

Biosecurity Framework for the Australian banana industry

March 2017



This Biosecurity Framework has been produced by the Australian Banana Growers' Council as a part of the Banana Strategic Industry Development Project that is funded by HIA Ltd using the banana industry R&D levy and matched funds from the Australian Government.

Background

Bananas are a highly genetically homogenous crop which are propagated from vegetative material and around 94% of the industry is grown in close proximity in North Queensland. Therefore, exotic and endemic pests and diseases as well as those under active containment pose a threat to banana production.

Purpose of framework

The aim of this framework is to examine the current extent of biosecurity preparedness within the banana industry – from growers' awareness levels to research gaps and the ability to contain (and continue to farm with) exotic pests given Australian production systems. The framework considers those pests and diseases that have been determined to be High Priority Pests (HPPs) in the Banana Industry Biosecurity Plan (2010) as well as other pests and diseases that impact on the banana industry.

In preparing this report and to give structure to the information currently available, this report uses the different elements of the biosecurity continuum to make an assessment about how well positioned the Australian banana industry is if it had to respond to an exotic pest (both exotic to Australia or currently found outside of a current production area). The elements include:

- Prevention of pest and disease movement into and within Australia;
- Preparedness - including:
 - Grower and general industry awareness;
 - Research including diagnostic tests;
 - Contingency planning.
- Surveillance;
- Response Actions including pest classification under the Emergency Pest Plant Response Deed; and
- Ongoing Management of the pest or disease.

This framework is the result of an assessment of existing, published information. Importantly the framework has a list of recommendations to guide possible further work in the banana biosecurity area. There is also a “traffic light” summary that reflects the current level of preparedness in response to each pest identified. The colour system used does not rate the importance/impact of the actual pest on the banana industry.

The assessment of the available information and subsequent preparation of the Banana Industry Biosecurity Framework would not have been possible without the research contribution of Dr Jay Anderson, Plant Pathologist, Research and Development for Primary Industries Pty Ltd.

Table of contents

Introduction	2
Table of contents	3
List of acronyms	4
Biosecurity Framework Summary Table	5
List of priorities and gaps	8
Specific Pest and Disease Information.....	10
Banana Bunchy Top Disease	10
Abaca Bunchy Top Disease	12
Banana Bract Mosaic Disease	14
Panama disease/ Fusarium wilt	16
Wilt disease of bananas	19
Black Sigatoka	22
Eumusae leaf spot.....	24
Banana Freckle.....	26
Yellow Sigatoka	28
Moko	30
Bugtok	32
Blood disease	34
Xanthomonas bacterial wilt	36
Exotic nematodes.....	37
Banana Skipper Butterfly	39
Spider mite.....	40
Coffee bean weevil	41
Conclusion	43
Appendix 1 General surveillance and prevention of movement of pests and diseases.....	44
Appendix 2 Terms use in the Queensland Biosecurity Act	45
Appendix 3 – maps of locations of pests	46
Banana Bunchy Top Virus	46
Banana blood disease	47
Bacterial wilt	47
Black Sigatoka	48
Banana skipper butterfly.....	48
Panama disease	49

List of acronyms

ABGC – Australian Banana Growers Council

BBTV – Banana bunchy top virus

BPPP – Banana Plant Protection Program, HIA funded project 2011 – 2016.

BQ – Biosecurity Queensland

BWAP – Banana wilt associated phytoplasma

CCEPP – Consultative Committee on Emergency Plant Pests

DAF – Department of Agriculture and Fisheries (Queensland)

EFSA – European Food Safety Authority

EPPRD – Emergency Plant Pest Response Deed

HFS – Horticulture and Forestry Science (a group within DAF)

HIA – Horticulture Innovation Australia

HPP – high priority pest

NAQS – Northern Australia Quarantine Strategy

NDP – National Diagnostic Protocol. Links to NDPs:

<http://plantbiosecuritydiagnostics.net.au/resource-hub/priority-pest-diagnostic-resources/>

PaDIL – Pest and Disease Image Library – online resource from the Australian Government's Department of Agriculture, in collaboration with Museum Victoria, Plant Health Australia, the Department of Agriculture and Food Western Australia and the Plant Biosecurity Cooperative Research Centre. <http://www.padil.gov.au/>

PEQ – post-entry quarantine

PHA – Plant Health Australia

QAAFI – Queensland Alliance for Agriculture and Food Innovation

QBAN – Quality Banana Approved Nursery

SEQ – South East Queensland

SPHDS – Subcommittee on Plant Health Diagnostic Standards

Biosecurity Framework Summary Table

	Organism	Pathways ^a	Awareness	Research	Prevention of movement	Surveillance	Diagnostics	Contingency plans	Management	EPPRD
	Exotic									
Abaca bunchy top virus			Yellow	Yellow	Green	Yellow	Yellow	Green	Green	NC
Banana bract mosaic disease			Yellow	Yellow	Green	Yellow	Yellow	Green	Green	√
Banana bunchy top virus (exotic strains)			Yellow	Green	Green	Yellow	Yellow	Green	Green	√
Blood Disease			Yellow	Yellow	Green	Yellow	Red	Red	Yellow	√
Moko			Yellow	Yellow	Green	Yellow	Red	Red	Yellow	√
Bugtok			Yellow	Yellow	Green	Yellow	Red	Red	Yellow	√
Bacterial wilt – <i>X. c. pv. musacearum</i>			Red	Red	Green	Yellow	Red	Red	Yellow	NC

	Organism	Pathways ^a	Awareness	Research	Prevention of movement	Surveillance	Diagnostics	Contingency plans	Management	EPPRD
Freckle disease		  								√
Eumusae leaf spot		  								√
Black Sigatoka		  								√
Banana skipper butterfly		 								√
Spider mite		 								√
Banana Wilt Associated Phytoplasma		 								?
Exotic nematodes		  								?

	Organism	Pathways ^a	Awareness	Research	Prevention of movement	Surveillance	Diagnostics	Contingency plans	Management	EPPRD
Restricted range										
Panama disease Tropical race 4		   	Green	Red	Yellow	Green	Yellow	Yellow	Red	X
Panama Race 1		   	Green	Red	Yellow	Yellow	Yellow	Yellow	Red	X
BBTV (Australian strain)		  	Red	Green	Red	Yellow	Green	Green	Yellow	X
Endemic										
Yellow Sigatoka and leaf spot diseases		  	Green	Green	Green	Green	Green	Yellow	Yellow	X
Coffee bean weevil		 	Green	Red	Yellow	Yellow	Yellow	Red	Red	X

Organism:  - virus,  - bacteria,  - fungus,  - butterfly,  - mite,  - phytoplasma,  - nematode,  - weevil. ^a Adapted from R. Sapuppo, J. Anderson “Risky Business” Roadshow presentation 2014  – planting material,  – fruit,  - soil,  – moved by insects or insects able to move themselves,  - tools, footwear and equipment,  – water,  – wind.

Colour indicates level of preparedness (rather than impact of pest) : **Red** - very little preparation, needs attention, **Orange** – moderate preparation, needs attention but not most urgent, **Green** - relatively well prepared, **Light orange** – unknown, needs further investigation

NC = not classified. √ = covered by the EPPRD. X = not covered by EPPRD. ?=not clear if covered by EPPRD.

List of priorities and gaps

The following recommendations are listed in order of priority.

- Continue to encourage growers to regularly look for anything unusual on their plants and get someone qualified to look at a symptom ASAP. There is potential to contain/eradicate pests and diseases if found early enough.
- Maintain existing systems and research capacity that are preventing the movement and establishment of exotic pests and diseases into Australia for example:
 - NAQS surveillance,
 - post entry quarantine facilities and conditions,
 - germplasm banks and
 - diagnostic, networking and high calibre technical knowledge capacity.
- Address potential for Banana Bunchy Top Virus (BBTV) spread from South East Queensland and Northern NSW to other growing regions by ensuring support for the BBTV containment program. There needs to be more information about this virus targeted at north Queensland growers. Clarification is required about the current EPPRD classification (pg 10).
- Maintain education program on Panama disease Tropical Race 4 and development, importation and testing of varieties with resistance to the disease. Update of PHA factsheet on the disease (pg16).
- Continue to develop management strategies for Panama disease (pg 16).
- Investigate a program for supply of black Sigatoka resistant varieties to replace susceptible varieties on Cape York in conjunction with a structured sentinel program to support for black Sigatoka detection. Support regular surveillance in the Cape (pg 22).
- Develop extension materials with information and high quality images on symptoms for growers to look for. Provide training for pest scouts on what to do if they find a suspect plant.
- Develop National Diagnostic Protocol (NDP) and Contingency plans for bacterial wilt diseases to enable a swift response if there was an incursion.
- Develop a north Queensland strategy to deal with feral bananas that could harbour potential incursions e.g. banana bunchy top virus
- Update of the industry biosecurity plan (IBP) and facts sheets.
- Categorise *Mycosphaerella eumusae* (cause of Eumusae leaf spot) under the EPPRD (pg 24)
- Understand more about the distribution of Eumusae leaf spot as well as other research on the disease. (pg 24)

- Address the lack of information on banana wilt associated phytoplasma (pg 19)
- Develop a diagnostic protocol and contingency plan for Banana Skipper Butterfly (pg 38)
- Review all draft NDPs and assess the resources required to finalise them.
- Develop management strategies for coffee bean weevil (pg 41)
- Any future surveillance projects, regardless of the pest or disease ,must include that inspectors also note and act on ANY unusual symptoms.

It is recommended that all of the priorities listed above are reviewed annually.

Specific Pest and Disease Information

Banana Bunchy Top Disease

Caused by *Banana Bunchy Top Virus*

Banana bunchy top virus (BBTV) is the most devastating banana virus disease world-wide. The virus is present in Southeast Asia and the South Pacific and is present in parts of India and Africa (refer to attached maps).

The disease causes a stunting and a choking of the banana plants and badly affected plants do not produce bunches. The disease is spread in infected planting material and by aphids (*Pentalonia nigronervosa*). There is no known resistance to the virus.

The virus has alternate hosts (*Canna*, *Heliconia*, *Strelitzia*) that are commonly found in backyards across Queensland.

The disease is under active containment in northern NSW and SEQ. There are however, concerns about the introduction of exotic strains into Australia as well as the introduction of the current strain(s) into north Queensland (NQ), NT and WA. The high density of plantings in north Queensland and the ubiquitous nature of the vector could make eradication difficult in north Queensland.

If the current virus was found outside of the existing regions, then it would be covered under the EPPRD.

Awareness and research

Grower awareness of the virus is high in northern NSW, moderate in SEQ and generally low amongst growers in NQ, NT and WA. Awareness in the gardening communities in SEQ and NNSW is currently relatively high due to work of BBTV project Phase I and II. There is a concern that without ongoing education, general public awareness will decrease. It is critical to maintain awareness of this pest to reduce the likelihood of the general public spreading the pest into the main Australian production area via the movement of contaminated planting material.

Due to the ongoing containment program in SEQ and northern NSW there are many resources on recognising and dealing with the disease. Material includes photos, popular articles, scientific literature and videos. There needs to be work done to determine whether these resources are up to date.

Research is currently being undertaken to understand latency of the virus in corms of banana plants as the disease has appeared in locations a long distance from other infected plants but in close proximity to where infected plants were removed over 12 months prior.

GAPS:

- NQ and WA growers lack knowledge about the disease and its symptoms.
- There needs to be continued effort to educate the general public about the risks of moving planting material outside of the B BTV zones (particularly in NSW and SEQ).

Prevention of movement

Into Australia

Prevention of movement into the country on planting material is covered under importation conditions. Banana is considered a high risk crop and therefore tissue culture plantlets are imported into post entry quarantine (PEQ) glasshouse under strict protocols.

Clean, well packed fruit is not a potential vector of the disease.

Within Australia

There are restrictions on the movement of planting material between States and also for some areas between biosecurity zones.

Encouragement of growers to use QBAN tissue culture plants to start new plantations.

GAPS:

- Biggest threat is the potential build-up of the disease in SEQ (and NSW if resources are lessened there) and then disease then spreading to other growing regions, potentially very easy for a member of the public to take infected suckers to NQ.
- Prior to Panama TR4 in NQ, lack of care by growers in sourcing planting material from neighbours in NQ, with the TR4 incursion growers now take much more care in sourcing plants.

Surveillance

Early infections have subtle symptoms and so can be difficult to identify.

Regular surveillance and eradication of BBTV infected plants is being undertaken as part of the HIA funded projects "National banana bunchy top virus program – Phase 3 – QLD (BA15006) and National banana bunchy top virus program – Phase 3 – NSW (BA15007).

Due to the longevity of funded BBTV projects, there are trained inspectors who can identify early symptoms and have an awareness to look for symptoms of other diseases.

ABGC's yellow Sigatoka inspector has had training on recognising the disease, however he has not had regular exposure to seeing infected material and so may have difficulty in identifying early infections.

GAPS:

- Growers need to be encouraged to closely monitor their plants and to know what actions to take if they notice something unusual.
- There is currently no succession planning for inspectors.

Diagnostics

Testing for BBTV is routinely performed by DAF/QAAFI however there is no National Diagnostic Protocol (NDP) (draft or ratified).

Expertise:

- Diagnostics: Dr John Thomas with Dr Kathy Crew.
- Visual identification: Barry Sullivan, Joshua Chapman David Peasley, Samantha Stringer (no longer working on BBTV but have extensive field experience).

GAPS:

- Fast assays, ratified NDP

Contingency/Covered under EPPRD

Incursion into NQ, NT and WA could be covered under EPPRD as the disease is under active control in northern NSW and SEQ. Work may be required on the classification of this disease.

A well-established plan for containment exists for this disease (Thomas, 2009). Research is currently being undertaken to understand the potential for the virus to remain latent in the eyes of corms and appear a number of years after the last detection of BBTV in a plantation. This has implications for declaring an area free of BBTV.

Management

Current management practice is to contain the disease and eradicate it from commercial plantations. Management relies on regular inspections and destroying infected plants. There is good information available on destruction methods of infected plants (standard operating procedures were updated in 2016) with more research being done to examine the efficacy of insecticides and herbicides at different times of year.

No resistant varieties.

GAPS:

- Major scientific gaps in knowledge about the disease have been or are being addressed.
- Increasing public awareness of how to report this disease is very important.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Banana-bunchy-top-disease-FS.pdf>

<http://abgc.org.au/projects-resources/industry-projects/banana-bunchy-top-virus/>

<http://www.promusa.org/Bunchy+top>

Thomas JE (2009) Strategies for the control of banana bunchy top virus – a review

Cook DC, Liu S, Edwards J, Villalta ON, Aurambout J-P, et al. (2012) Predicting the Benefits of Banana Bunchy Top Virus Exclusion from Commercial Plantations in Australia. PLoS ONE 7(8): e42391. doi:10.1371/journal.pone.0042391

Stringer S, Sullivan B and Peasley D. SOP for destruction of BBTV infected plants. ABGC.

Abaca Bunchy Top Disease

Caused by *Abaca bunchy top virus*

Abaca bunchy top virus (ABTV) affects abacas plants and has some similarities to *banana bunchy top virus* as they are both Babuviruses. Abacá, (*Musa textilis*) is a species of banana native to the Philippines and is grown as a commercial crop in the Philippines, Ecuador, and Costa Rica. It has a great economic importance as it is harvested for its fibre that is pulped and

used in a variety of specialized paper products including tea bags, filter paper and banknotes. The fruit is inedible and is rarely seen as harvesting occurs before the plant produces fruit.

ABTV symptoms in abaca plants are similar to those caused by BBTV in banana plants.

For some time it was thought ABTV was caused by *banana bunchy top virus* but abaca bunchy top virus was described for the first time in 2008 (Sharman et al, 2008).

Strains of the virus in Malaysia have been recorded from banana while banana plants in the Philippines have grown alongside infected abacá plants and remained free of the virus.

Awareness and research

Active research is being undertaken in the Philippines to understand more about the disease as well as other viruses of banana (Cruz et al, 2016).

GAPS:

- There is very little awareness of the disease in all banana growing states of Australia however awareness by growers of the related *Banana Bunchy Top Virus* is high in SEQ and northern NSW.
- There are large gaps in understanding the different strains of the virus, where it is present and potential resistance in abacá.
- There is no PHA factsheet for the virus.

Prevention of movement

Like BBTV, ABTV is spread by banana aphids (*Pentalonia nigronervosa*) and in infected planting material.

Into Australia

Prevention of movement into the country is covered under PEQ glasshouse. Similar potential for entry as for exotic strains of *BBTV*.

Within Australia

There are restrictions on the movement of planting material between states. Encouragement of growers to use QBAN tissue culture plants to start new plantations will decrease the possibility of moving infected planting material. ABTV is not currently listed in the *Biosecurity Act 2014* as being either prohibited or restricted matter.

GAPS:

- Grower awareness of this virus is not high however since Panama TR4 being detected in NQ, there is an increased awareness of the importance of using clean planting material.

Surveillance

There is no specific surveillance activities targeting this disease.

Diagnostics

There are specific PCR primers for ABTV. They have been tested against the small number of known isolates in existence (currently six).

Expertise: Dr John Thomas (QAAFI), Dr Murray Sharman (DAF) did the studies on ABTV in mid 2000s, Dr Kathy Crew (DAF).

GAPS:

No NDP for ABTV.

Contingency/Covered under EPPRD

An incursion into Australia would be covered under EPPRD but the disease has not been categorised.

GAPS:

There is no contingency plan but there is a well-established plan for containment and eradication of BBTV (Thomas, 2009) that could be used. There would be overlap in contingency plans between BBTV, ABTV and BBrMV, but they differ in:

- Mode of transmission (non-persistent vs persistent) and vector species (*Pentalonia* only vs a wide range of species)
- Host range differences – BBrMV has some known hosts (*Alpinia*, *Elletaria*) outside *Musa*. Alternative hosts for ABTV and BBTV are likely, but still a work in progress.

Management

Potentially similar as for BBTV. No resistant varieties.

GAPS:

- Very little is known for ABTV but in the absence of specific knowledge, the industry response would be similar to BBTV.

Resources

Sharman M, Thomas, J, Skabo S and Holton T (2008) Abaca´ bunchy top virus, a new member of the genus *Babuvirus* (family *Nanoviridae*). *Archives of Virology* 153: 135-147.

Cruz FCS, Belen GB and Alviar AN (2016) Serological and molecular detection of mixed bunchy top and mosaic virus infections in abaca (*Musa textilis* Nee) *Philippine Agricultural Scientist* 99(1): 88-98

Banana Bract Mosaic Disease

Caused by *Banana bract mosaic virus* (*Potyvirus*)

Banana Bract Mosaic Virus causes Banana Bract Mosaic Disease (also called Kokkan). It was first found in the Philippines in 1979. The disease can cause significant losses (up to 40%) and can infect banana and abacá. The most striking symptoms are purple mosaic symptoms on male flower bracts and can cause distortion of bunches and underdeveloped fingers.

The disease is exotic to Australia. It is present in the Philippines, India and Sri Lanka.

Although belonging to a different group of viruses to BBTV, BBrMV is also spread by the banana aphid (*Pentalonia nigronervosa*). Three other aphids widespread within Australia also vector the disease; corn aphid (*Rhopaloshiaphum maidis*), cotton or melon aphid (*Aphis gossypii*) and cowpea aphid (*Aphis craccivora*). Unlike for BBTV, BBrMV is non-persistently transmitted meaning that aphids are no longer infective after moulting and the aphid is only able to spread the virus for a short period of time.

Awareness and research

There is a PHA Factsheet for the disease.

GAPS:

- There is very little specific awareness of the disease in Australia however the impact of virus diseases in general is high in SEQ and northern NSW (because of BBTV) but significantly less in NQ, WA and NT.

Prevention of movement

Into Australia

Prevention of movement into the country is covered under PEQ glasshouse. Similar potential for entry as for exotic strains of BBTV.

Within Australia

There are restrictions on the movement of planting material between states and between biosecurity zones within some states.

GAPS:

Grower awareness of this virus is not high however since Panama TR4 being detected in NQ, there is an increased awareness of the importance of using clean planting material. Encouragement of growers to use QBAN tissue culture plants to start new plantations.

Surveillance

The NAQS and BQ surveys are conducted regularly around Cape York and urban NQ. Staff looks for any unusual symptoms and teams are aware of the range of exotic pests and diseases.

The staff employed in the HIA funded projects for BBTV and yellow Sigatoka inspections take note of unusual symptoms and seek help if need be.

There is a large range of pest scouting services used by growers and inspection of plantations by growers. Some growers inspect plants very closely and others do many operations by calendar and may miss seeing the development of issues in the field.

GAPS:

Growers need to be encouraged to closely monitor plants but also know what actions to take if they notice something unusual.

Diagnostics

Expertise:

- Dr John Thomas (QAAFI),
- Dr Kathy Crew (DAF),
- Dr Andrew Geering (QAAFI).

GAPS:

- There is a draft NDP which has not yet been ratified.

Contingency/Covered under EPPRD

Incursion into Australia would be covered under EPPRD and the disease has been categorised as Category 3.

GAPS:

There is no contingency plan but there is a well-established plan for containment and eradication of BBTv. There would be overlap in contingency plans between BBTv, ABTV and BBrMV, but they differ in:

- Mode of transmission (non-persistent vs persistent) and vector species (Pentalonia only vs a wide range of species)
- The (unknown) potential for seed transmission of BBrMV only – only relevant to wild seeded bananas).
- Host range differences – BBrMV has some known hosts (Alpinia, Elletaria) outside Musa. Alternative hosts for ABTV and BBTv are likely, but still a work in progress.

Management

Management practices would be similar as for BBTv. There virus is aphid vectored but the virus only survives in the aphids for a short period of time.

GAPS:

- No resistant varieties

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Banana-bract-mosaic-virus-FS.pdf>

<http://www.padil.gov.au/pests-and-diseases/pest/main/136660>

Panama disease/ Fusarium wilt

Caused by the fungus *Fusarium oxysporum* f.sp. *cubense*

The disease is characterised by a yellowing of the older leaves and an eventual collapse to form a 'skirt'. When cut open there are brown streaks through the water conducting vessels of the pseudostem. Yields are severely impacted and eventually affected plants die. The symptoms are similar to those caused by Moko.

The disease is soil-borne and can remain infective in the soil for up to 40 years. In addition to transmission via soil the disease can be spread in infected bits and suckers, on farming equipment and via fungal spores in flood and irrigation water. It can take some time between the infection of the roots of a plant and symptoms to develop, meaning that the disease can be spread without people realising it is present.

There are a number of races of *F. o.* f.sp. *cubense* each with a different host range.

Race 1 affects Lady Finger, Sugar and Ducasse, but not Cavendish.

Race 2 affects 'Bluggoe' and other cooking bananas

Race 3 is not a pathogen of banana and affect *Heliconia*

Race 4 has the widest host range and is the most destructive. It affects all varieties that Race 1 and 2 affect as well as 'Cavendish' and others which are resistant to Race 1 and 2.

Race 4 is divided into Subtropical Race 4 which affects Cavendish in subtropical conditions and when the plant is subject to stress and Tropical Race 4 which does not require predisposing factors for infection to occur.

Race 1 is present in nearly all banana growing countries in the world. Tropical Race 4 has been present in South East Asia for some years, where it has had a significant impact, but more recently has been found in Mozambique, Jordan, Lebanon and Pakistan (<http://panamadisease.org/en/map>).

Tropical Race 4 was first found in Australia near Darwin in 1997 where it significantly impacted on local banana production. In March 2015 the disease was found for the first time in Queensland on a commercial farm near Tully.

Awareness and research

Since the incursion of Tropical Race 4 awareness of Panama disease has increased significantly both in growers and the general community particularly in NQ.

A large amount of extension and communications materials have been developed since the detection in NQ. Workshops to help growers develop and implement on-farm biosecurity plans were delivered.

NSW Biosecurity has produced a Panama Tropical Race 4 alert and also undertook well promoted surveillance in April 2015 in northern NSW.

There is a PHA factsheet that requires updating.

Panama research has been ongoing for many years in Australia (the world's first record of Panama disease was Race 1 – found at Eagle Farm, Brisbane in 1876). Research efforts increased in the late 1990s early 2000s due to the incursion of Tropical Race 4 in the NT. Research was also part of the CRC for Tropical Plant Pathology and the follow-up CRC for Tropical Plant Protection. In recent years ongoing efforts have been made as part of the Banana Plant Protection Program (2011 – 2016). With the detection in NQ there has been an increase of funding from the Federal Government for research into the disease.

GAPS:

- Adherence to good biosecurity practices will need to be promoted as the initial activity surrounding the detection in Tully reduces.
- There is a gap in the epidemiology knowledge of the disease. Many studies were started prior to 1960 when Race 1 was affecting 'Gros Michel' production but were stopped when the Race 1 resistant 'Cavendish' was found. In order to prolong the life of any tolerant/resistant varieties found basic questions on epidemiology (study of the disease in plant populations) need to be addressed.

Prevention

Into Australia

Planting material being bought into the country must go through PEQ as part of the import conditions.

F. o. f. sp. cubense is not moved in banana fruit.

Within Australia

There are state and territory restrictions on movement of planting material, soil and farm implements, there are also restrictions on movement between biosecurity zones.

In NQ growers have been assisted with the development of on-farm biosecurity plans to prevent movement onto their farms. The workshops focused on making sure potentially infected material is not moved from one farm to another.

Prior to the Tropical Race 4 incursion in NQ, Banana Bunchy Top teams undertook measures to ensure they did not spread Race 1 or Subtropical Race 4 in SEQ and northern NSW. The Yellow Sigatoka Liaison Officer undertakes measures to lessen the potential spread of soil borne diseases as part of his routine inspection work.

Surveillance

BQ has an extensive surveillance program in place in the NQ production region that has targeted commercial plantings. BQ teams also respond to public enquiries about residential plants or feral bananas.

Panama disease is a high priority for NAQS surveillance.

The Yellow Sigatoka Officer and BBTV inspectors have been trained to look for TR4 symptoms.

NSW DPI undertook surveillance for banana freckle and Tropical Race 4 in April 2015.

GAPS:

- There will be a change to the BQ surveillance strategy which will mean they employ a more targeted, risk based approach to inspections. This may create gaps.

Diagnostics

There is a diagnostic method using 'Vegetative Compatibility Groups' (VCG) of growing various races of *F. oxysporum* f.sp. *cubense* with 'tester' isolates. This test takes a number of weeks but produces reliable results for all known races of Panama disease.

There is a reliable molecular diagnostic protocol available.

Expertise:

- Wayne O'Neill (DAF - VCG testing, culturing of the fungus, routine use of molecular diagnostics)
- Dr Juliane Henderson (QAAFI – development of molecular tests).
- Dr Julie Pattermore. (DAF)
- Lynton Vawdry (DAF).

GAPS:

- A SHPDS ratified diagnostic assay

Contingency/Covered under EPPRD

Tropical Race 4 was categorised as a Category 2 pest, but as the pathogen itself cannot be demonstrated to be practically eradicated it was not deemed to be covered under the EPPRD.

There was no contingency plan for the Tropical Race 4 at the time of detection. Planning for containment of the Tully incursion soon after the incursion was led by BQ with input from other parts of DAF, ABGC, QAAFI and banana growers.

GAPS:

- Contingency plan if there is an incursion of Tropical Race 4 in an area outside NQ or NT.

Management

Race 1

- Many 'Lady Finger' (and other Race 1 susceptible varieties) growers have had strict quarantine procedures in place on their properties to prevent the introduction of the disease.
- Management of Race 1 on infected properties has been left up to individual growers.
- Growers would try to prevent the movement of the fungus by undertaking operations to reduce spread of the disease to unaffected areas on the farm.
- In affected plantations in SEQ and northern NSW, plants are grown on steep slopes and operations are undertaken manually so there has slow spread of the disease. When the spread of Race 1 makes it uneconomical to farm, growers switch to 'Cavendish' or change crops all together.

Tropical Race 4

The current focus is containment of the disease and assisting growers in developing their on-farm biosecurity plans including prevention of movement of soil and planting material off their own farms.

GAPS:

- Agronomically suitable and consumer acceptable Tropical Race 4 varieties.
- There is potential to learn from 'Lady Finger' growers who have been living with Race 1 for many years, although it should be noted that Tropical Race 4 is thought to be more aggressive on susceptible cultivars.

Resources

PHA fact sheet: <http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Panama-disease-FS.pdf>

Biosecurity Queensland Tropical Race 4 Grower Kit: <https://publications.qld.gov.au/dataset/panama-disease-tropical-race-4-grower-kit>

ABGC Panama disease information: <http://abgc.org.au/panama-tr4/>

NSW Department of Primary Industries alert: http://www.dpi.nsw.gov.au/data/assets/pdf_file/0011/516764/Exotic-Pest-Alert-Panama-disease-Tropical-Race-4.pdf

Wilt disease of bananas

Symptoms of wilted banana plants with vascular tissues with discontinuous streaks of brown were first being noted in cooking bananas growing near dead or dying coconut trees in Papua New Guinea. The coconut trees were infected with a phytoplasma that is associated

with 'Bogia Coconut Syndrome' (Davis, 2009). A phytoplasma was later found in the bananas using a PCR assay and subsequent targeted surveys undertaken in PNG in 2009 and 2010 (Davis et al, 2012) consistently found a particular phytoplasma associated with wilted bananas. Further studies (Davis et al, 2015) have found a group of closely related phytoplasmas from bananas which have similarities with phytoplasmas from wilted coconut plants.

It should be noted that Koch's Postulates (whereby a potential causal organism is conclusively proven to be the cause of a disease) has not been undertaken for this disease yet but phytoplasmas are consistently associated with the symptoms.

Phytoplasmas are like a small bacteria except they have a single membrane instead of cell wall and are unable to survive outside of a suitable host, either a plant or an insect vector. Thus they are unable to be grown up in pure culture which makes demonstrating Koch's postulates more difficult. Due to not being able to survive outside a host, phytoplasmas can only be spread via vegetative planting material or insect vectors such as leafhoppers and not via tools such as cane knives.

Phytoplasmas affecting banana have been recorded in PNG and the Solomon Islands, they are not known to occur in Australia.

The impact of the disease has not been described. The disease is thought to be spread via infected planting material and by vectors. Suggested vectors are leafhoppers.

Awareness and research

It is unlikely many growers or consultants would be aware of the disease as it has only just been recently described, and is not recorded in Australia.

NAQS staff were among the first to identify the disease in surveys and link it with a potential phytoplasma.

GAPS:

It is not known nor an estimate made on what kind of impact this disease could have in Australia.

Very little research has been conducted thus far; Koch's postulates has not been undertaken, it is not known what vectors the disease nor an extensive survey been undertaken to establish geographic spread.

The phytoplasmas from coconut wilt affected plants and wilt affected plants are very similar and more work needs to be done to examine the link between the two and potential vectors.

Prevention

Into Australia

The disease is currently exotic to Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

GAPS:

- Knowledge on the presence of the disease in the Pacific and on vectors of the disease and their potential movement.

Surveillance

NAQS undertake regular surveillance in northern Australia and also in neighbouring countries when invited. BWAP is not specifically listed in the NAQS target list however coconut wilt is listed. NAQS staff do look for any unusual symptoms on bananas as part of their regular surveillance.

GAPS:

NAQS are well aware of this disease but there is a gap in grower and consultant knowledge about the disease and symptoms in Australian production areas.

Diagnostics

There is a 'general' assay for phytoplasmas which is undertaken on plants in PEQ glasshouse testing.

The development of a specific assay was commenced as part of the Banana Plant Protection Program and will be continued in the new HIA project (BA16005).

Expertise:

- Dr Richard Davis (NAQS – visual symptoms)
- Dr Juliane Henderson (molecular assay).
- Professor Geoff Gurr (insect vectors)

GAPS:

- A SHPDS ratified diagnostic assay
- Once potential vectors are identified, some experts would need training in identification of the vectors.

Contingency/Covered under EPPRD

The disease is not currently listed in the Banana Industry Biosecurity Plan (BIBP) as the disease was not known at the time of writing of the plan. The BIBP is currently being reviewed. Although the disease is not known to occur in Australia, surveillance is undertaken for unusual symptoms on bananas and it has not been found in Australia.

There is no contingency plan for the disease.

GAPS:

- The disease has not been categorised.
- The disease is not listed in BIBP
- There is no contingency plan and it will be difficult to develop one without more basic research on the disease being undertaken.

Management

As very little is known about this disease at present it is hard to devise management plans.

It is not known if there are varieties which are resistant to the disease or to the potential vectors.

GAPS:

- So little is known about the disease that a management strategy would need to be based on strategies used for similar diseases such as BBTV.

Resources

Davis, 2009 <http://www.musarama.org/en/image/phytoplasma-associated-wilt-symptoms-157.html>

Davis RI, Kokoa P, Jones LM, Mackie J, Constable FE, Rodoni BC, Gunua TG, Rossel JB (2012) A new wilt disease of banana plants associated with phytoplasma in Papua New Guinea (PNG). *Australasian Plant Disease Notes* 7: 91-97.

Davis RI, Henderson J, Jones LM, McTaggart AM, O'Dwyer C, Tsatsia F, Fanai C and Rossel JB (2014) First record of a wilt disease of banana plants associated with phytoplasmas in Solomon Islands. *Australasian Plant Disease Notes* 10: 14

Black Sigatoka

Caused by *Mycosphaerella fijiensis*

Black Sigatoka (also called black leaf streak, BLS) is one of the most devastating banana diseases in the world. It is present in the Pacific, Asia, Africa, Latin America and the Caribbean. The disease is present on Norfolk Island and in the Torres Strait. There have been incursions onto the Australian mainland multiple times, each time with the pathogen being eradicated with the most recent incursion being into NQ growing region in 2001.

The casual organism may also be called *Pseudocercospora fijiensis* or *Paracercospora fijiensis* but most of the literature refers to *Mycosphaerella fijiensis*. While the fungus is related to the one which causes yellow Sigatoka (*Mycosphaerella musicola*) which is already present in Australia, the lifecycle of the *M. fijiensis* is much shorter than *M. musicola* (meaning the fungus can cause greater damage in a shorter period) and *M. fijiensis* is able to infect a wider range of hosts.

The disease appears as small brown/ reds flecks on the undersides of leaves expanding to black lesions and finally grey necrotic sunken patches. In severe infections leaves die and yields are reduced and uneven ripening of bunches occurs. Yield losses of up to 50% can occur. Control is through regular de-leafing and an intensive fungicide program (over 36 sprays a year). The fungus develops fungicide resistance very quickly under these conditions.

Awareness and research

Awareness of black Sigatoka is high in the industry due to the successful effort to eradicate the disease from North Queensland after the 2001 incursion of the disease.

There are many images available of the disease however symptoms are not diagnostic.

There is a lot of international research is being done on the disease and Australian researchers have links into these programs.

Prevention

Into Australia and within Australia

The disease is currently exotic to mainland Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse.

The disease is present in the Torres Strait (providing a potential pathway to mainland Australia) and NAQS and BQ regularly survey the area. In previous years black Sigatoka resistant varieties were provided to the communities on Cape York Peninsula and surrounds to prevent the planting of susceptible varieties which could provide a pathway for the disease from the Torres Strait.

Fruit is a potential pathway. The Philippines have requested to export fresh fruit to Australia. Conditions imposed by the Australian Government mean that fruit must be from an area of low pest prevalence. As yet no Filipino (or other nations) company has attempted to demonstrate they would meet the import conditions of Australia.

There is a potential for spores to blow into northern mainland Australia from PNG or the Torres Strait, hence the need for ongoing surveillance.

GAPS:

- Evidence based quarantine measures to prevent the potential movement of the disease into Australia must be continued.

Surveillance

The disease is present in the Torres Strait and NAQS and BQ regularly survey the area. BQ also conduct regular urban surveillance in NQ for banana diseases including black Sigatoka.

In 2014 BQ did a review of their surveillance program.

Samples are provided by the Yellow Sigatoka Liaison Officer to the DAF plant pathologists at Mareeba who test isolates collected from leaf spots in the production areas.

GAPS:

- There will need to be continued support for surveillance in NQ and the NT.

Diagnostics

Expertise:

- Kathy Grice (DAF),
- Dr Juliane Henderson (QAAFI) and
- Lynton Vawdry (DAF).

Both Kathy Grice and Juliane Henderson have seen the disease in the field overseas and worked with the molecular diagnostic. Dr Richard Davis has field experience with the disease.

There is a draft NDP.

GAPS:

- A SHPDS ratified diagnostic assay

Contingency/Covered under EPPRD

There is an eradication plan from the successful 2001 incursion which could be used as a basis for any further incursions. In addition there are many similarities between *M. fijiensis* and *Phyllosticta cavendishii* which is currently subject to an eradication program in the NT.

As black Sigatoka is under active containment in Australia (Norfolk Island and Torres Strait) it is covered under the EPPRD if an incursion was to occur on the mainland,

It is a Category 2 pest.

GAPS:

- No obvious gaps.

Management

There are management strategies for yellow Sigatoka and these could be used for black Sigatoka but with much shorter intervals for spraying and more severe de-leafing programs

GAPS:

- Breeding of commercially acceptable resistant cultivars. If the disease was to establish in Australia there may not currently be consumer acceptance of resistant/tolerant cultivars.
- Access to effective fungicides which *M. fijiensis* does not have the potential to develop resistance.

Resources

<http://pbt.padil.gov.au/index.php?q=node/6&pbtID=166>

<http://www.apsnet.org/publications/apsnetfeatures/Pages/blacksigatoka.aspx>

<http://www.apsnet.org/edcenter/intropp/lessons/fungi/ascomycetes/Pages/BlackSigatoka.aspx>

<http://www.agriculture.gov.au/biosecurity/australia/naqs/naqs-target-lists/black-sigatoka>

Eumusae leaf spot

Caused by *Mycosphaerella eumusae*

Eumusae leaf spot was first described in 2000 and hence there is still relatively little information on it.

The fungus is able to infect leaves and fruit (Thangavelu et al. 2007).

The fungus is closely related to the fungi which cause black and yellow Sigatoka and is thought to behave in a similar manner. *M. eumusae* is able to cause disease on the dessert bananas that are resistant to black and yellow Sigatoka.

The fungus is present in southern India, Sri Lanka, Thailand, Malaysia, Vietnam, Mauritius, and Nigeria. It is expected to be found in other areas when surveys are completed in locations where previous surveys could not attribute similar leaf symptoms to *M. fijiensis* or *M. musicola*. The fungus is exotic to Australia.

Awareness and research

There is very little grower awareness of this disease.

There is a PHA fact sheet for the disease as well as a PaDIL page (see resources below).

Prevention

Into Australia

The disease is currently exotic to Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a potential pathway but fresh fruit imports from affected countries into Australia are not occurring.

There is a potential for spores to blow into northern mainland Australia from PNG or Indonesia if the disease were to establish in these countries. The need for ongoing surveillance by NAQS is critical.

GAPS:

- Evidence based quarantine measures to prevent the potential movement of the disease will be critical.

Surveillance

NAQS and BQ regularly survey northern Australia.

As part of the Banana Plant Protection Program, DAF tested isolates collected from leaf spots in the production areas. The Yellow Sigatoka Liaison Officer is able to supply samples.

GAPS:

- Continued support for surveillance in NQ and the NT will be critical.

Diagnostics

Expertise:

- Kathy Grice (DAF),
- Dr Juliane Henderson (QAAFI).

There is a draft NDP.

GAPS:

- A SHPDS ratified diagnostic assay

Contingency/Covered under EPPRD

The disease would be covered under the EPPRD however it has not been categorised.

There is no specific contingency or eradication plan, however much could be used from the black Sigatoka and Banana Freckle plans.

GAPS:

- Very little is known about this disease so all planning would be done based on assumptions from knowledge for black and yellow Sigatoka.

Management

GAPS:

- Very little is known about this disease (e.g. potential sources of resistance, how fast the fungus may develop resistance to fungicides). Potential management practices would be based on knowledge for black and yellow Sigatoka.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/03/Eumusae-leaf-spot-FS.pdf>

Thangavelu R, Carlier J, Henderson J & McTaggart AR (2007) Eumusae leaf spot (*Mycosphaerella eumusae*) Updated on 10/16/2007 Available online: PaDIL - <http://www.padil.gov.au/pests-and-diseases/pest/main/136640/7749>

Carlier J, Zapater M-F, Lapeyre F, Jones DR & Mourichon X. (2000) Septoria leaf spot of banana: A newly discovered disease caused by *Mycosphaerella eumusae* (anamorph *Septoria eumusae*). *Phytopathology* **90**: 884-890.

Crous PW & Mourichon X (2002) *Mycosphaerella eumusae* and its anamorph *Pseudocercopsora eumusae* spp. nov.: casual agent of eumusae leaf spot disease of banana. *Sydowia* **54**:35-43.

Banana Freckle

Caused by *Phyllosticta cavendishii*

Infections by *Phyllosticta cavendishii* cause raised 'freckles' on the leaves and fruit of banana plants. The disease can reduce the photosynthetic area of the leaves reducing yields and caused mixed ripening. Unsightly blemishes cause downgrading of fruit.

There are different strains of the fungus and they have been divided into 'Cavendish-infecting (Cavendish competent) and non-Cavendish infecting. Until 2013 banana freckle was present in Australia but only on non-Cavendish plants. Part of the difficulties with the fungus is being able to distinguish the two (or potentially more) different strains. This led to the removal of all banana plants (Cavendish and others) in the NT eradication zones of the 2013 eradication program.

Awareness and research

High level of awareness amongst growers and community, especially in NT due to the incursion into the NT in July 2013.

There is a PHA fact sheet for the disease as well as a PaDIL page (see resources below).

Dr Mee-Hua Wong completed her PhD on the disease and published a number of papers (see below).

Prevention

Into Australia

The 2013 incursion into the NT is currently being eradicated.

Prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a potential pathway but fresh fruit imports into Australia are not occurring.

Within Australia

Restrictions on the movement of planting material between states and between biosecurity zones within some states

GAPS:

- Continued support for evidence based quarantine measures to prevent the potential movement of the disease will be critical.
- It is not known how the inoculum that caused the 2013 incursion arrived into Australia. Understanding this would help to prevent future incursions.

Surveillance

NAQS and BQ regularly survey northern Australia.

GAPS:

- The 2013 incursion was not picked up as part of a survey but rather from an NT DPI staff member seeing the disease on a farm near Darwin.

Diagnostics

Expertise:

- Dr Lucy Ran-Nguyen (NT DPI),
- Dr Jose Liberato (NT DPI),
- Kathy Grice (DAF),
- Dr Juliane Henderson (QAAFI).

There is no NDP but there are molecular tests which have been used extensively throughout the NT incursion/eradication campaign.

GAPS:

- A SHPDS ratified diagnostic assay

Contingency/Covered under EPPRD

The disease is covered under the EPPRD and is a category 3 pest. The current eradication program is being undertaken under the Deed.

Prior to the incursion there was no contingency plan for the disease. There is now a plan that is specific to the NT which could be modified for other locations.

One of the advantages of eradicating the disease from the NT, is the distance between hosts. This is a very different situation to NQ. If there was an incursion in NQ, a response plan would need to be more like the 2001 black Sigatoka plan.

GAPS:

- Contingency plan more suitable to NQ production area.

Management

Management techniques similar to those used for black Sigatoka would be required as well as additional measures to protect the fruit from blemishes.

GAPS:

- Varieties resistant to banana freckle along with other leaf spot diseases.

Resources

<https://nt.gov.au/industry/agriculture/food-crops-plants-and-quarantine/banana-freckle-eradication-program>

<http://abgc.org.au/biosecurity/banana-freckle-response/>

<http://www.planthealthaustralia.com.au/wp-content/uploads/2015/03/Banana-freckle-FS.pdf>

<http://www.padil.gov.au/pests-and-diseases/pest/main/136600>

Wong, MH, Henderson, J and Drenth, A (2013) Identification and differentiation of *Phyllosticta* species causing freckle disease of banana using high resolution melting (HRM) analysis. *Plant Pathology* **62**: 1285 - 1293

Wong, MH, Crous, PW, Henderson, J, Groenewald, JZ and Drenth, A (2012) *Phyllosticta* species associated with freckle disease of banana. *Fungal Diversity* **56**: 173-187.

Yellow Sigatoka

Caused by *Mycosphaerella musicola*

Yellow Sigatoka is endemic in all banana growing areas of Australia except for the growing area around Carnarvon in WA. When left unchecked the disease affects the photosynthetic ability of leaves and yields are decreased and mixed ripening can occur. Disease pressure is much higher in tropical NQ than in SEQ and NSW.

Until 2015 yellow Sigatoka control was mandatory for growers in Queensland who were not allowed to have any more than 5% leaf spot on one leaf (Plant Protection Regulation 2002). This limit was set to help control the build up of inoculum in plantations because it can spread very easily to neighbouring farms. The regulations changed in 2016 and this leaf spot provision is no longer contained in the regulations. Instead, there is the Banana Industry Biosecurity Guideline that describes to growers how they are to manage this disease to meet their General Biosecurity Obligation (GBO). To help growers meet their obligations ABGC has employed a HIA-funded 'Yellow Sigatoka Liaison Officer' since 2010. This officer visits every commercial banana farm in North Queensland twice a year.

Yellow Sigatoka is controlled with regular de-leafing to remove inoculum sources and a range of fungicide sprays rotated to avoid the development of resistance to the sprays by *M. musicola*. There are varieties which are resistant to yellow Sigatoka but they do not have consumer acceptance nor the agronomic characters currently desired.

Awareness and research

Growers in NQ are very aware of the disease due to the work of the Yellow Sigatoka Liaison Officer.

The Banana Industry Biosecurity Guideline also describes to growers what they need to do to manage leaf spot.

Current research in Australia has mostly been on efficacy of different fungicides as well as screening new varieties for yellow Sigatoka resistance.

Prevention

Within Australia

The Carnarvon growing region is the only area without yellow Sigatoka. Movement controls into Carnarvon targeting other pathogens also prevent the movement of yellow Sigatoka.

GAPS:

- If any new areas are developed for banana growing then there is the opportunity to put in place protocols to prevent the introduction of yellow Sigatoka to the area.

Surveillance

As part of the Banana Plant Protection Program, DAF tests isolates collected from leaf spots in the production areas by the Yellow Sigatoka Liaison Officer.

The yellow Sigatoka isolates are also checked to examine if the isolates are developing resistance to the systemic fungicides.

Diagnostics

- Expertise: Kathy Grice (DAF),
- Dr Juliane Henderson (QAAFI).
- Louis Lardi (ABGC) – visual inspection.

Diagnostics are usually not required unless regulatory action is being taken by BQ.

There are protocols for *M. musicola* that distinguish it from *M. fijiensis*.

Contingency/Covered under EPPRD

Not applicable.

Management

Regular de-leafing and fungicide applications applied as part of an anti-resistance strategy.

GAPS:

The General Biosecurity Obligation contained in the new Biosecurity Act and Regulation are yet to be tested. This may impact on ongoing management of the disease.

The continued role of the Yellow Sigatoka Liaison Office is critical to the management of the disease.

Resources

National Banana Extension and Development Program Factsheet: “Top ways to manage banana fungicide resistance fact sheet”.

Banana Industry Biosecurity Guideline (Department of Agriculture and Fisheries, 2016).

Moko

Caused by *Ralstonia solanacearum* biovar 1 and race2

Moko affects a range of banana varieties and plantains. Similar to Panama disease, on infected plants the oldest leaves turn yellow and die first, the rest of the leaves are then affected and eventually the pseudostem collapses. Fruit can also be affected with the flesh of infected fruit turning brown and then grey.

The bacteria causing Moko can be spread in infected soil, via water, cane knives and farm machinery. Moko can also be spread by root to root contact. Insects play a large role in moving the disease; Trigona bees, wasp and other flying insects vector the disease and can move long distances (reports of over 90km for some strains of Moko).

The disease is present in Central and South America, the Caribbean and the Philippines.

Moko, Bugtok and blood disease are often grouped together. It is accepted that blood disease is caused by a distinct bacterium, the causal organisms of all three diseases grouped into the '*Ralstonia solanacearum* complex'.

GAPS:

Further taxonomic work has clarified the naming of the pathogens but further work is still required, especially as the two bacteria which cause Moko and Bugtok are distinct from one another but are hard to distinguish using current lab tests. Correct identification could delay an EPPRD response should there ever be an incursion.

Awareness and research

There is some awareness of this disease by growers because of its relevance to the Import Risk Analysis that was conducted for the importation of fresh bananas from the Philippines. However, while growers are aware of the disease it is unlikely they would be able to describe the symptoms nor know what to look for in their plantations.

There is a PHA fact sheet for the disease as well as a PaDIL page (see resources below).

Prevention

Into Australia

The disease is currently exotic to Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a pathway but fresh fruit imports in Australia are not occurring.

GAPS:

- There will need to be continued support for evidence based quarantine measures to prevent the potential movement of the disease e.g. on-going for import of fruit conditions.

Surveillance

NAQS and BQ regularly survey northern Australia.

GAPS:

- There will need to be continued support for surveillance in NQ and the NT into the future.

Diagnostics

A major emphasis will be placed on researching Moko, Bugtok and Blood Disease for the development of accurate diagnostics in the HIA funded project BA16005. There is an assay for Moko.

Expertise:

- Dr Nandita Pathania (DAF),
- Dr Anthony Young (formerly DAF, now USQ),
- Dr Mark Fagan (formerly CRC for Tropical Plant Protection),

There is a draft NDP. It is unclear if the draft clearly distinguishes between Moko, Bugtok and Blood Disease.

The current standard protocol is more than 10 years old so confirmation is required as to whether it still works against the existing isolates.

As there is potential for a hold up in diagnostics due to the diversity of *Ralstonia* species, a finalised NDP (incorporating the latest taxonomic information is a priority.

GAPS:

- A SHPDS ratified diagnostic assay.

Contingency/Covered under EPPRD

The disease is covered under the EPPRD and is a Category 2 pest.

GAPS:

- There is no contingency plan for moko disease or any of the other bacterial diseases. If detected in Australia, a swift response would be required as insects could spread the disease quickly and over a great distance.

Management

There are no resistant varieties and *Heliconia* is also a host.

Filipino companies have a system of destroying infected plants that involves burning the plant and the site of the infection with rice hulls to heat treat the soil below. Provided that infected plant material, sap and soil from below the infected plant is not spread around or disturbed, the bacteria will break down in the soil relatively quickly (6-12 months).

As the bacterium can spread in sap, farming tools (cane knives, hook knives etc.) need to be regularly and thoroughly disinfected.

A complication to the Australian production system compared to overseas is our high reliance on mechanised operations, If the bacterium did get into a plantation in NQ (where there is a high use of machinery) the bacterium could spread very quickly via wet soils, cane knives and other farming tools.

GAPS:

- Management systems for highly mechanised Australian production systems.
- Management systems for dealing with vectors.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Moko-FS.pdf>

<http://www.padil.gov.au/pests-and-diseases/pest/main/136650>

Fegan, M and Prior P (2006) Diverse members of the *Ralstonia solanacearum* species complex cause bacterial wilts of banana. Australasian Plant Pathology **35**: 93-101

Bugtok

Caused by *Ralstonia solanacearum* biovar 1 and race2

The disease occurs in the Philippines, it affects ABB cooking bananas but does not have an impact on export 'Cavendish'. Unlike Moko and blood disease, Bugtok infections affect fruit and bracts but symptoms are rarely seen in the pseudostem. Infection is thought to be via thrips transmitting the disease to the flowers. The pulp of affected fruit turn grey to yellow and only a few fingers or all of the fingers in a bunch may be affected. Bracts may turn black and have bacteria oozing from them. The disease is not thought to be transmitted in planting material.

One of the difficulties with the bacteria which causes Bugtok is that it is extremely difficult to distinguish it from the bacteria which causes Moko.

Awareness and research

There is probably less awareness of this disease than Moko (although there may be some knowledge because of its relevance to the import risk analysis for importing fresh bananas from the Philippines). It is unlikely that growers would know what the symptoms are.

There is a PHA fact sheet as well as a PaDIL page for Moko and Bugtok.

Prevention

Into Australia

The Bugtok bacterium is thought to not be carried in planting material but any planting material being brought into the country is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a pathway but fresh fruit imports into Australia are not occurring.

GAPS:

- There will need to be continued support for evidence based quarantine measures to prevent the potential movement of the disease.

Surveillance

NAQS and BQ regularly survey northern Australia.

GAPS:

- There will need to be continued support for surveillance in NQ and the NT.

Diagnostics

A major emphasis will be placed on researching Moko, Bugtok and Blood Disease for the development of accurate diagnostics in the HIA funded project BA16005. There is an assay for Moko.

Expertise:

- Dr Nandita Pathania (DAF),
- Dr Anthony Young (formerly DAF, now USQ),
- Dr Mark Fagan (formerly CRC for Tropical Plant Protection).

There is a draft NDP for *Ralstonia solanacearum* race2 but it is unclear if the draft clearly distinguishes between Moko, Bugtok and Blood Disease.

The current standard protocol is more than 10 years old so confirmation is required as to whether it still works against the existing isolates.

There is potential for a hold up in diagnostics due to the diversity of *Ralstonia* species. Therefore a finalised NDP (incorporating the latest taxonomic information Safni et al 2014) is a priority.

GAPS:

- A SHPDS ratified diagnostic assay

Contingency/Covered under EPPRD

Moko and Bugtok are covered under the EPPRD and is a Category 2 pest.

GAPS:

- There is no contingency plan for Bugtok disease or any of the other bacterial diseases. This is a priority.

Management

GAPS:

- Management systems for highly mechanised Australian production systems.
- Management systems for dealing with vectors.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Moko-FS.pdf>

<http://www.padil.gov.au/pests-and-diseases/pest/main/136650>

Safni I, Cleenwerck I, De Vos P, Fegan M, Sly L, Kappler U. (2014) Polyphasic taxonomic revision of the *Ralstonia solanacearum* species complex: proposal to emend the descriptions of *Ralstonia solanacearum* and *Ralstonia syzygii* and reclassify current *R. syzygii* strains as *Ralstonia syzygii* subsp. *syzygii* subsp. nov., *R. solanacearum* phylotype IV strains as *Ralstonia syzygii* subsp. *indonesiensis* subsp. nov., banana blood disease bacterium strains as *Ralstonia syzygii* subsp. *celebesensis* subsp. nov. and *R. solanacearum* phylotype I and III strains as *Ralstonia pseudosolanacearum* sp. nov. *International Journal of Systematic and Evolutionary Microbiology*. **64**:3087–103.

Fegan, M and Prior P (2006) Diverse members of the *Ralstonia solanacearum* species complex cause bacterial wilts of banana. *Australasian Plant Pathology* **35**: 93-101

Blood disease

Caused by: *Ralstonia syzygii* subsp. *celebesensis*

Symptoms are similar to Panama disease and Moko. Leaves turn yellow, wilt and form a 'skirt'. When cut open affected plant will have reddish-brown discoloration of the vascular tissue. Freshly cut stem surfaces may exude bacteria white to red-brown in colour. Fruit may turn black. Transmission of the disease is thought to be in a similar manner to that of Moko i.e. via insects transmitting the disease to flowers, via infected fruit, soil and on farming implements. Spread has been rapid in Java (to a distance of over 25km per annum in some areas) which supports the insect dispersal hypothesis (Eden-Green, 1994).

The disease is present in Indonesia including West Papua, but until recently it had not been found elsewhere in the world until a recent incursion in Malaysia (limited distribution).

Awareness and research

There is likely to be some awareness of this disease by growers because of its relevance to the import risk analysis for fresh bananas from the Philippines.

There is a PHA fact sheet for the disease as well as a PaDIL page.

The taxonomy of this disease has only just recently updated (Safni et al 2014) and is yet to be widely adopted. More research needs to be done to better understand the bacterium as many assumptions about blood disease are based on Moko.

Prevention

Into Australia

The disease is currently exotic to Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a potential pathway but fresh fruit imports into Australia are not occurring.

GAPS:

- There will need to be continued support for evidence based quarantine measures to prevent the potential movement of the disease.

Surveillance

NAQS and BQ regularly survey northern Australia.

GAPS:

There will need to be continued support for surveillance in NQ and the NT.

Diagnostics

A major emphasis will be placed on researching Moko, Bugtok and Blood Disease for the development of accurate diagnostics in the HIA funded project BA16005. There is an assay for Moko.

Expertise:

- Dr Nandita Pathania (DAF),
- Dr Anthony Young (formerly DAF, now USQ),
- Dr Mark Fagan (formerly CRC for Tropical Plant Protection),

There is a draft NDP. This may need to be reviewed based on the latest taxonomic information (Safni et al, 2014). It is unclear if the draft clearly distinguishes between Moko, Bugtok and Blood Disease.

GAPS:

- Lacking a SHPDS ratified diagnostic assay.
- Lacking widespread recognition of the current taxonomic assignment.

Contingency/Covered under EPPRD

The disease is covered under the EPPRD and is a Category 2 pest.

GAPS:

- There is no contingency plan for blood disease or any of the other bacterial diseases.

Management

Management is expected to be similar as for Moko disease.

A lack of understanding about transmission of the disease and confirmation of which vectors are involved could hamper control measures targeting transmission.

GAPS:

- Management systems for highly mechanised Australian production systems.

Resources

<http://www.padil.gov.au/pests-and-diseases/pest/main/136649>

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Blood-disease-FS.pdf>

Eden-Green, SJ (1994) Banana Blood Disease. Musa Disease Fact Sheet No.3:

http://www.bioversityinternational.org/uploads/tx_news/Banana_blood_disease_127.pdf

Safni I, Cleenwerck I, De Vos P, Fegan M, Sly L, Kappler U. (2014) Polyphasic taxonomic revision of the *Ralstonia solanacearum* species complex: proposal to emend the descriptions of *Ralstonia solanacearum* and *Ralstonia syzygii* and reclassify current *R. syzygii* strains as *Ralstonia syzygii* subsp. *syzygii* subsp. nov., *R. solanacearum* phylotype IV strains as *Ralstonia syzygii* subsp. *indonesiensis* subsp. nov., banana blood disease bacterium strains as *Ralstonia syzygii* subsp. *celebesensis* subsp. nov. and *R. solanacearum* phylotype

I and III strains as *Ralstonia pseudosolanacearum* sp. nov. International Journal of Systematic and Evolutionary Microbiology. **64**:3087–103.

Xanthomonas bacterial wilt

Caused by *Xanthomonas vasicola* pathovar *musacearum*

Xanthomonas bacterial wilt (XBW) has been present on Ensete plants in Ethiopia since 1968 but in the last 15 years it has spread and is now present in Ethiopia, Kenya, Uganda, Democratic Republic of Congo, Burundi, Rwanda and Tanzania on dessert and cooking bananas.

The symptoms of the disease are very similar to Panama and Moko and whole plants can be killed within a month of first symptoms appearing. One characteristic symptom is the oozing of yellow bacterial exudate out of cut pseudostems of badly affected plants.

Awareness and research

Very little awareness of this disease in Australia.

Research is being undertaken in Africa where management plans have been developed.

GAPS:

- Awareness of the disease is low in Australia.

Prevention

Into Australia

The disease is currently exotic to Australia and prevention of movement into the country with planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

Fruit is a potential pathway but fresh fruit imports into Australia are not occurring.

GAPS:

- There will need to be continued support for evidence based quarantine measures to prevent the potential movement of the disease e.g. on-going for import of fruit conditions.

Surveillance

None specifically conducted for XBW.

GAPS:

- There will need to be continued support for surveillance in NQ and the NT.

Diagnostics

Expertise:

- Dr Juliane Henderson (QAAFI),
- Dr Nandita Pathania (DAF)

There is no diagnostic test available.

GAPS:

- No assay exists.

Contingency/Covered under EPPRD

Not yet categorised but would come under the Deed.

GAPS:

- There is no contingency plan.

Management

Management systems have been developed in Africa and are reportedly working well when supported with extension programs. These management systems may not work in a highly mechanised production system like in Australia.

The bacterium is spread via planting material, insect vectors, in soil and water, on farming implements and via animal vectors such as rats, birds, bats and livestock.

GAPS:

- Management systems for highly mechanised Australian production systems.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Banana-Xanthomonas-wilt-FS.pdf>

EFSA assessment of risk of introduction <http://www.efsa.europa.eu/en/efsajournal/pub/669>

<http://www.promusa.org/Xanthomonas+campestris+pv.+musacearum#footnote7>

<http://www.promusa.org/Xanthomonas+wilt>

Exotic nematodes

Under the current import conditions, there is an extremely low chance of nematodes entering Australia on banana plants provided they are imported through the correct channels. However, there is a chance that they could enter Australia on other products such as the burrowing nematode *Radopholus similis* on fresh ginger from Fiji.

In January 2013 conditions to import fresh ginger from Fiji to Australia were published. This included treatment of consignments with methyl bromide. In mid-2014 live root knot nematodes were found in a consignment of ginger in Sydney indicating that the methyl bromide did not kill the root knot nematodes (which are closer to the surface of the ginger rhizome than the burrowing nematodes).

There was a Australian Government review of the conditions which came to the conclusion that no live quarantine pests were found (root knot nematode was not considered a quarantine pest) and that experiments were needed to understand the relatedness and host preference of burrowing nematodes from Fiji. This information would then be compared to Australian isolates.

Awareness and research

There is likely to be very little grower awareness of the exotic nematodes. Very little research has been done.

Research has commenced to look at the different populations of *Radopholus similis* in Australia and Fiji. This work will compare if they are genetically different and if there are differences in pathogenicity. The results should be available in 2017.

GAPS:

- There is a gap in the level of knowledge about the pathogenic differences between Australian and Fijian isolates of burrowing nematode.

Prevention

Into Australia

Movement into the country with banana planting material is covered under import conditions requiring holding of plants in PEQ glasshouse with testing.

GAPS:

- Potential to come into Australia on fresh ginger imports from Fiji if methyl bromide treatments do not work.

Surveillance

GAPS:

- No formal surveillance.

Diagnostics

Expertise: Jenny Cobon (DAF)

GAPS:

- An understanding of the diversity of lesion nematodes in Australia and Fiji.

Contingency/Covered under EPPRD

GAPS:

- Not enough information to know if it is required.

Management

GAPS:

- There is not enough information to know if different management practices would be required in addition to the current practices for endemic burrowing nematode.

Resources

<http://www.agriculture.gov.au/biosecurity/risk-analysis/plant/import-conditions-fresh-ginger-from-fiji>

Banana Skipper Butterfly

Erionata thrax

Banana skipper butterfly is native to South East Asia. It is now present in South East Asia, Papua New Guinea, Mauritius, Guam and Hawaii.

The symptoms of infestation are large cut sections on banana leaves rolled into tight cocoon shapes. Damage to bananas is from reduced photosynthetic area due to feeding and rolling. Banana skipper butterfly affects all cultivated bananas.

Awareness and research

There is probably not a high level of awareness of this pest despite characteristic symptoms of infestation. There is a PHA fact sheet.

Previous research was done by CSIRO into control of the pest using biological control agents. There would be benefit in revisiting this research to look for any knowledge gaps or material/information that could be shared with growers.

Prevention

Into Australia

Eggs could be potentially moved on planting material but movement into the country with banana planting material is covered under import conditions requiring holding of plants in PEQ glasshouse.

There is a risk associated with the illegal movement of planting material between PNG, Torres Strait Islands to mainland Australia (eg via Cape York).

Within Australia

The butterfly can move short distances by flying. Longer distance dispersal is via eggs on planting material.

Surveillance

NAQ target banana skipper butterfly in their surveillance.

GAPS:

Pest scouts could potentially undertake surveillance but it is likely that growers do not have a lot of knowledge about this pest.

Diagnostics

Expertise:

- Donna Chambers (DAF),
- Bruno Pinese (DAF – may no longer work in the field).

GAPS:

- A diagnostic protocol. There is a closely related butterfly which may cause confusion if there is an incursion.

Contingency/Covered under EPPRD

Banana skipper butterfly is covered under the Deed and is a category 4 pest.

GAPS:

- There is no contingency plan.
- While there is confidence that the parasites that CSIRO released into PNG keep these pests in check, it is not known what the impacts of the insecticides used to control other banana insect pests would have on the banana skipper butterfly.

Management

GAPS:

Knowledge on the effect of the Australian insecticide program on parasites of the banana skipper butterfly.

Resources

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Banana-skipper-butterfly-FS.pdf>

<http://www.ento.csiro.au/biocontrol/skipper.html>

<http://www.cabi.org/isc/datasheet/21833>

Banana spider mite

Tetranychus piercei

T. piercei causes damage on a range of crops resulting in a high economic impact. The mite has been recorded in Asia, Indonesia, Malaysia and Papua New Guinea. Mites feed on the leaves thereby reducing the photosynthetic area. This leads to reduced yields and potentially mixed ripening. Spider mites also produce a fine web.

Tetranychus gloveri (cotton red mite) was present in the NT and in 2014 the mite was found in banana plantations in NQ. By the time it was detected it had established and was deemed too difficult to eradicate by CCEPP due to the wide range of weed host plants.

Awareness and research

There would be low awareness of banana spider mite amongst growers and early infestations could look like other mite damage.

Prevention

Into Australia

T. piercei is exotic to Australia.

Mites can only travel short distances unaided. Any long distance dispersal will be via planting material.

Banana planting material introduced to Australia must go through PEQ.

Within Australia

Banana spider mites could be moved on planting material. Movement controls for pathogens should limit the spread of banana spider mites if an incursion into Australia occurred.

Surveillance

GAPS: Difficulty for growers to distinguish banana spider mite from other mites.

Diagnostics

Expertise: Owen Seeman (Queensland Museum).

There is a draft NDP.

GAPS: A ratified diagnostic protocol.

Contingency/Covered under EPPRD

T. piercei is covered under the Deed and is a category 4 pest.

GAPS: There is no contingency plan.

Management

Banana spider mites feed on a wide range of host plants meaning if they were to establish in Australia, control measures would need to also target alternate hosts.

For the mite populations currently in Australia, issues arise on bananas growing in dry, dusty conditions or where a chemical application has knocked out predators which normally keep mite populations in check. It is not known if there are predators present in Australia which would suppress *T. piercei* if it were to establish here

GAPS:

- Effects of natural predators
- Alternative control measures.

Resources

<http://pbt.padil.gov.au/index.php?q=node/6&pbtID=116>

<http://www.planthealthaustralia.com.au/wp-content/uploads/2013/01/Banana-spider-mite-FS.pdf>

Coffee bean weevil

Araecerus fasciculatus

The coffee bean weevil is a pest of stored products. It is present on the east coast of Australia but absent from WA. It does not damage bananas but rather survives in the dried flower parts that remain attached to the fruit.

The main problem for growers is the rejection of consignments into WA when coffee bean weevil is found.

Awareness and research

Awareness of the pest is high amongst NQ banana growers who export to WA.

Prevention

Into Australia

Consignments of dried goods coming into Australia are subject to inspections for pests.

Within Australia

Consignments of fruit are inspected on arrival into WA fruit are removed from 6 cartons and placed on a white inspection tray where flower ends are flicked off fruit and insects collected and examined. If a grower gets a detection the fruit must be treated at the growers cost (fumigation may cause damage to fruit particularly if there is condensation on the fruit), re-exported at the growers cost or disposed of by deep burial at the cost to the grower. The next consignment that the grower sends will then be subject to a higher rate of inspection.

Surveillance

Nil formal.

Diagnostics

Expertise: Dr Rolf Oberprieler (CSIRO) has provided literature in the past and may be able to assist with identification.

GAPS:

- A diagnostic protocol.

Contingency/Covered under EPPRD

If there was an incursion into WA eradication could potentially be covered under EPPRD. Further clarification on this point is required.

GAPS:

- Contingency plan for incursion into WA.

Management

It is thought that coffee bean weevils invade the flower parts when the fruit is in the field. The current control measure is to use water or manually remove flower parts off the bunches of fruit just before they enter the packing shed. This adds a considerable cost to packing. Some growers are more thorough than others at removing the flower parts.

GAPS:

- In field control measures for coffee bean weevil.

Resources

<http://www.padil.gov.au/pests-and-diseases/pest/main/135950/7030>

Conclusion

This desk top analysis highlights that the banana industry has a strong foundation in biosecurity preparedness. Research, to varying extents, has been done on most of the High Priority Pests. However, there are gaps that need to be filled and this can be done over time according to priority. Given the economic importance of the banana industry and the public's love for Australian bananas, it is important that the industry continues to build on its existing knowledge, reduce the research gaps and prepare the industry against future potential incursions. It is also vitally important that the scientific capacity that currently supports the industry is maintained.

The detection of Panama tropical race 4 in north Queensland has shown growers across Australia that they must not be complacent when it comes to on-farm biosecurity. It is hoped that this developing biosecurity culture amongst growers continues. It can then be supplemented and strengthened with new knowledge as it emerges.

The list of recommendations, informed by the analysis in this report will guide future research projects as the industry implements a more strategic and proactive approach to filling the gaps in its biosecurity knowledge and practices.

General surveillance and prevention of movement of pests and diseases

Domestic Quarantine

Domestic Quarantine (DQ) have a website with information for travellers (<http://www.quarantinedomestic.gov.au/>) divided by State/Territory. Information on movement of bananas is listed. It is suspected that very few travellers check the website prior to moving. DQ also produce brochures to provide to travellers and also work with organisations (like the Defence Force) to provide information on interstate quarantine issues when staff are relocated.

Northern Australia Quarantine Strategy (NAQS)

NAQS undertake activities to minimise the risk of pest and disease incursions into the north of Australia, they are a group within the Department of Agriculture and Water Resources. They assess the risks, undertake regular surveillance activities, liaise with local communities, manage the biosecurity risk in the Torres Strait and contribute to Australian and international initiatives.

NAQS surveillance areas:



Terms use in the Queensland Biosecurity Act

From: <https://www.daf.qld.gov.au/biosecurity/about-biosecurity/biosecurity-act-2014/information-and-resources-about-the-act/overview-and-foundation-principles/terms-used-under-the-biosecurity-act>

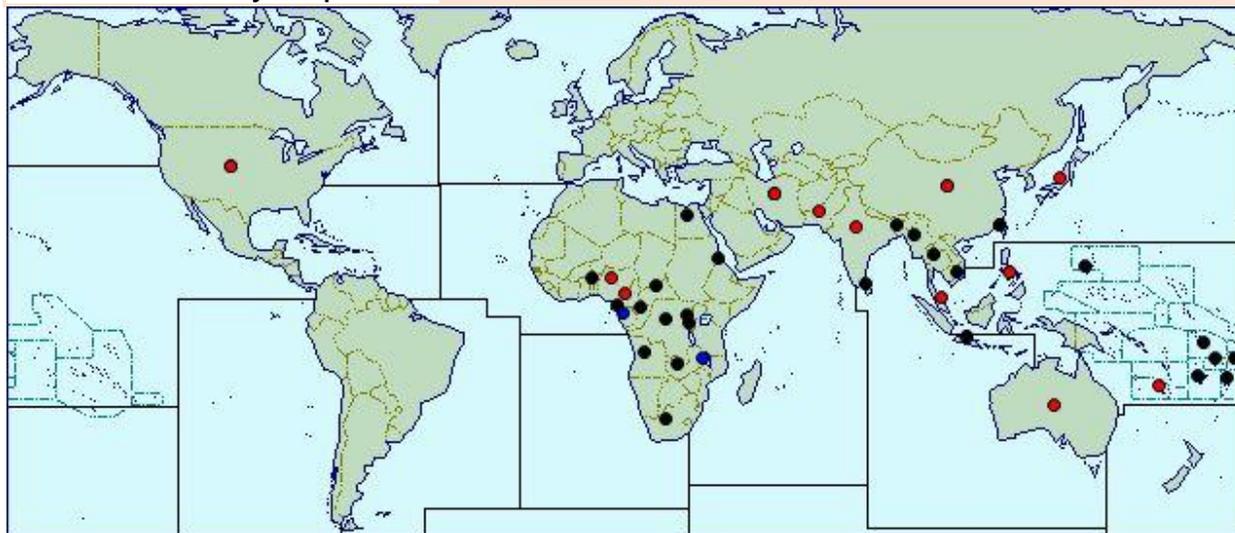
Prohibited matter: Prohibited Matter is biosecurity matter not currently present or known to be present in Queensland. It is prohibited because it may have a significant adverse effect on a biosecurity consideration if it did enter Queensland.

Restricted matter: Restricted Matter is biosecurity matter found in Queensland that may have adverse effects on a biosecurity consideration if conditions or restrictions under the Act were not imposed.

Appendix 3 – maps of locations of pests

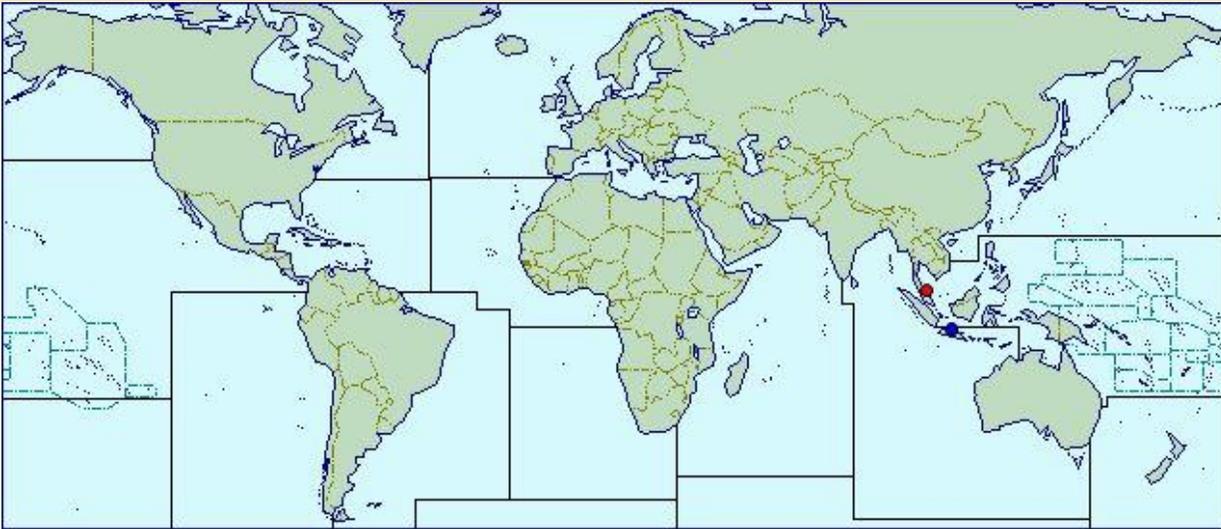
Sourced from: <http://www.cabi.org/isc/> . More detailed maps for each country are available.

Banana Bunchy Top Virus

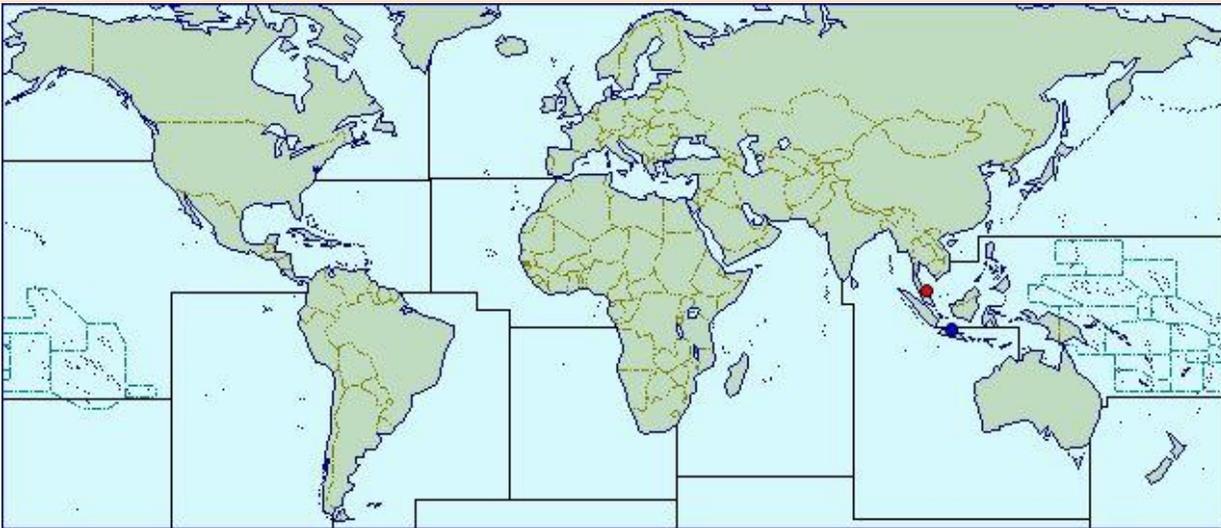


■ Present, no further details	■ Evidence of pathogen
■ Widespread	■ Last reported
■ Localised	■ Presence unconfirmed
■ Confined and subject to quarantine	■ See regional map for distribution within the country
■ Occasional or few reports	

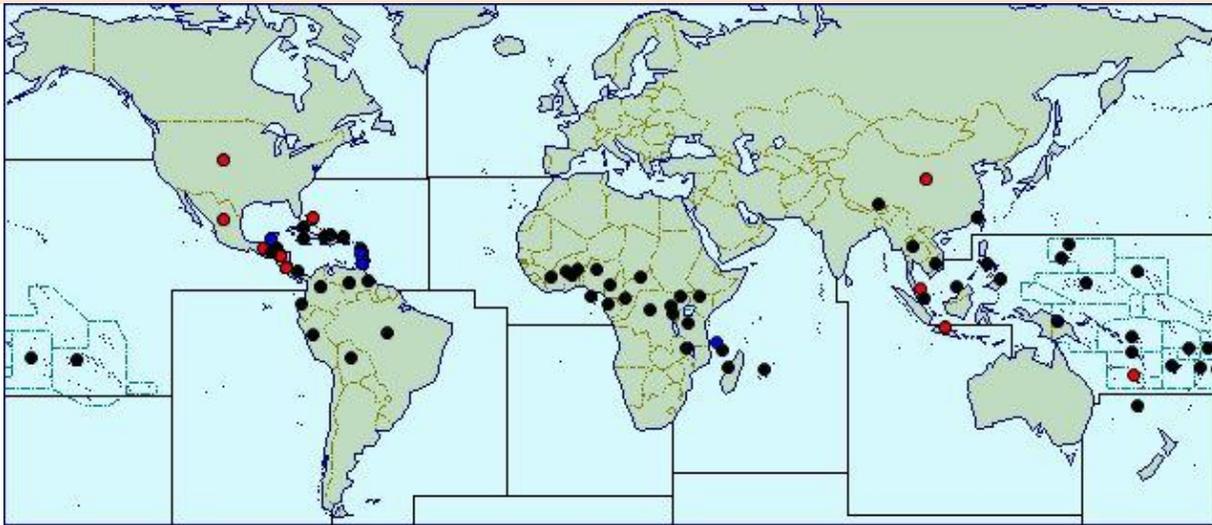
Banana blood disease



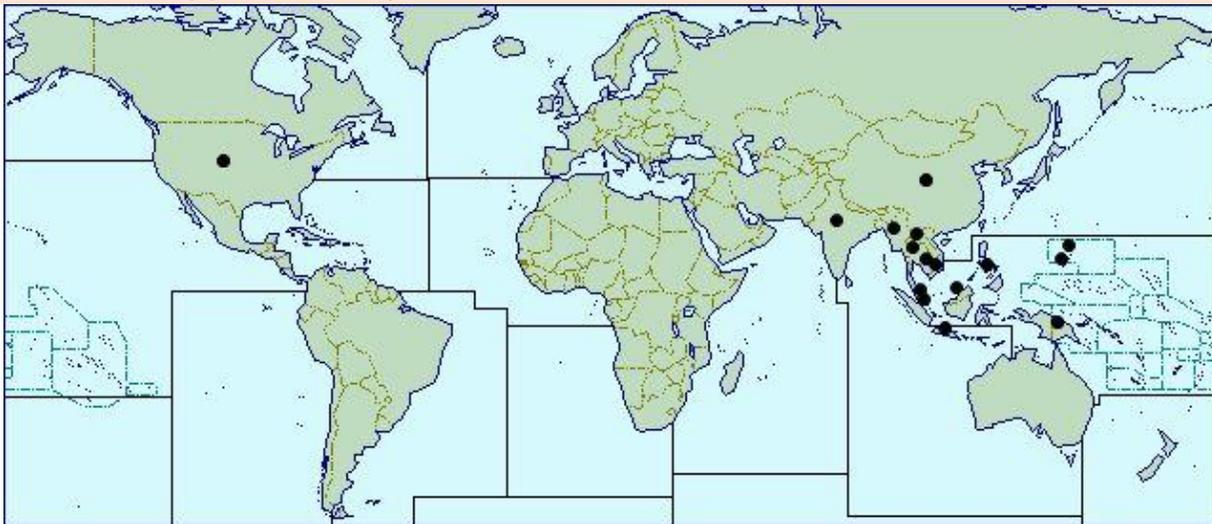
Bacterial wilt



Black Sigatoka



Banana skipper butterfly



Panama disease

