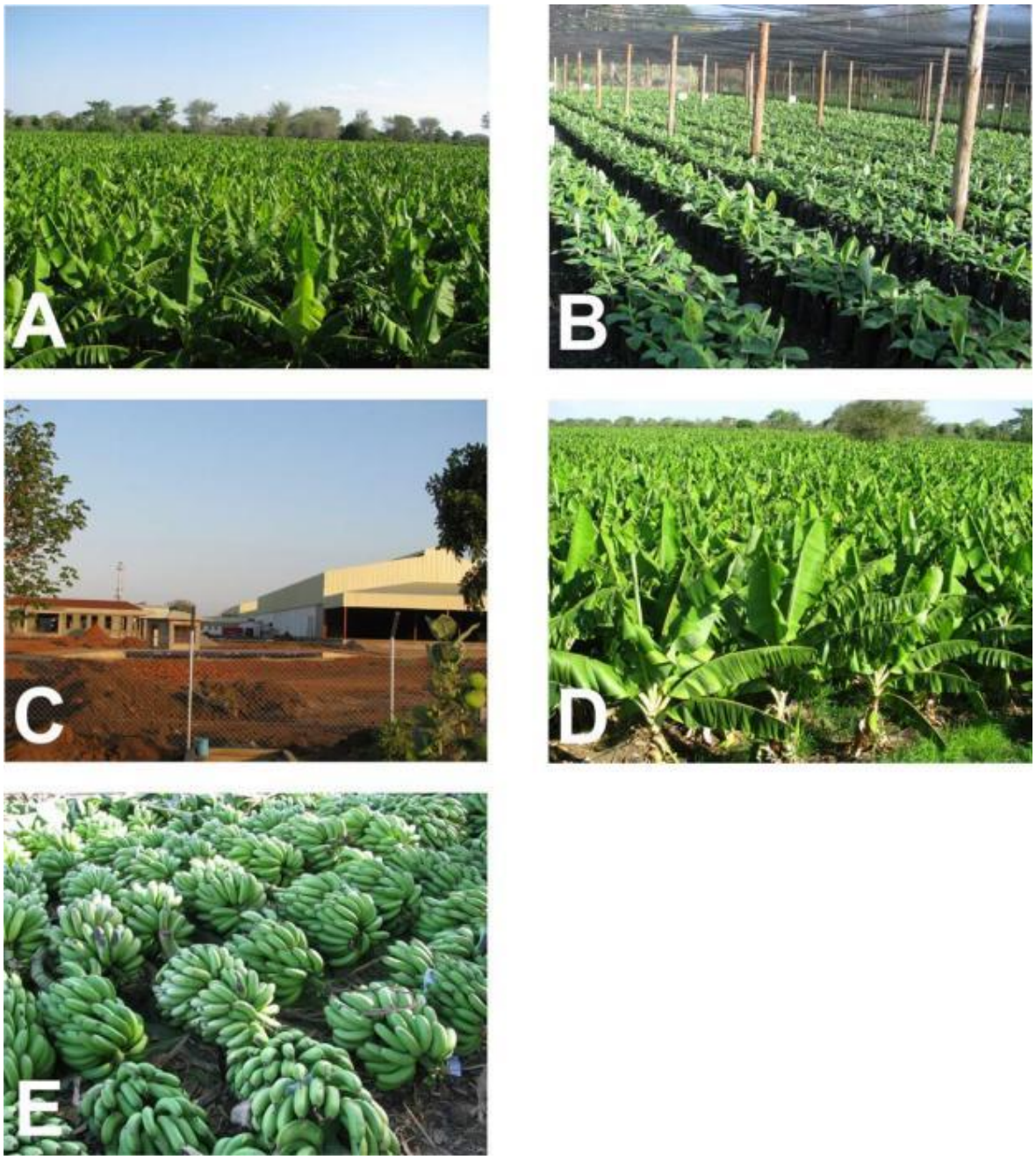


Figure 5. The banana plantations of Mangoes Malawi (A,D); pulping factory(C); shade net facility where clean planting material is kept (B); and bananas ready for consumption (E).

4.2. Chitedze Agricultural Research Station

Chitedze Agricultural Research Station is situated just outside Lilongwe and coordinates research services in cereals, legumes, oilseeds and fibres, soils and agricultural engineering. The headquarters of DARS is located at Chitedze (Figure 6).

Strengths:

- The Biotechnology Programme is based at Chitedze, headed by Dr. I. Benesi.
- A new biotechnology lab will be established soon, the building is about to be completed
- Most molecular equipment is there already and the lab is functional
- High technology equipment, i.e. real time PCR machine is available

Infrastructure and human capacity needs:

- Currently the lab is used mostly for cassava research, and if indexing of more crops, including banana will be done therefore PCR machines and equipment infrastructure will be required.
- Skilled laboratory technicians focused on banana indexing will be needed. It will be better to have a dedicated person for banana virus indexing instead of students that come and go
- An outside screen house is currently being constructed where plants used for positive controls can be kept

Challenges:

- To establish virus testing protocols for banana
- To find skilled personnel to run a virus indexing centre for banana that will be able to establish an accredited lab to ensure clean planting materials for banana
- Need support from Government to maintain the lab infrastructure

Recommendation:

The infrastructure at Chitedze is suitable for establishing a banana virus indexing laboratory.

Figure 6. Facilities at Chitedze Research Station (A); the current biotechnology lab (B); the new facilities (C,D) and green house in progress (E).

4.3. Bunda College/LUANAR

Bunda College is part of Lilongwe University of Agriculture and Natural Resources (LUANAR). We visited the tissue culture facility where Irish potato, sweet potato and banana are propagated by tissue culture. Propagation of Irish potato is currently the main activity of the lab, but sweet potato and banana are maintained. The tissue culture facility at Bunda College is small but working efficiently. There is a media preparation room with autoclave and all necessary equipment for media preparation. The plant preparation room have two big laminar flow cabinets, enough space to seat six workers. The growth room have sufficient space for 20 000 plants in tissue culture (Figure 7).

Strengths:

- There is an existing modern screen house facility that can be used to keep plants cultivated from tissue culture.
- The human resource at Bunda is very capable to expand the facility to include banana for production of clean planting materials.

Infrastructure and human capacity needs:

- A quarantine facility to keep tested mother plants is not in place and investment in such a facility is needed.
- A very skilled technician is currently doing all the tissue culture work and it will be possible for her to train more people to do banana tissue culture.

Challenges:

- Media preparation chemicals is not readily available

Recommendation:

The tissue culture facility at Bunda College is suitable for establishing a banana tissue culture lab. A facility to keep mother block material for propagation is currently not in place.

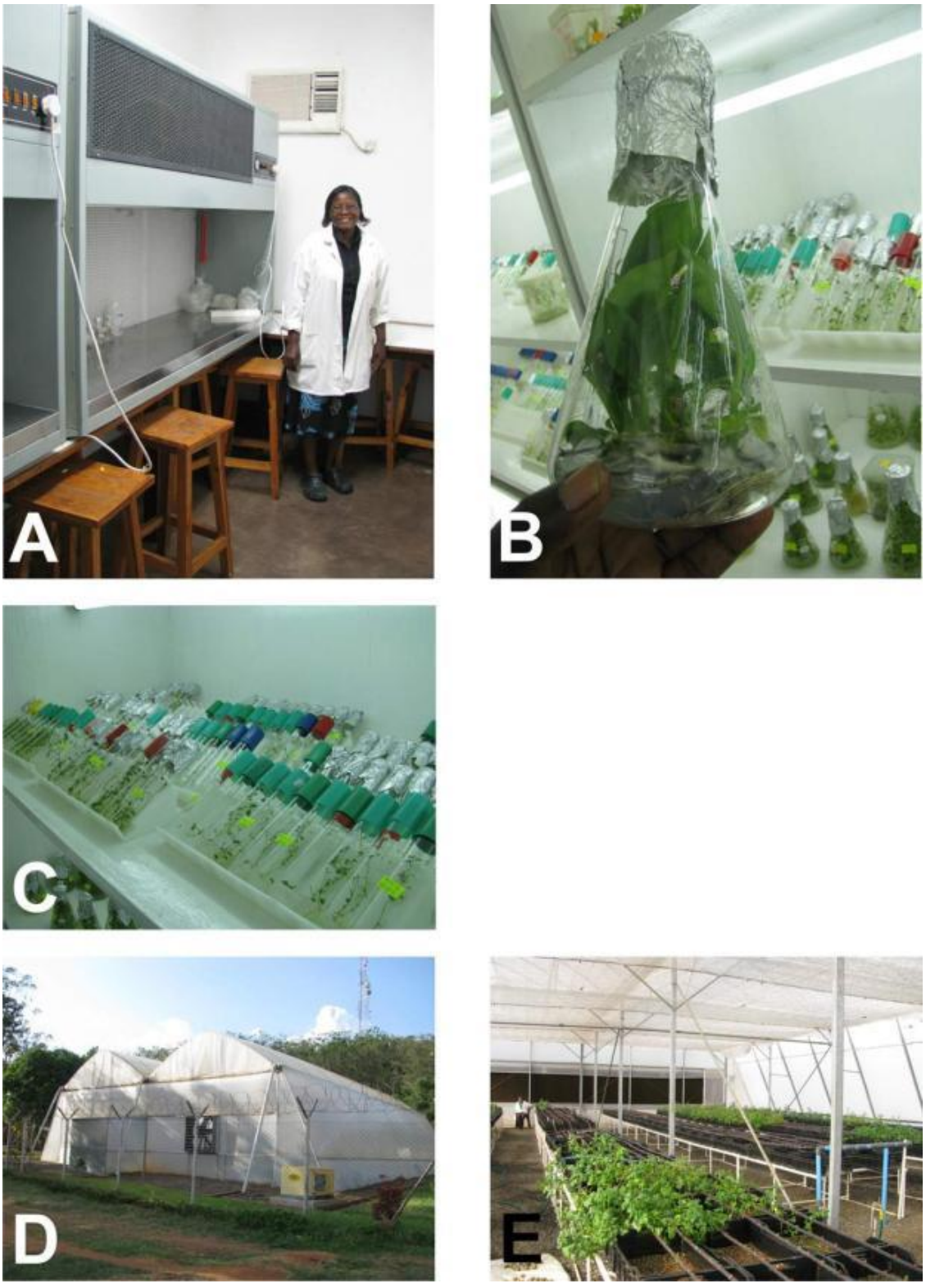


Figure 7. Tissue culture facilities at Bunda College (A); banana tissue culture (B); potato tissue culture (C); green house facility where propagated banana plants can be hosted (D, E)

4.4. Bvumbwe Agricultural Research Station

Bvumbwe Agricultural Research Station is located in Limbe, South of Blantyre in Malawi. The research station coordinates research services in Horticulture and Plant Protection. Dr. Jooste visited the tissue culture facility and related facilities in Bvumbwe as well as the potential virus indexing lab.

Tissue culture facility: Dr Felistus Chipungu is heading Horticulture research in Malawi and introduced Dr. Jooste and Mr Soko to the existing tissue culture facility. Their main activities include tissue culture of Irish potato, banana and sweet potato. The facility consists of a media preparation room with autoclave and water purification system. One laminar flow cabinet is in place in the transfer room. There is room for another flow cabinet in this room. Four growth chambers with racks are available for tissue culture flasks. There will be enough space if banana tissue culture is implemented in the lab. It is also possible to expand the buildings to accommodate more tissue culture facilities. A quarantine facility to keep mother material is available, but needs an upgrade. It is estimated to cost $12000-15000 to upgrade the existing structure. Another green house facility exists that can be used to keep the propagated plants. Renovations of this facility are also necessary. The cost to renovate these facilities is approximately $50 000 (Figure 8).

Strengths:

- An existing tissue culture facility already in place and the buildings can be expanded to accommodate the propagation of banana plants
- Four growth chambers to accommodate tissue culture plants from different crops

Infrastructure and human capacity needs:

- Trained human capacity will be needed to work on banana. Currently there is one researcher and three technicians in the lab. Developing human capacity for banana tissue culture is important.
- The floor of the facility needs renovation to ensure a hygienic working environment
- Another laminar flow cabinet will be beneficial to ensure mass propagation
- The air-conditioning system in one of the growth chambers is not fully functional and needs a service

-Bulbs for the growth room should be serviced and replaced where necessary

- Quarantine facilities are functional at present but need an upgrade
- Renovation of green house facilities necessary, not functional at present

Challenges:
- Chemicals for media preparation not readily available
-Renovation of green houses will require investment in the project

Recommendation:
The tissue culture facility at Bvumbwe Research Station will be suitable for propagation of clean materials for banana, but the supporting structures, i.e., quarantine facilities and greenhouses need renovation.

Virus indexing centre at Bvumbwe: Mr M. Soko showed Dr Jooste around the facilities. This is an existing lab with a lot of potential. Presently they only do ELISA detection of BBTV in this lab. Mr. Soko indicated that they might be receiving some funding from the Australian government /BMG for research in evaluating transgenics developed by Queensland University of Technology and it is hoped that some equipment will be included.

Strengths:
- The lab structure exists and can easily be transformed into a virus indexing centre.
- A BBTV ELISA test is optimised and used in the lab

Infrastructure and human capacity needs:
- Almost all equipment for a molecular lab is lacking
- Mr. Soko and a technician will travel to Montpellier in France in February 2014 to receive training on banana virus indexing procedures. This will benefit virus indexing for banana in Malawi and they can train human resources in other labs, i.e. Chitedze, on return.
- More human capacity will be needed to supply a functional banana virus indexing service
- Need for purpose-built renovation of the laboratory

Challenges:
- Set up of molecular biology lab with the right equipment
- Obtain the correct kits for molecular applications and testing
- Retain a high quality standard for testing banana material

Recommendation:

It is possible that the facility can become a banana virus indexing centre although it will need investment in equipment and human resources

Figure 8. Tissue culture facilities at Bvumbwe Research Station (A, B); the quarantine facility (C); the green houses that need renovations (D); the potential virus indexing lab (E, F).

5. Conclusions of field visits

From the field visits it was clear that Malawi has the potential to establish a world class banana industry that includes knowledgeable commercial producers and accredited tissue culture and virus indexing laboratories. It was clear that certain existing facilities within the government institutes would be suitable to be transformed into these facilities. Two facilities that would be suitable to accommodate a virus indexing centre are the biotechnology lab at Chitedze and the virus lab at Bvumbwe Research stations. Both labs would be able to establish and run a virus indexing centre keeping in mind that human capacity and infrastructure challenges has to be addressed. Facilities for tissue culture also exist, but the question was asked if the tissue culture lab should not be a private sector enterprise. Investors in such an enterprise are necessary. The existing tissue culture facilities are available at Bunda College and Bvumbwe Research Station. Both these facilities have the capacity to expand to accommodate banana tissue culture.

Examples for the commercial production of banana in Malawi were seen at the Hortnet farm of the Washoni brothers and Mangoes Malawi. BBTV are contained at both farms by good management practises. Both producers imported material from other countries that resulted in high costs. Production of clean planting materials in Malawi will increase profits in this market. BBTV pest-free areas can be established to minimise crop losses and reduce the spread of the disease. Commercial producers that show potential in banana production should be assisted by an organised banana industry in Malawi. They can train other upcoming producers in management strategies to ensure that the production of good banana crops.

There is good potential for banana production in Malawi.

6. Recommendations of this report

Although the focus of the PPG is on developing virus indexing capacity of banana planting materials, we would like to highlight some additional factors that may need to be considered to ensure that the production of disease free planting materials in Malawi will be sufficient to ensure optimal banana production and disease management, especially for BBTV.

The phytosanitary requirements for a competitive local banana industry with the potential to become a regional supplier of fruit and/ or propagating material will require a more holistic approach to target pest management on various levels. It will require substantial financial inputs to develop not only tissue culture and virus indexing facilities but also to create a policy framework to allow intensive BBTV controls such as targeting sources of inoculum by eliminating crop refuges, vector control for BBTV, replacement of infected mats, cultivation of BBTV tolerant banana varieties, establishing buffer zones and promoting cultural methods that will assist in pest management.

The following are recommendations relating to the establishment of a virus indexing facility and banana tissue culture propagation laboratory:

Establishing a virus indexing centre for banana in Malawi:

Some infrastructure capacity exist at the Chitedze Research Station and also at the Bvumbwe Research Station that can be developed into a virus indexing centre for banana material but substantial financial and human resource inputs will be required at each facility. However, it will be crucial for banana production in Malawi to develop a virus indexing centre/centres to ensure the production of clean banana planting materials. The importance of such a facility is evident from the reasons mentioned in the report.

This report recommends that the virus indexing centre remains in the public domain, especially if the aim would eventually be to also export disease free material to the region. Having disease free planting material commercially available at a reasonable price would be a major requirement if the banana industry in Malawi is to be revived. It is doubtful whether a private laboratory would be able to provide material at a reasonable / competitive price (with imported

material) if a laboratory is to be built from scratch by the private sector, and without some capital investment (e.g. providing facility) from the public sector.

Estimated costs to upgrade existing infrastructure and resources to a functioning virus indexing centre at the two potential public sector laboratories are listed and compared in Table 4 below. Operating costs (e.g. electricity) of the laboratory are not included in the calculations as it is expected to be provided/budgeted for by the NPPO once the indexing centre is established.

Requirements for virus indexing facility	***Chitedze Research Station***		***Bvumbwe Research Station***		***Estimated cost to establish (US$)***
1. Equipment	**Yes**	**No**	**Yes**	**No**	
Pipettes	√			√	1800
PCR machine	√ (will need additional one for banana work)	√		√	7500
Electrophoresis apparatus	√ (will need additional one for banana work)	√		√	1800
Gel documentation system	√			√	4700
Balance	√		√		1400
Water bath	?	√		√	1400
Incubation oven	?	√		√	2800
Refrigerator	√		√		280
Freezer	√			√	4700
Ice maker	?	√		√	1800
PCR workstation	√			√	4600
pH meter	√		√		1800
Bench top centrifuge	√ (will need additional one for banana work)	√		√	3700
Autoclave	√		√		2800
Microwave oven	√			√	100
TOTAL		US$**19000**		US$ **34**	

				900	
2. Enzymes, chemicals, consumables to get started		√		√	10000
TOTAL		US$ **10000**		US$ **10000**	
3. Human resources		√		√	20000
TOTAL		US$ **20000**		US$ **20000**	
4. Lab structure	√		√		30000 (Bvumbwe)
ESTIMATED TOTAL		US$ **49000**		US$ **64900**	

Table 4. Requirements for the establishment of a virus indexing centre in Malawi

Recommendations:

- The virus indexing centre should remain in the public domain. It should include tests for *Banana bunchy top virus* (BBTV) and other virus diseases of banana including *Banana streak virus* (BSV), *Banana mild mosaic virus* (BMMV), *Banana bract mosaic virus* (BBrMV) and *Cucumber mosaic virus* (CMV). In light of other threats in the region like Banana *Xanthomonas* Wilt and FOC TR4, capacities should also be built in those areas.
- Diagnostic and human capacities should be developed to ensure that specific researchers and technicians are full time employed and responsible to management the banana virus indexing centre/centres and ensure that diagnostic methodologies are updated regularly. See Table 4 for detailed requirements as per facility options.
- Optimised protocols should be implemented in the virus indexing centre/centres. Regional training opportunities also exist for example at the Agricultural Research Council, Plant Protection Research Institute (ARC-PPRI) in South Africa.
- Quality control tests can be done by other laboratories in the region, for instance the virus indexing lab at ARC-PPRI in South Africa.
- Positive controls for virus indexing tests should be imported and maintained in quarantine facilities to ensure high quality and repeatable results. In view of this, the

establishment of appropriate quarantine facilities for high risk material are crucial for maintaining controls.

- Infrastructure should be developed to ensure the availability of sufficient laboratory equipment. Table 4 shows the equipment currently available at Chitedze Research Station and Bvumbwe Research Station for comparative purposes. The Chitedze Research Station is better equipped and will need fewer financial inputs to upgrade to a national virus indexing facility.
- Facilities: The biotechnology lab at Chitedze Research Station and the lab at Bvumbwe Research Station are both suitable to establish a banana virus indexing centre at. A proposal for funding of equipment to test transgenic material (BBTD resistance) is under way for Bvumbwe. However, the NPPO cannot confirm at this stage whether virus testing equipment will be included. So, based on the current situation the Chitedze Research Station will be the preferred laboratory as it is best equipped and closer to the capital for logistical and regulatory purposes. The molecular lab at Chitedze has been renovated recently. The Bvumbwe lab exists within a building but will need some paint and renovations on working surfaces as well as work on water and electricity supply.
- Human resource capacity will have to be strengthened at both locations. At least one dedicated person needs to be trained and employed to be focused on banana virus indexing.
- It is recommended that the virus indexing facility remain a public function for regulatory purposes and be contained in DARS/ NPPO of Malawi.
- It will be easier from a logistical point of view to have the tissue culture laboratory located as close as possible to the virus indexing centre/lab.

Based on the above considerations the existing laboratory at the Chitedze Research Station will be the preferred location for developing a public sector virus indexing facility.

Establishing a banana tissue culture facility to ensure clean planting materials:

All pest free material currently planted in Malawi was imported from tissue culture facilities in South Africa, India, and Israel. The development of a banana tissue culture facility will be required to produce clean planting material locally.

Investment from the private sector is needed to accommodate a privately owned enterprise. At this stage there are two potential private sector investors, namely Mangoes Malawi and a Mr Patrick Khembo, who are considering such an enterprise. However, at the time of this report there were no definite business plans to guide financial projections, or detail regarding the location(s), existing or potential infrastructure development plans, or size of proposed private facilities available from either of these two potential private sector investors/ developers.

However, two other facilities exist that have been visited by Dr Jooste and have the potential to be transformed and/or expanded into a tissue culture facility. Facilities at Bunda College/ Lilongwe University of Agriculture and Natural Resources (LUANAR) and Bvumbwe Research Station (public sector) are both suitable to be expanded to accommodate a banana tissue culture facility although at Bvumbwe Research Station more financial inputs will be required. Estimated costs to upgrade existing infrastructure and resources to establish a banana tissue culture laboratory at one potential public sector laboratory (Bvumbwe Research Station) and one potential university laboratory (LUANAR) are listed and compared in Table 5 below. Other operating costs (e.g. electricity etc.) of the tissue culture laboratory are not included in these calculations as it is expected to be provided/ budgeted for by the tissue culture laboratory.

It is estimated, based on existing models in literature and in practice, that a laboratory of approximately 5000 sq ft. would be able to produce 1 - 1.25 million tissue culture plants. In addition a screen house facility of approximately 5000 sq ft. would be recommended to house the mother plants and provide area for hardening of tissue culture plants. The estimations in Table 5 are based on a projection for a tissue culture laboratory that will be able to produce at least 1 million tissue culture plantlets. The current capacity in the existing facilities is for 20 000 tissue culture plants.

Requirements for banana tissue culture facility	***Bunda College/ Lilongwe University of Agriculture and Natural Resources (LUANAR)***		***Bvumbwe Research Station***		***Estimated cost to establish (US$)***
1. Laboratory structure	**Yes**	**No/ Not adequate**	**Yes**	**No/ Not adequate**	
Media store	√		√		
Post autoclave area	√		√		
Culture transfer room	√		√		

Growth rooms	√ (at the moment have space for 20 000 plantlets)	√	√ (4 but needs some upgrades)	√	
Change area	√		√		
Laboratory for media preparation	√		√		
Wash area	√		√		
Office		√	√		
2. Screen house with water supply system, mother plant area, hardening of plantlets area, thermometer, hygrometer, air cooler etc (approx size 5000 sq ft.)	√ (Screen house only for mother block material needed)	√	√ (mother block, quarantine facility, screen house to harden plantlets available but not functional. Needs upgrade)	√	
TOTAL		US$**60000**		US$**100000**	
3. Laboratory and office equipment					
Autoclave	√		√		2800
Analytical Balance	√		√		1400
pH meter	√		√		1800
Laminar airflow	√ (2)		√(1) (needs additional)	√	5000
Distillation set	√ (needs upgrade)	√	√ (needs upgrade)	√	6500
Computer system	√ (needs upgrade)	√	√ (needs upgrade)	√	3400
Air conditioners	√ (needs upgrade and servicing) (3)	√	√ (not all functioning, upgrade and service)(6)	√	1800
Refrigerator	√		√		300
Oven	?	√		√	300
Air filters	√ (2) (upgrade and	√	√ (5) (upgrade and	√	350

	maintenanc e)		maintenanc e)		
Rotary shaker		√		√	450
Dissecting kits/ Inoculation instruments	√ (will need additional)	√	√ (will need additional)	√	2000
Growth room racks	√		√		600
Trolleys		√ -2		√-2	50
Trays	√ (will need additional 10)	√	√ (will need additional 10)	√	20
Lab clothes	√ (additional disposable masks, hat, shoe covers)	√	√ (additional disposable masks, hat, shoe covers)	√	1000
Incinerator	?		?		450
Tube lights for growth rooms	√ (needs upgrade and maintenanc e)	√	√ (needs upgrade and maintenanc e)	√	3000
Miscellaneous glassware	√ (more needed)		√ (more needed)		1000
Lab tables and office desks and chairs	?	Chairs needed-3		Chairs needed-3	650
TOTAL		US$ **25700**		US$ **37150**	
4. Start-up chemicals, consumables		√		√	10000
TOTAL		US$**1000 0**		US$**10000**	
5. Human resources • Manager - 1 • Laboratory scientist/ technician-2 • Screen house - 2 • Administrative - 1	√ (currently 1 skilled lab technician and 1 Screen house caretaker)	√	√ (currently 3 technicians-specific staff for banana tissue culture necessary)	√	
TOTAL					
ESTIMATED TOTAL*		US$ **96700**		US$ **147150**	

Table 5. Requirements for the establishment of a banana tissue culture laboratory in Malawi.

*The estimated totals exclude the cost of human resource capacity and expansion of

facilities, it include the additional insect free screen house for mother block material at LUANAR and renovation funds for two existing structures at Bvumbwe Research Station.

A third option would be a completely new private sector tissue culture facility, developed by one of the two possible investors identified above. In this case, a new facility would have to be established as no infrastructure exists.

Should the aim be to establish a completely new laboratory at LUANAR that is newly built and equipped, the costs would increase to approximately US$2 million. While there is enough land available at LUANAR to establish a new facility from scratch, the authors believe that the existing facility (though small) is so well established with competent technical staff that it would be more cost effective to expand on existing infrastructure at LUANAR, rather than build a completely new laboratory. To establish a new facility at LUANAR will need additional funding or private sector investment of an estimated 2 million USD.

Recommendations:

- Based on the current capacities and physical location (i.e. closer to capital), this report views that the preferred option for a tissue culture facility will be at LUANAR. The facility at LUANAR is well developed but the capacity is small (20 000 plants). The existing laboratory structure is generally sufficient to add banana tissue culture propagation and only need some expansion of the growth rooms; mostly financial inputs will be required for additional space in the screen-house for the banana mother block material. As indicated above, an investment of approximately USD96,700 would be sufficient to develop existing infrastructure at LUANAR to include a banana tissue culture facility.
- If the tissue culture facility is to be established at a government based locality, then a business plan should be developed where funds generated within the facility are controlled and channelled back to the facility to ensure proper functionality in terms of infrastructure, water supply, electricity, buying of chemicals and equipment.
- Technical human capacities should be developed.
- A private - (semi) public sector collaborative approach to establish the tissue culture laboratory at LUANAR is also an option which deserves serious consideration. LUANAR is an academic institution and already involved with various partnerships with other role-players in the agricultural sector in Malawi. The public sector expressed interest in a

public-private partnership for the tissue culture laboratory at LUANAR. Although the potential private sector investors were not willing to commit to this at the time of the workshop, or during follow-up in May 2014, the private sector remains interested and open to discuss possible investment/participation, pending the outcome of this study and possible follow-up. The private sector also indicated that interest in pursuing this option would depend on improved public sector capacity to establish and implement regulatory aspects to support the production of disease free bananas.

The following additional recommendations that focus on reduction of sources of inoculum and the spread of BBTV were formulated based on the information gathered during the workshop and field visits and it is strongly recommended that these should be considered by the NPPO in support of/ addition to the above for a broader national approach towards managing BBTV in Malawi.

Production of banana:

Producers should be assisted to optimise the production of banana in Malawi by an organised banana industry that will focus on 1) mitigating BBTV and other virus diseases and pests, 2) assist producers to obtain maximum profits from the crop, and 3) ensure that clean planting material is available locally.

Recommendations:

- Private sector could be organised within an industry body/association that is inclusive of small scale and commercial farmers, and would improve information dissemination, training and general coordination of the banana industry.
- Public and private sector should collaborate to develop a national banana pest management strategy that is enforced by means of a national policy.

Surveillance for BBTV and other banana pests:

The capacities within the public sector (NPPO and extension services) and private sector could be integrated to ensure that the records of pest outbreaks and spread should be centralised and readily available to assist with national control of banana pests.

Recommendations:

- A national pest survey should be the first step in developing a national banana pest strategy to determine and confirm banana pest distribution and other potential pest free areas in Malawi.
- There is currently surveillance by extension officers but the system should be streamlined and expanded to also include private sector inputs. *The development of a process to centralise surveillance records and training of extension officers should be included in a project proposal.*
- A more streamlined reporting system should be developed. As a signatory to the IPPC, there should be a commitment by the NPPO to report pest status.
- Eradication of high risk quarantine pests, like BBTV, will require destruction of production units (commercial and small scale farmers) and should be considered as a major potential expense. Producers should be well informed to ensure cooperation in this regard.
- Pest awareness should be included in the national pest management strategy. Awareness of diseases should be encouraged in the public and private sector through pamphlets/posters and organising informative road shows in all the banana producing regions in Malawi. These informative sessions in different regions can be organised to transfer knowledge on disease symptoms, management practises, banana production practises, mitigation strategies for BBTV and other virus diseases and pests. Especially the education of small scale and subsistence farmers is necessary.

National management strategies to control the spread of BBTV:

The Plant Protection Act (1969) has been reviewed to include provisions for the management of the pest outbreaks and its implementation is now pending Parliamentary approval. The revised legislation include clear provisions of movement control in support of the establishment of pest free areas and adjustments in punitive measures for those found guilty of moving infected plant material into pest free areas. The enforcement of the legislation is entrusted with the NPPO of Malawi which exists in the Plant Protection Services section in DARS.

Malawi's export potential depends on the ability of the country to manage relevant quarantine organisms effectively and ensure compliance with specific trade partner import requirements. In

this regard, a broader approach to the management of banana pests in Malawi is recommended.

Recommendations:

- Appropriate policies and/or regulations will be necessary to enforce national pest management controls. For example, the movement and/or destruction of planting material can be controlled with the collaboration of the Ministry of Agriculture with police by implementing roadblocks to report movement of planting materials.
- Risk assessment, diagnostic and inspection capacities within the NPPO should be strengthened through human and infrastructural resources. Especially the extension services should be developed to ensure efficient disease management of banana fruit and propagation material produced in Malawi.
- Awareness and training in pre- and post-harvest pest management practises for producers will contribute to national pest management efforts.
- Strategies and action plans must be developed to assist the NPPO to enforce those provisions of the new revised legislation that pertains to the establishment of pest free areas.
- Although containment and delimitation are stipulated in the new legislation the enforcement thereof needs to be strengthened

We conclude by stating that investment in pest free banana cultivation in Malawi will be beneficial for the country. A project proposal to develop virus indexing capacity and establish a tissue culture laboratory in Malawi is supported.

7. Appendixes

Appendix 1: List of participant contact details

Participant attendance list: **9 December 2013**

	NAME	Institution	E-mail
1	Owen M Chirwa	Lilongwe ADD	omduli05@yahoo.com
2	E Chongwe	Retired Scientist	edgar_chongwe@yahoo.com
3	Lobin Lowe	Producer and Member of Parliament	lowelobin@yahoo.com
4	Frankie Washoni	Producer	hortinet@afrcia-online.net
5	Maurice Washoni	Producer	hortinet@afrcia-online.net
6	Amon W.Phiri	Dept of Crop development	phiriad@yahoo.co.uk
7	Isaac B. Gokah	MOIT	Isaacb.gokah@gmail.com
8	Simon Mng'omba	ICRAF	s.mngomba@cgiar.org
9	Ibrahim Benesi	DARS	ibenesi@sdnp.org.mw
10	David Kamangira	DARS	davidkamangira1@gmail.com
11	Jacinta Nyaika	LUANAR/Bunda College	jnyaika@gmail.com
12	M. Soko	Scientist at Bvumbwe Research Station	Misheck_soko@yahoo.com

Participant attendance list: **10 December 2013**

	NAME	Institution	E-mail
1	E.D.L. Mazuma	Chitedze Research Station, DARS	elisamazuma@gmail.com
2	David Kamangira	DARS	davidkamangira1@gmail.com
3	Lobin Lowe	Producer and Member of Parliament	lowelobin@yahoo.com
4	Isaac B. Gokah	MOIT	Isaacb.gokah@gmail.com
5	Ibrahim Benesi	DARS	ibenesi@sdnp.org.mw
6	Mathias Nkhoma	Department of Crops	matiyasi@yahoo.com
7	Jacinta Nyaika	LUANAR/Bunda College	jnyaika@gmail.com
8	M. Soko	Scientist at Bvumbwe Research Station	Misheck_soko@yahoo.com

Appendix 2: Agenda of Workshop

WORKSHOP ON DEVELOPING VIRUS INDEXING CAPACITY FOR BANANA PLANTING MATERIALS IN MALAWI - 9 - 10 December 2013 in Lilongwe, Malawi

Facilitator: Dr. E. Jooste (ARC-Plant Protection Research Council, South Africa)

DAY ONE - Monday 9 December 2013

Participants: Private sector stakeholders, and MrSoko

08:30- 08:45	**Opening and welcome - Dr A Mtukuso**
08:45 - 09:00	**Introduction and background of feasibility study – Dr. E. Jooste**
09:00 - 10:00	**Banana pest profile in Malawi and regulatory requirements to develop virus-free banana planting materials in Malawi.**
10:00 - 10:30	**Capacity in private sector to contain BBTV in Malawi.**
10:30 - 11:00	**Tea**
11:00 - 12:00	**Commercial opportunities to produce disease-free planting materials for local and regional use.Private sector interest and potential for public private partnerships.**
13:00 - 14:00	**Lunch**
14:00 - 15:30	**Commercial opportunities to produce disease-free planting materials for local and regional use.Assessment of existing or potential capacities, e.g. location, infrastructure and HR.**
15:30 - 16:00	**Capacity of stakeholders to meet regulatory requirements for exporting banana planting materials into the region.**
16:00 - 17:00	**Summary of conclusions and recommendations from Day 1.**

WORKSHOP ON DEVELOPING VIRUS INDEXING CAPACITY FOR BANANA PLANTING MATERIALS IN MALAWI - 9 - 10 December 2013 in Lilongwe, Malawi

Facilitator: Dr. E. Jooste (ARC-Plant Protection Research Council, South Africa)

DAY TWO - Tuesday 10 December 2013

Participants: Public sector stakeholders only

08:30 - 09:00	**Opening and background of feasibility study – Dr. E. Jooste**
09:00 - 10:30	**Assessment of banana pest profiles, including spread of BBTV, and NPPO capacities to contain/ control quarantine pests. NPPO capacities to contain/ control BBTV in Malawi.**
10:30 - 11:00	**Tea**
11:00 - 13:00	**NPPO diagnostic capacities, infrastructure and HR, to provide regulatory testing.**
13:00 - 14:00	**Lunch**
14:00 - 15:00	**Capacity of stakeholders to meet regulatory requirements for exporting banana planting materials into the region.**
15:00 - 15:30	**Prospective interest of donors and development partners to fund or co-fund such a project, including any synergies with existing/ planned projects.**
15:30 - 16:30	**Summary of conclusions and recommendations from Day 2**

Appendix 3: Questionnaires used during Workshop

Questionnaire A

Participant focus group: NPPO, PRODUCERS, RESEARCHERS

NAME:…….. Date:……../……../…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:……

E-MAIL: ……

TEL NO:……

Aim of questionnaire: To do an assessment of the current status of BBTV in Malawi, including its status as a quarantine pest, with particular focus on districts with the greatest potential for banana production.

1.1. **What surveillance programmes are being conducted by public, and/or private sector to monitor spread of BBTV?**

……
……
……
……
……

1.2. What risk management practices are applied on farm level (private sector) to prevent introduction and/or spread of BBTV in production areas?

……
……
……
……
……

1.3. What management practices are being implemented to control the spread of BBTV?

Eg details of surveillance, movement controls, containment/ destruction of infected plantations (Please indicate who is responsible for taking these management decisions and who are implementing them)

……
……

……
……
……

1.4. Please indicate what NPPO capacity exists to do national surveillance of all production areas to confirm spread of BBTV

(Include inspections and diagnostic capacities)

……
……
……
……
……

1.5. Please add any additional information about BBTV

……
……
……
……
……

Questionnaire B

Participant focus group: NPPO, PRODUCERS, RESEARCHERS

NAME:……k

Date:……/……/……..

STAKEHOLDER:

INSTITUTION:

E-MAIL: .....

TEL NO:.....

Aim of questionnaire: To do an assessment of the pest profile for bananas in Malawi, with particular focus on NPPO regulatory services in districts with the greatest potential for banana production

1. **Which areas are to be used for local production? Which areas are to be used for development of export markets?**

2. **Climatic data of production areas including temperature, rainfall and relative humidity**

3. The months of the year when the commodity would be produced, harvested, and exported

4. Current and potential export markets for:

4.1 Banana fruit:

4.2. Banana tissue culture material:

5. List any surveillance and certification schemes currently applied to the crop, including field management information

6. Please indicate standard post-harvest processes e.g. post harvest disinfestation, treatment, inspection and sampling/quality control, packaging/labelling methods, storage conditions and transportation applied to fruit for local market

7. Please indicate what trade barriers are experienced with export of Malawi bananas to other countries in the region, if appropriate

8. Pest list of banana - Mark relevant columns

Table 1.A summary of pests on banana (de Villiers et al., 2002)

Pest	Common name	Scientific name	Geographic distribution in Malawi Yes/No/not sure	Quarantine pest Yes/No	Reference
Nematodes	Spiral nematodes	*Helicotylenchu*s spp			
	Burrowing nematodes	*Radppholus similis*			
	Rootknot nematodes	*Meloidogyne* spp.			
	Lesion nematode	*Pratylenchus* spp.			
	Reniform nematode	*Rotylenchus* spp.			
Banana slug		*Urocyclus flavescens*			
Mites	Citrus grey mite	*Calacarus citrifolii*			
	Ornamental flat mite	*Brevipalpus obovatus*			
	Reddish-back flat mite	*Brevipalpus phoenicis/ Tetranychus amicus*			
	Crimson spider mite	*Tetranychus lombardinii*			
Banana grasshopper		*Abisares viridipennis*			
Banana aphid		*Pentalonia nogronervosa*			
Scale insects	Red scale	*Aonidiella aurantii*			
	Circular purple scale	*Chrysomphalus aonidum*			
	Banana white scale	*Aspidiotus alaeidis*			
	Coconut scale	*Aspidiotus destructor*			
Thrips	Banana thrips	*Hercinothrips bicinctus*			
	Flower thrips	*Thrips exilicornis*			
Beetles	Common fruit chafer	*Pacnoda sinuate flaviventris*			
	Banana weevil	*Cosmopolites sordidus*			
	Sugarcane snout beetle	*Ellimenistes laesicollis*			
Moths		*Lobesia stericta*			
		Cryptoblabes gnidiella			
		Pyrodercus rileyi			
	Tomato semi-looper	*Chrysodeixis acuta*			
Bush pig		*Potamochoerus porcus*			
Fungal and bacterial infections	Fusarium wilt	*Fusarium oxysporum* f.sp.*cubense*			
	Cordana leaf spot	*Cordana musae*			
	Armillaria corn rot	*Armilaria* spp.			
	Erwinia rhizome rot	*Erwinia chrysanthemi*			
	Heart rot	*Erwinia musae*			
	Black sigatoka	*Mycosphaerella fijiensis*			
	Yellow sigatoka	*Mycosphaerella musicola*			
	Leaf speckle	*Mycosphaerella mussae*			
	Deightoniella leaf spot	*Deightoniella torulosa*			
	Bacterial wilt of banana	*Xanthomonas campestris* pv. *musacearum*			
	Cigar-end rot	*Verticillium theobromae*			
	Moko disease	*Ralstonia solanacearum, race 2*			
	Banana blood disease	*Ralstonia solanacearum* phylotype IV			

Pest	Common name	Scientific name	Geographic distribution in Malawi Yes/No/not sure	Quarantine pest Yes/No	Reference
	Dreschlera leaf spot				
Viruses	Banana streak disease	*Banana streak virus(BSV)*			
	Banana mosaic	*Cucumber mosaic virus (CMV)*			
	Banana bunchy top disease	*Banana bunchy top virus (BBTV)*			
	Banana bract	*Banana bract mosaic virus (BBrMV)*			
	Banana mild mosaic	*Banana mild mosaic virus (BMMV)*			

9. CONTACT DETAILS

Contact details of the relevant specialists in the fields of Botany, Horticulture, Entomology, Nematology, Mycology, Virology, etc. within the NPPO, must be provided.

10. Any other comments

Questionnaire C- Researchers and Academia

Participant focus group: Researchers and Academia

NAME:…….. Date:……../……/..…

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:…….....
.....

E-MAIL: .....

TEL NO:.....

Aim of questionnaire: To establish human resource needs (including virus indexing and tissue culturing at professional and technical level), infrastructural requirements and costs related to the production and development of clean planting material for banana.

**Tables used in this questionnaire are based and/or adapted from the IPPC PCE questionnaire (FAO, 2003)*

A. Human resources and Facilities Capacity Evaluation

Human Resources				
Technical	**Yes**	**No**	**Comments**	
1	Are there currently trained professionals in Malawi to run a banana tissue culture lab?			
1.1	If yes, describe their qualifications and level of experience?			Basic degree= Honours degree= Masters degree= PhD=
1.2	What training needs will professionals of a banana tissue culture facility require?			
		Yes	**No**	**Comments**
2	Are there currently trained professionals in Malawi to run a virus indexing service for a banana industry?			
2.1	If yes, describe their qualifications and level of experience?			Basic degree= Honours degree= Masters degree= PhD=
2.2	What training needs will professionals of a banana virus indexing lab require?			
3	Are there currently trained professionals to identify Bacterial and Fungal infections of banana?			
3.1	If yes, describe their qualifications and level of experience?			Basic degree= Honours degree= Masters degree=

				PhD=
		Yes	**No**	**Comment**
3.2	What training needs will professionals working with Bacterial and Fungal infections of banana require?			
4	Are there currently trained entomologists working on banana pests in Malawi?			
4.1	If yes, describe their qualifications and level of experience?			Basic degree= Honours degree= Masters degree= PhD=
4.2	What training needs will entomologists require to study the pests of banana?			
5	Are there any trained nematologists working on banana and banana soils?			
5.1	If yes, describe their qualifications and level of experience?			Basic degree= Honours degree= Masters degree= PhD=
		Yes	**No**	**Comment**
5.2	What training needs will a nematologist require to study the soils and root diseases caused by nematodes of banana?			
6	Is there a need to train students to strengthen the support to the banana industry in Malawi? Please explain			
Facilities				
Buildings				
7	Is there a laboratory in Malawi that has the capacity to be transformed into a banana tissue culture facility?			
7.1	If yes, where is the lab situated?			
7.2	Describe the structural changes that is necessary to convert the facility to a banana tissue culture facility			
8	Is there a laboratory in Malawi that has the capacity to be used as a banana virus indexing centre?			
8.1	If yes, where is the lab situated?			
8.2	Describe the structural changes that is necessary to convert the facility to a banana virus indexing centre			
		Yes	**No**	**Comment**
Documented Procedures / Standards				
9	Are there documented procedures for identification of insect pests on banana?			
9.1	If yes, which insect pests can be identified according to documented procedures?			
10	Are there documented procedures for identification of fungal and bacterial diseases on banana?			
10.1	If yes, which fungal and bacterial diseases of banana			

	can be identified according to documented procedures?			
11	Are there documented procedures for identification of viruses and virus-like organisms on banana?			
11.1	If yes, which virus and virus-like diseases of banana can be identified according to documented procedures?			
12	Are there documented procedures for identification of nematodes affecting banana?			
12.1	If yes, which nematodes important for banana can be identified according to documented procedures? Up to what level can they be identified?			
13	Are there documented procedures for identification of weeds in banana fields?			
14	Is there a regulatory framework or standards for the accreditation of external (non-NPPO) laboratories, including audit protocols?			
15	Are there documented quality control procedures (e.g. to ISO 9000 series standards) for laboratory operations?			
Research Capabilities				
16	Are there other organizations outside the NPPO (e.g. research or educational institutions) which undertake research on **banana diseases**? Please list them and specify the research they conduct			
17	Are there other organizations outside the NPPO (e.g. Research or Educational Institutions) which undertake research on **banana tissue culture**? Please list them and specify the research they conduct			
Admin Facilities				
18	Do you have access to a well-connected internet system? List any constraints			
19	Give a summary of the computer equipment available			
20	Do you have access to phone lines and a fax machine?			
21	List other admin needs			

Pest Diagnostic Capabilities -
Virology Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Micropipettes			
2	pH meter			
3	Binocular stereo zoom (dissecting) microscope			
4	Fume Hood			
5	Top loading balance			
6	Analytical balance			
7	Computers			
8	Hot plates			
9	Magnetic stirrer			
10	Blender			
11	High-speed refrigerated centrifuge			
12	Rotary shaker			
13	Spectrophotometer			
14	Lyophilizer			
15	Illuminated magnifier			
16	Laboratory chemicals			
17	Micro-centrifuge			
18	Autoclave			
19	Water purification system			
20	-20 degrees C freezer			
21	Refrigerator			
22	Microwave oven			
23	Temperature incubators			
24	Specialist chemicals			
25	Cold light source			
26	Laboratory glassware			
27	Electrophoresis equipment			
28	ELISA equipment: ELISA reader, ELISA plate washer, multichannel pipette			
29	Waterbath			
Advanced laboratory equipment				
30	Ultra Microtome			
31	Ultra Centrifuge			
32	PCR machine			
33	Ultra Low-temperature freezer (-80 degrees C)			
34	Electron Microscope			
35	Hybridization oven			
36	Ultraviolet crosslinker			
37	High speed vacuum freeze drier			
38	Ultraviolet viewer with Polaroid camera			
39	Gel documentation system			
40	Are there any other items of equipment considered appropriate to be added? If YES, list in the comment box.			

Pest Diagnostic Capabilities -
Fungal and Bacterial Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Illuminated magnifier			
2	ELISA equipment			
3	Lyophilizer			
4	BOD incubator			
5	Spectrophotometer			
6	Laminar flow cabinet			
7	pH meter			
8	Rotary shaker			
9	High speed centrifuge			
10	Autoclave			
11	Microwave oven			
12	Dissection equipment			
13	Bacterial cell counter			
14	Near-UV lights (black-lights)			
15	Computers			
16	Hot plates			
17	Magnetic stirrer			
18	Micro-centrifuge			
19	Fume Hood			
20	Analytical balance			
21	Top loading balance			
22	Micropipettes			
23	Laboratory glassware			
24	Temperature incubators			
25	Refrigerator			
26	-20 degrees C freezer			
27	Binocular stereo zoom (dissecting) microscope			
28	Blender			
29	Electrophoresis equipment			
30	Cold light source			
31	Fluorescence microscope			
32	Water purification system			
33	Culture collection			
34	Laboratory chemicals			
35	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities -
Nematology Equipment

No	Question	Answer		Comment
Equipment				Yes No
1	Trays			
2	Laboratory glassware			
3	Magnetic stirrer			
4	Hot plates			
5	Micropipettes			
6	Laboratory chemicals			
7	Culture collection			
8	Autoclave			
9	Blender			
10	Soil corers			
11	Refrigerator			
12	Dissection kits			
13	-20 degree freezer			
14	Compound microscope			
15	Dissecting microscope			
16	Centrifuge			
17	Temperature incubators			
18	Water bath			
19	Nematode sieving apparatus			
20	Illuminated magnifier			
21	Nematode counting dishes			
22	Mist extraction apparatus			
23	Spades			
24	Microwave oven			
25	Nematode extraction funnels			
26	Cold light source			
27	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities -
Entomology Equipment

No	Question	Answer		Comment
Equipment				Yes No
1	Compound microscope			
2	Cold light source			
3	Binocular stereo zoom (dissecting) microscope			
4	Illuminated magnifier			
5	Insect rearing chamber(s)			
6	X-ray equipment			
7	Computers			
8	Micropipettes			
9	Hot plates			
10	Top loading balance			
11	Magnetic stirrer			
12	Analytical balance			
13	Blender			
14	Laboratory glassware			
15	Refrigerator			
16	Curation equipment			
17	Autoclave			
18	Laboratory chemicals			
19	-20 degrees C freezer			
20	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities -
Weed Science Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Autoclave			
2	Seed sampling equipment			
3	Herbarium facilities			
4	Centrifuge			
5	Laboratory glassware			
6	Illuminating magnifier			
7	Hot plates			
8	-20 degrees C freezer			
9	Laboratory chemicals			
10	Water bath			
11	Compound microscope			
12	Dissecting microscope			
13	Magnetic stirrer			
14	Microwave oven			
15	Dissection kits			
16	Cold light source			
17	Refrigerator			
18	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities -
Tissue culture Facility

No	Question	Answer		Comment
Equipment		Yes	No	
1	Autoclave			
2	Laboratory glassware			
3	-20 degrees C freezer			
4	Laboratory chemicals			
5	pH meter			
6	Microwave oven			
7	Refrigerator			
8	Laminar flow cabinet			
9	Jars and consumables			
10	Sterile working equipment			
11	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Questionnaire D- NPPO

Participant focus group: NPPO

NAME:…….. Date:……../……/…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:……

E-MAIL: .....

TEL NO:.....

**Tables used in this questionnaire are based and/or adapted from the IPPC PCE questionnaire (FAO, 2003)*

Aim of questionnaire: To establish human resource needs (including virus indexing and tissue culturing at professional and technical level), infrastructural requirements and costs related to the production and development of clean planting material for banana of the NPPO.

No	Question	Answer		Comment
Human Resources				
Technical				
1	Are general Entomologists considered necessary for the NPPO?			
1.1	If yes, how many general entomologists are there in the NPPO? List their qualification			Basic degree= Honours degree= Masters degree= PhD=
1.2	How many general Entomologists (not included above) outside the NPPO (e.g. research or educational institutes) may assist in diagnosis of banana pests? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
2	Are Fungal Pathologists (specialists) considered necessary for the NPPO?			
2.1	If yes, how many Fungal Pathologists are there in the NPPO. List their qualification?			Basic degree= Honours degree= Masters degree= PhD=
2.2	How many Fungal Pathologists outside the NPPO (e.g. research or educational institutes.) may assist in the diagnosis of banana diseases? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
3	Are Bacterial Pathologists (specialists) considered necessary for the NPPO?			
3.1	If yes, how many Bacterial Pathologists are there in the NPPO? List their qualification			Basic degree= Honours degree= Masters degree= PhD=
3.2	How many Bacterial Pathologists outside the NPPO (e.g. research or educational institutes) may assist in			Basic degree= Honours degree=

	the diagnosis of banana diseases? List from which Institute they are.			Masters degree= PhD=
4	Are Plant Virologists (specialists) considered necessary for the NPPO?			
4.1	If yes, how many Plant Virologists are there in the NPPO? List their qualification			Basic degree= Honours degree= Masters degree= PhD=
4.2	How many Plant Virologists outside the NPPO (e.g. research or educational institutes) may assist in the diagnosis of viruses of banana? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
5	Are general Pathologists (deals with fungal pathology, bacteriology and virology) considered necessary for the NPPO?			
5.1	If yes, how many general Pathologists are there in the NPPO? List their qualification			Basic degree= Honours degree= Masters degree= PhD=
5.2	How many general Pathologists outside the NPPO (e.g. research or educational institutes) may assist in diagnosis of banana diseases? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
6	Are Nematologists (specialists) considered necessary for the NPPO?			
6.1	If yes, how many Nematologists are there in the NPPO?			Basic degree= Honours degree= Masters degree= PhD=
6.2	How many Nematologists outside the NPPO (e.g. research or educational institutes) may assist in diagnosis of banana soils and root nematodes? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
7	Are Weed Scientists considered necessary for the NPPO?			
7.1	IF yes, how many Weed Scientists are there in the NPPO?			Basic degree= Honours degree= Masters degree= PhD=
7.2	How many Weed Scientists outside the NPPO (e.g. research or educational institutes) may assist in diagnosis? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=
8	How many technical laboratory support staff (lab. assistants and technicians) are there in the NPPO?			Basic degree= Honours degree= Masters degree= PhD=
8.1	How many technical laboratory support staff (lab. assistants and technicians) outside the NPPO (e.g. research or educational institutes) may assist in diagnosis? List from which Institute they are.			Basic degree= Honours degree= Masters degree= PhD=

Management				
9	How many full-time laboratory managers are employed by the NPPO?			Basic degree= Honours degree= Masters degree= PhD=
10	How many of these managers have received management training?			
11	How many scientists also manage a laboratory?			Basic degree= Honours degree= Masters degree= PhD=
12	How many of these part-time managers have received management training?			
13	How many management support staff (secretarial / clerical) are employed by the NPPO?			
14	How many computer / information technology support staff are employed by the NPPO?			Basic degree= Honours degree= Masters degree= PhD=
15	How many other support staff (maintenance, laborers, drivers, cleaners etc) are employed by the NPPO?			
16	Is there a national manager/coordinator for pest diagnostic services?			
Facilities				
Buildings				
17	How many laboratories are there in the country that are capable of diagnosis in Mycology / Bacteriology for the NPPO?			
18	How many laboratories are there in the country that are capable of diagnosis in Plant Virology for the NPPO?			
19	How many laboratories are there in the country that are capable of diagnosis in Nematology for the NPPO?			
20	How many laboratories are there in the country that are capable of diagnosis in Entomology for the NPPO?			
21	How many laboratories are there that are capable of diagnosis in Weed Science?			
22	How many laboratories are there that are capable of doing tissue culture work?			
23	How many insect-proof quarantine facilities which are NOT temperature controlled (e.g. Glasshouse, Screen house) are there?			
24	How many insect-proof temperature controlled facilities are there?			
25	How many air filtered and temperature controlled containment facilities are there?			
26	Do any of the laboratories have facilities for keeping insect collections which can be used by NPPO staff when required?			

27	Do any of the laboratories have facilities for keeping culture (bacterial and fungal) collections which can be used by NPPO staff when required?			
28	Do any of the laboratories have weed seed collections which can be used by NPPO staff when required?			
Documented Procedures / Standards				
29	Are there documented procedures for identification of arthropod pests on banana?			
29.1	If yes, which arthropod pests can be identified according to documented procedures?			
30	Are there documented procedures for identification of fungal and bacterial diseases on banana?			
30.1	If yes, which fungal and bacterial diseases of banana can be identified according to documented procedures?			
31	Are there documented procedures for identification of viruses and virus-like organisms on banana?			
31.1	If yes, which virus and virus-like diseases of banana can be identified according to documented procedures?			
32	Are there documented procedures for identification of nematodes affecting banana?			
32.1	If yes, which nematodes important for banana can be identified according to documented procedures? Up to what level can they be identified?			
33	Are there documented procedures for identification of weeds in banana fields?			
34	Is the NPPO capable of conducting research on rapid diagnostic techniques for the detection of economically important pests?			
35	Are there documented quality control procedures (e.g. to ISO 9000 series standards) for laboratory operations of the NPPO?			
Research Capabilities				
36	Are there other organizations outside the NPPO (e.g. research or educational institutions) which undertake research on **banana diseases**? Please list them and specify the research they conduct			
37	Is the NPPO capable of conducting research on treatment procedures for the detection of economically important pests?			
38	Are there other organizations outside the NPPO (e.g. Research or Educational Institutions) which undertake research on **banana tissue culture**? Please list them and specify the research they conduct			
39	Are there any other questions considered appropriate to assess the strengths and weaknesses of the NPPO in this section? If YES, list them in the comment box.			
Admin Facilities of the NPPO				

40	Do you have access to a well-connected internet system? List any constraints			
41	Give a summary of the computer equipment available			
42	Do you have access to phone lines and a fax machine?			
43	List other admin needs			

Pest Diagnostic Capabilities - NPPO
Virology Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Micropipettes			
2	pH meter			
3	Binocular stereo zoom (dissecting) microscope			
4	Fume Hood			
5	Top loading balance			
6	Analytical balance			
7	Computers			
8	Hot plates			
9	Magnetic stirrer			
10	Blender			
11	High-speed refrigerated centrifuge			
12	Rotary shaker			
13	Spectrophotometer			
14	Lyophilizer			
15	Illuminated magnifier			
16	Laboratory chemicals			
17	Micro-centrifuge			
18	Autoclave			
19	Water purification system			
20	-20 degrees C freezer			
21	Refrigerator			
22	Microwave oven			
23	Temperature incubators			
24	Specialist chemicals			
25	Cold light source			
26	Laboratory glassware			
27	Electrophoresis equipment			
28	ELISA equipment: ELISA reader, ELISA plate washer, multichannel pipette			
29	Waterbath			
Advanced laboratory equipment				
30	Ultra Microtome			
31	Ultra Centrifuge			
32	PCR machine			
33	Ultra Low-temperature freezer (-80 degrees C)			
34	Electron Microscope			
35	Hybridization oven			
36	Ultraviolet crosslinker			
37	High speed vacuum freeze drier			
38	Ultraviolet viewer with Polaroid camera			
39	Gel documentation system			
40	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities - NPPO
Fungal and Bacterial Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Illuminated magnifier			
2	ELISA equipment			
3	Lyophilizer			
4	BOD incubator			
5	Spectrophotometer			
6	Laminar flow cabinet			
7	pH meter			
8	Rotary shaker			
9	High speed centrifuge			
10	Autoclave			
11	Microwave oven			
12	Dissection equipment			
13	Bacterial cell counter			
14	Near-UV lights (black-lights)			
15	Computers			
16	Hot plates			
17	Magnetic stirrer			
18	Micro-centrifuge			
19	Fume Hood			
20	Analytical balance			
21	Top loading balance			
22	Micropipettes			
23	Laboratory glassware			
24	Temperature incubators			
25	Refrigerator			
26	-20 degrees C freezer			
27	Binocular stereo zoom (dissecting) microscope			
28	Blender			
29	Electrophoresis equipment			
30	Cold light source			
31	Fluorescence microscope			
32	Water purification system			
33	Culture collection			
34	Laboratory chemicals			
35	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities - NPPO
Nematology Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Trays			
2	Laboratory glassware			
3	Magnetic stirrer			
4	Hot plates			
5	Micropipettes			
6	Laboratory chemicals			
7	Culture collection			
8	Autoclave			
9	Blender			
10	Soil corers			
11	Refrigerator			
12	Dissection kits			
13	-20 degree freezer			
14	Compound microscope			
15	Dissecting microscope			
16	Centrifuge			
17	Temperature incubators			
18	Water bath			
19	Nematode sieving apparatus			
20	Illuminated magnifier			
21	Nematode counting dishes			
22	Mist extraction apparatus			
23	Spades			
24	Microwave oven			
25	Nematode extraction funnels			
26	Cold light source			
27	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities - NPPO
Entomology Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Compound microscope			
2	Cold light source			
3	Binocular stereo zoom (dissecting) microscope			
4	Illuminated magnifier			
5	Insect rearing chamber(s)			
6	X-ray equipment			
7	Computers			
8	Micropipettes			
9	Hot plates			
10	Top loading balance			
11	Magnetic stirrer			
12	Analytical balance			
13	Blender			
14	Laboratory glassware			
15	Refrigerator			
16	Curation equipment			
17	Autoclave			
18	Laboratory chemicals			
19	-20 degrees C freezer			
20	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities - NPPO
Weed Science Equipment

No	Question	Answer		Comment
Equipment		Yes	No	
1	Autoclave			
2	Seed sampling equipment			
3	Herbarium facilities			
4	Centrifuge			
5	Laboratory glassware			
6	Illuminating magnifier			
7	Hot plates			
8	-20 degrees C freezer			
9	Laboratory chemicals			
10	Water bath			
11	Compound microscope			
12	Dissecting microscope			
13	Magnetic stirrer			
14	Microwave oven			
15	Dissection kits			
16	Cold light source			
17	Refrigerator			
18	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Pest Diagnostic Capabilities - NPPO
Tissue culture Facility

No	Question	Answer		Comment
Equipment		Yes	No	
1	Autoclave			
2	Laboratory glassware			
3	-20 degrees C freezer			
4	Laboratory chemicals			
5	pH meter			
6	Microwave oven			
7	Refrigerator			
8	Laminar flow cabinet			
9	Jars and consumables			
10	Sterile working equipment			
11	Are there any other items of equipment considered appropriate to be added to this section? If YES, list them in the comment box.			

Questionnaire E- Producers

Participant focus group: Producers (small scale and commercial producers)

NAME:…….. Date:……../……/…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors/Producer

INSTITUTION:.....

E-MAIL ADDRESS:.....

TEL NUMBER:.....

Aim of questionnaire: To determine the commercial challenges and opportunities to produce disease free planting materials in Malawi

LOCAL MARKET

1. Are you currently growing banana? Yes/No

Which Cultivar/s are you growing? Cooking bananas vs plantain

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2. Where do you obtain your planting material from?

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3. Role and importance of banana production:

3.1. Is banana a staple food for your family? Yes / No

If Yes, how much are consumed per day?.....

3.2. How many hectares of your land are planted with banana?

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3. 3. How much of your income depend on banana production?

……

3.4. Do you think growing bananas are a profitable enterprise? Yes / No

Motivate your answer:

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……

4. Constraints to banana production:

List the constrains you experience with banana production (resources available, pest management, economic impacts, infrastructure, labour available, soil fertility)

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……

5. How do you implement integrated pest management? Or not at all?

1. Planting of healthy material ☐
2. Vector control ☐
3. Removal of sources of infection, ☐
weeds, infected suckers
4. Phytosanitation-virus indexing ☐
5. Planting resistant cultivars ☐
6. Geographical or temporal isolation ☐

6. Diseases on banana:

List the diseases on banana you are aware of

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7. Do you know how to identify *Banana bunchy top virus*? Yes / No

If yes, describe the symptoms you see in the field

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8. In the case of establishing pest-free areas for banana production in Malawi, would you be willing to destroy infected plantations and replace them with healthy material from the newly established tissue culture and virus indexing centre?

If no, why?

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If yes, what financial and infrastructural inputs will you need to establish pest-free areas?

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Questionnaire F

Participant focus group: NPPO, Private sector, Researchers, Producers, Donors, Development partners

NAME:…….. Date:……../……/…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:.....

E-MAIL ADDRESS:.....

TEL NUMBER:.....

Aim of questionnaire: To determine the linkages and complementaries to other capacity building activities supported by other donors and development partners in Malawi

1. What other planned agricultural activities supported by o**ther donors** are taking place in Malawi and how will these projects compliment the banana industry in Malawi?

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2. How will the propagation of clean planting material for banana and setting up a banana virus indexing centre link with other **research opportunities** at research institutes in Malawi?

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3. How will the establishment of a banana tissue culture and a virus indexing centre influence the **other agricultural** markets in Malawi?

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4. Are there existing facilities that can be used or transformed into banana tissue culture facilities? Where are they?

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5. Are there existing facilities that can be used and develop as a banana virus indexing centre, also testing for other diseases and pests of banana? Where are they?

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6. Are there any indications where a pest-free area can be established?

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7. Are there interest of donors and or development partners to fund or co-fund all or part of the project should the outcome of the feasibility study support the development of banana tissue laboratory and virus indexing capacity in Malawi?

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Questionnaire F- Tissue culture facility

Participant focus group: Development partners, NPPO, Researchers, Private sector

NAME:…….. Date:……../……/…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:.....

E-MAIL ADDRESS:.....

TEL NUMBER:.....

Aim of questionnaire: To determine the commercial challenges and opportunities to produce disease free planting materials in Malawi - laboratory information

What information is available to determine the following value chain factors:

1. Cost of input supplies:

1.1. What would it cost to establish a mother block(s) for tissue culture lab

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1.2. Where would this mother block(s) be situated, i.e. distance from laboratory

.....

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1.3. Is there private sector interest to establish such a laboratory or expand an existing facility?

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.....

1.4. Location of tissue culture lab and distance from:

1.4.1. Regulatory diagnostics services laboratory

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1.4.2. Production areas

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1.5. Market information (prices, trends, buyers, suppliers)

1.5.1. What are price options for obtaining virus free material currently?

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1.5.2. Would producers be willing to pay more for virus free planting material as opposed to cheaper but infected materials?

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1.5.3. What annual volume of planting materials is expected to be sold to the local market?

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……

1.5.4. What annual volume of planting materials is expected to be sold to regional markets?

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1.5.5. What options exist to import planting material to establish the tissue culture laboratory mother block(s)?

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1.6. Financial services:

1.6.1. Are there national interest to provide credit support or insurance for establishing a laboratory?

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1.6.2. Does existing legislation allow for the establishment and regulatory controls that would be required to develop tissue culture material for export markets?

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1.7. Transport Services

1.7.1. What would be arrangements for transport of testing samples to regulatory laboratory?

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1.8. Quality assurance

1.8.1. What quality assurance systems would have to be out into place to be competitive in the regional market?

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1.8.2. Regular phytosanitary testing and virus indexing will be required for the local and regional markets. What capacities exist in private and public sector to have the required regulatory controls and monitoring in place for exports to the region?

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1.8.3. Establishing and maintaining buffer zones around the mother blocks/ tissue culture laboratory may be required by regional markets for certain pests. What capacities exist to have the required regulatory monitoring in place for exports to the region?

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Questionnaire G-Trade and Industry

Participant focus group: Trade and Industry

NAME:…….. Date:……../……/…..

STAKEHOLDER: Government/Private sector/ Research and academia/development partner/donors

INSTITUTION:.....

E-MAIL ADDRESS:……

TEL NUMBER:.....

BANANA PRODUCTION IN MALAWI

1. How many hectares of land are currently under commercial production?

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2. How many hectares of land are currently under small scale/ informal production?

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3. Are there any plan for major expansion of this industry in Malawi? And if so, are such projects/ programmes for industry expansion funded by private or public sector?

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4. Are there any international/ donor funded projects or programmes with theaim of expanding commercial banana production in Malawi. Please provide details.

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5. What are the total number of banana producers in Malawi? What percentage of the total producers are (1) large commercial producers, (2) small scale commercial producers and (3) subsistence farmers.

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6. In which production areas are commercial producers dominant? Please provide details of numbers or percentage of total produces.

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7. How many farm workers are employed by the commercial producers?

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8. Does Malawi have market access for banana fruit to any markets? If so which markets and are the Pest risk assessments available?

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9. Which potential export markets have been targeted? What are the major SPS trade obstacles to access these markets?

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10. What percentage of locally produced bananas are currently exported?

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11. What percentage of locally produced bananas are sold to the consumer via the retail or formal sector? And which percentage are traded informally?

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……

12. What is the average domestic market price for bananas/ kg? Informal and formal markets?

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Appendix 4: List of Figures

Figure 1. A map of Malawi indicating the major banana production areas of the country in green

Figure 2. Map of surveyed locations in Malawi (indicated with circles). Region of first BBTD outbreak is indicated (a) and direction of disease spread indicated with arrow. 1=Lilongwe, and 2= Blantyre

Figure 3. Typical BBTV symptoms seen in (A) stunted plants, (B) banana aphid transmitting the virus, (C) streaks on pseudostem, (D) immature banana suckers infected with BBTV and (E) banana suckers infected with BBTV without rooting systems.

Figure 4. The farm of the Washoni brothers (A) brothers in blue shirts; (B) banana plantations; (C, F) current shade net facility; (D, E) structure for growing suckers

Figure 5. The banana plantations of Mangoes Malawi (A,D); pulping factory(C); shade net facility where planting material is kept (B) and bananas ready for consumption (E).

Figure 6.Facilities at Chitedze Research Station (A); the current biotechnology lab (B); the new facilities (C,D) and green house in progress (E).

Figure 7. Tissue culture facilities at Bunda College (A); banana tissue culture (B); potato tissue culture (C); green house facility where propagated banana plants can be hosted (D, E)

Figure 8. Tissue culture facilities at Bvumbwe Research Station (A, B); the quarantine facility (C); the green houses that need renovations (D); the potential virus indexing lab (E, F).

Appendix 5: List of Tables

Table 1. A summary from producers on aspects of banana production

Table 2.The pest list on banana in Malawi; indicating distribution of pests within Malawi and the quarantine pest status.

Table 3. A summary of the implementation of IPM by two commercial farmers and a small scale farmer

Table 4. Requirements for the establishment of a virus indexing centre in Malawi

Table 5. Requirements for the establishment of a banana tissue culture laboratory in Malawi

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