# Readiness and Response Plan for

# *Ceratocystis fimbriata* affecting kiwifruit and kiwiberries

**April 2017**

Biosecurity through Partnership

Ministry for Primary Industries
Manatū Ahu Matua

# Contents

# Foreword

*Ceratocystis fimbriata* is a fungal complex with a wide host range and wide geographic and genetic diversity. Strains (or "types") may be host specific and/or have restricted distributions in some instances. This plan only caters to one host – kiwifruit and kiwiberry (*Actinidia sp.*) – and has been created under the Government Industry Agreement for Biosecurity Readiness and Response, via the Kiwifruit and Kiwiberry Sector Operational Agreement.

The plan provides information on:

- What we know about *C. fimbriata* (context)
- How we would respond
- What knowledge gaps exist

The audience for this plan includes members of *C. fimbriata* responses and readiness projects.

When considering this plan, it needs to be noted that a *C. fimbriata* strain may enter the country affecting any potential host or a variety of hosts, which may or may not include kiwifruit. Those strains identified as potentially affecting kiwifruit may also affect other host species.

Due to the limited understanding of *C. fimbriata*, it is difficult to predict with any great certainty which species may be affected by any one strain. For this reason, this initial plan has only focused on the kiwifruit sector, which identified the fungus as a high-risk organism.

This plan was drafted for readiness purposes in response to non-NZ strains of *C. fimbriata* or those pathogenic to kiwifruit.

# Document Purpose

The purpose of this readiness plan is to inform decision-making when preparing for and responding to *Ceratocystis fimbriata*. **This document is divided into three parts, each of which may be read and used independently to provide information to progress response work and readiness projects for *C. fimbriata.*** It provides an overview of the current knowledge of the organism (Part 1), a proposed high-level response action plan that broadly identifies the tools and resources required to respond to a positive detection of a harmful strain of *C. fimbriata* to kiwifruit in New Zealand (Part 2), and current knowledge gaps and research that could improve readiness (Part 3). More detailed information is included in the appendices. This document is a 'living document' and shall be reviewed and updated if and when new response tools become available.

# Part 1 – Current knowledge of the organism

Part 1 provides known information on *Ceratocystis fimbriata*, including the risk pathways, This part is suitable for those that need to familiarise themselves with *C. fimbriata* for readiness or response purposes, e.g. the Intelligence workstream in a response.

## 1 Summary of Risk

*Ceratocystis fimbriata* is emerging worldwide as a major plant pathogen. In Brazil, it has caused significant damage to kiwifruit orchards, with some growers reporting up to 50 % vine loss over the past five years.

A specific strain of this pathogen is considered one of the most significant biosecurity threats to the New Zealand kiwifruit industry, and is likely to be a threat to the kiwiberry sector also.

**Likelihood of entry: Moderate.** *C. fimbriata* is present in over 35 countries, including New Zealand, in a wide range of hosts. There is significant uncertainty about which strains present a risk to kiwifruit, where these strains are present and the possible entry pathways.

**Likelihood of exposure and establishment: Moderate.** The likelihood is dependent on the host and entry pathway, and therefore significant uncertainty is associated with this assessment. There is likely to be suitable host material and climatic conditions in the kiwifruit growing regions of New Zealand, although this may also be strain dependent. Existing control tools have limited effectiveness.

**Impact: High.** The pathogenic kiwifruit strain in Brazil would likely cause significant production impacts to the New Zealand kiwifruit industry if it were to establish here as potentially all kiwifruit cultivars are susceptible. The impact of other strains is unknown. Market access impacts are unlikely for fruit, however pollen and germplasm may be affected.

(Please note: this is a summary of the current understanding of risk. A comprehensive risk assessment has not been completed and there is significant uncertainty associated with both the entry and establishment values, although impact is likely to be high given the issues observed in Brazil and the pathogenicity screening undertaken.)

## 2 Surveillance and Detection

Should this pathogen arrive, early detection would contribute to retaining containment and possibly eradication options.

There are no active or targeted surveillance programmes currently in operation for this organism, and the diagnostic tools to enable this are still under development.

With current knowledge, surveillance for this pathogen may consist of combining visual inspections of vines together with on-site investigation of symptoms, including examining lesions under low power magnification and cutting into stems with a sterilised blade to look for tissue staining. This work may best fit with general orchard inspections for other diseases.

In most orchards, inspections like this are likely to consist of moving through and scanning vines. There may be benefits in developing an informed structured approach to see if detection probabilities can be improved.

In the event that structured inspections take place in orchards throughout the industry, planning will be needed to cover triaging to separate suspect samples requiring formal diagnostic input from non-suspect samples. Clear definition and labelling of samples to be sent to MPI diagnostic laboratories is essential.

## 2.1 Current active surveillance

There is no current active surveillance programme.

## 2.2 Current passive surveillance

A passive surveillance programme is key for the reporting of risk organisms to MPI. A report to the biosecurity hotline (0800 80 99 66) is the active approach for identifying and responding to a possible incursion. The MPI passive surveillance programme is focused on utilising all available residents within the country to identify biosecurity risk organisms.

Passive surveillance is the primary surveillance tool utilised by MPI and KVH for kiwifruit pests. KVH constantly encourages the kiwifruit industry (growers and post-harvest) to report any unusual symptoms on kiwifruit orchards. Efforts have been made to raise awareness of this pathogen by profiling it in the "Most Unwanted" collateral, articles in the KVH Bulletin and Kiwifruit Journal on the KVH website, and profiling it at various industry meetings.

## 2.3 Biology and Epidemiology

*Ceratocystis fimbriata* is a complex of soil-borne fungal pathogens, which cause wilt disease in a number of plant species, including kiwifruit (*Actinidia*), by compromising the vascular system. The *C. fimbriata* complex has a wide and unpredictable host range, both as a simple wound coloniser and as an aggressive plant pathogen.

In the past 15 years, new host crops and new epidemics of *Ceratocystis* wilt have been reported worldwide, especially in Brazil and Asia. In 2010, significant impacts were observed on kiwifruit orchards in the Farroupilha area of Rio Grande do Sul, Brazil. There have been no reports of impacts to kiwifruit from this pathogen outside of Brazil to date.

In New Zealand, one strain of the *C. fimbriata* complex is known to be present. It was first identified in 1907 and causes black rot on kumara (*Ipomoea batatas*), however, this strain has been found to be non-pathogenic to kiwifruit and is also believed to be host-specific to kumara.

(See Appendix 5, for further background information).

## 2.4 Symptoms

(See also Section 3: Diagnostics)

It is unknown how long it takes for an infected plant to show symptoms in the field. In pathogenicity trials, kiwifruit plants inoculated with *C. fimbriata* showed symptoms within 10-12 days on average. How this correlates to natural infection and symptom expression in the field is not known and is a key knowledge gap to be addressed with research, however anecdotal evidence suggests plants may be infected but remain asymptomatic for many years.

At some point after infection the vascular system becomes blocked, resulting in vine wilting and collapse soon after. Rapid vine collapse in absence of injury is a distinctive characteristic and complete vine collapse can occur within three days of the first observation of symptoms

Dead kiwifruit vines are often adjacent to each other creating a circle of dead vines as the disease moves through soil and root systems. Browning of the xylem can be seen in infected vines moving from canes to leaders, trunks and even down to roots.

Wilting and dying plants should be inspected closely for vascular discoloration of the woody xylem. A horizontal cross section of the wood will often show a radial pattern to the staining, while longitudinally the discoloration is often in streaks (Figure 1). Other fungi can induce similar discoloration, although this will typically be more solid and less "streaky".

## 2.5 Risk strains

The most dramatic disease losses and the greatest array of hosts have been found in Brazil, mostly on non-native hosts.

The *C. fimbriata* complex is broken up into "clades" of closely related strains and potentially a number of species native to different regions of the world. The most aggressive plant pathogens are in the Latin America Clade (LAC), which is native to South America, Central America, the Caribbean, and eastern USA. Strains of the LAC pose the greatest threat to crop production, both where the strains are native and where they have been introduced. Impacts to kiwifruit have only been reported from strains in the LAC, however other clades within the *C. fimbriata* complex may also present a risk and must also be considered in risk assessments (Harrington 2015).

Two strains in particular have been highlighted as particular concerns in addition to the known kiwifruit pathogenic strain in Brazil as they have similar genetic characteristics to South American *C. fimbriata* populations;

1. South China – where a group of closely related strains have been found on eucalyptus, taro and loquat and are also causing substantial mortality on pomegranate in Yunnan and Sichuan,
2. An outbreak causing mortality to mango in Oman and Pakistan, pomegranate in India, and Acacia in Indonesia.

For further information on host/country combinations of strains see Appendix 6.

## 2.6 Natural spread mechanisms

*Spread mechanisms are covered in section 4 & 5, the following is a brief overview of natural spread mechanisms from a biological perspective taken from Harrington (2015).*

**Sporulation on and in hosts**
Disease cycles for *Ceratocystis* wilt on various hosts are complicated, in part due to the multitude of spore forms and means of dispersal of the pathogen.

The pathogen may sporulate on canker surfaces, wounded parts of diseased trees, and pruning cuts within 24–48 hours. Sporulation occurs during periods of high moisture content during warm months, and infection of pruning wounds may be limited during cold winter periods.

Thin-walled conidia (asexual spores) are produced by most members of the complex which may be spread by insects or rain and enter soil or waterways, but these spores are probably most important in mechanical transmission. Mycelium mats are generally thought to be important as a site for fungal feeding and acquisition of spores by insect vectors, though it is not clear if this is an important dispersal mechanism for members of the LAC. Spores from mats do not normally spread far by rain or insects. Walter (1949) found that only wounds on trees within 8 m of a diseased London plane became infected in an undisturbed stand.

Along with conidia, ascospore masses form from black ascocarps (perithecia) held together in a sticky, hydrophobic matrix, so the spores are not readily dispersed in water but instead have an affinity for the hydrophobic exoskeleton of insects. All species in the *C. fimbriata* complex are homothallic through unidirectional mating type switching, and most sporulating mats will produce this sexual stage even if there is no cross-fertilization from other strains. With such selfing, the sexual state may persist in introduced populations derived from even a single genotype. However, perithecia and ascospores may not be essential for epidemics, and the relative importance of ascospores vs. phialoconidia is not clear.

Members of the complex are also capable of outcrossing, so introduction of two or more genotypes of the pathogen to a region allows for generation of new recombinants, and such recombinants may be more aggressive than either of the originally introduced genotypes. Fungal propagules expelled from infected trees by sawing or as boring insects clean their tunnels may be dispersed by wind or rain splash for relatively short distances. Aleurioconidia of *C. platani* are abundant in stained sapwood and, once liberated, can infest soil and waterways. Aleurioconidia are believed to be the most common survival units because they are thick-walled, pigmented and durable, and aleurioconidia are abundant in discolored wood and insect frass. The contaminated frass of the boring insects may be important for wound colonization of nearby trees, for contributing to soilborne inoculum, and for contamination of waterways. The fungus may survive in wood fragments in the soil and in river water for months or years.

These natural spread mechanisms are summarised in the table below.

**Table 1**. Natural spread mechanisms of spores

| | **Short distance spread, less robust** | | | **Long distance spread, more robust** |
|---|---|---|---|---|
| | **Phialoconidia (A)** | **Doliformconidia (B)** | **Ascospores (C)** | **Aleurioconidia (D)** |
| **Shape** | Thin-walled, cylindrical | Thin-walled, barrel shaped | Sticky hydrophobic matrix | Thick walled, durable |
| **Found** | Mycelium mats on open wounds & cankers | | Mycelium mats | In sap inside infected plant |
| **Survival** | Short | | | Long (months to years) |
| **Dispersal mechanisms** | Rain (short distance), insects, mechanical via tools, waterways & soil (but not as durable as D). | | Adhere to insects, mechanical via tools, not spread via water | Enter wounds via frass, root grafts, mechanical via tools, enter soil & waterways via wood fragments, sawdust & frass, plant propagative material |

# 3 Diagnostics

## 3.1 Visual symptoms

Wilting and dying plants should be inspected closely for vascular discoloration which is typically a radial pattern in a cross section, and streaky discoloration in a longitudinal section.

**Figure 1.** Symptoms of *C. fimbriata* infection in kiwifruit (Brazil) Clockwise from top; leaf wilt and curl, cane shrivelling and vine discoloration.

This discoloration can be differentiated from other vascular wilt which tend to follow the annual growth rings (on a cross section cut). Other fungi, such as *Botryosphaeria* spp. or *Lasiodiplodia theobromae*, can induce similar xylem discoloration, especially in stressed hosts, although the discoloration is generally more solid and less "streaky" with these other pathogens. LAC *C. fimbriata* do form characteristic pigmented growth that a mycologist (fungal scientist) may be able to recognise with using a microscope (dark brown aleurioconidia in the stained sapwood) (Panconesi et al. 2003).

## 3.2 Isolation

Due to the lack of available DNA-based specific diagnostic methods, current testing in New Zealand is based on isolating the fungus into culture using baiting methods or special media, which is followed by morphological and molecular identification. The fungus is fast growing and does produce characteristic structures in culture within less than one week. This process has a 1 -2 week turnaround time but is highly reliable due to the distinct morphology of *C. fimbriata.*

## 3.3 Molecular methods

There is currently no specific PCR test available for *C. fimbriata*. Previous studies have used culture based methods where the internal transcribed spacer (ITS) region is amplified and sequenced from isolated fungal cultures. The results have demonstrated a high degree of variability in the ITS region and therefore this section of the fungal genome might not be the most reliable marker for specific test development and additional genes should be examined as potential barcode genes for *C. fimbriata*. Nevertheless, if the ITS region is successfully amplified and sequenced, it is a useful region for identification.

The development of primers for *C. fimbriata* specific PCR assay is a high priority and a current project of Plant and Food Research, funded by KVH/ Zespri. The project will evaluate the suitability of the ITS region for test development and proceed to develop primers from other genes if necessary. While an assay that distinguishes all known risk strains would be desirable this is considered an unlikely outcome, rather the project is likely to deliver a broad assay that picks up all *Ceratocystis* isolates and is able to distinguish the NZ kumara isolate from those. The expected completion date is March 2018.

## 3.4 Diagnostic service providers

There are multiple service providers available for diagnostics, however under the Biosecurity Act 1993, MPI must be the agency to complete the initial testing where the organism is suspected. Other service providers may be utilised once the organism has been found to be present in New Zealand, providing protocols can be agreed.

# 4 Potential entry pathways of *C. fimbriata* into New Zealand

This information is considered accurate within the current knowledge base, however it will be updated upon completion of a formal risk assessment.

## 4.1 Country of origin pathways

Although widespread, it is considered that goods, travellers and transport from the following countries hold a higher risk for *C. fimbriata* than other areas:

| Tier 1 Risk Areas (Highest Risk Area) | Tier 2 Risk Areas |
|---|---|
| • Brazil | • South China<br>• Oman<br>• Pakistan<br>• India<br>• Indonesia |

Tier 1 - Brazil - is considered the greatest risk area as a strain that impacts kiwifruit is present

Tier 2 – a pathogenic strain is present in these countries which Dr Tom Harrington suggests is likely to impact kiwifruit in addition to the hosts it is currently impacting in those countries

## 4.2 Item specific pathways

### 4.2.1 Movement of infected plant material

A range of plant species have been identified as hosts for *C. fimbriata* including kiwifruit (*Actinidia* sp.), which is known to be infected by multiple genotypes of this fungus. Infected host plant material is considered to be the most important pathway for introducing the pathogen to new areas. This identifies plant material imports as a high-risk entry pathway, most likely through the imports of ornamental nursery stock (cuttings, whole plants, dormant bulbs and tubers) alongside kiwifruit cultivars for propagation. *C. fimbriata* has been identified as a target organism in the Kiwifruit Plant Certification Scheme (run by KVH), a biosecurity standard that all kiwifruit nurseries must meet.

### 4.2.2 Soil

Soil, used machinery, containers, or passenger belongings such as shoes or camping gear are a risk of containing soil sourced from the *C. fimbriata* infested area. As soil is considered a main source of inoculum for *C. fimbriata*, it is important to note that any personal items (shoes, camping gear etc.) could harbour the fungus, whether they stem from rural or urban areas.

Fungal diseases carried by soil are managed on potential entry pathways by basic (general) and/ or specific requirements in the relevant Import Health Standards (IHS).

### 4.2.3 Saw dust and frass

Used machinery, tools and passenger belongings contaminated with saw dust or frass (excrement from larvae) present another potential entry pathway for *C. fimbriata.* Saw dust and frass can be produced by wood boring insects feeding on infected trees and harbour *C. fimbriata*. This is a much lower risk for entry than infected nursery stock and may be more important as an internal dispersal pathway.

### 4.2.4 Wood packaging

This pathway is unlikely to be a significant threat, when treatment procedures are correctly followed. Wood packaging is mainly ISPM 15 stamped, therefore wood packaging has been heat treated or fumigated on pre-export which will mitigate the insects. In addition, inspection for pests and diseases is carried out on arrival.

# 5 Establishment and dispersal pathways

Natural spread of *C. fimbriata* is limited as the pathogen is soil borne and does not produce windborne spores (see Section 2.6 Natural Spread Mechanisms). Human assisted transmission on propagation material, soil and tools present the greatest risk of spread within orchards and between growing regions.

**Table 2**. Likelihood of various mechanisms spreading *C. fimbriata* over short and long distances

| | **Likelihood of spread** | | |
|---|---|---|---|
| **Spread mechanism** | **Between vines** | **Between orchards** | **Between growing regions** |
| Plant propagative material | Low | High | High |
| Tools and equipment | High | High | High |
| Root graft | High | Low | Low |
| Water run-off | High | Moderate | Low |
| Vector transmission | Moderate | Low | Low |
| Plant fragments, saw dust & frass | Moderate | Low | Low |
| Contaminated soil | Low | High | High |
| Sporulation | Moderate | Low | Low |

Modes of dispersal include the following:

## 5.1 Plant propagative material

Nurseries have been strongly associated with movement of *C. fimbriata* around the world. Of particular concern are symptomless cuttings dispersing the pathogen over long distances.

## 5.2 Transmission on tools and equipment

Tools and equipment used on infected plants can carry the pathogen between vines. Pruning tools especially create wounds that are a common entry point for the pathogen.

## 5.3 Root graft transmission

Root grafting is when roots of neighbouring plants become intertwined. This can provide a pathway for pathogen transmission and is thought to have contributed to the spread of *C. fimbriata* within orchards in Brazil.

## 5.4 Water run-off

As a soil-borne pathogen, *C. fimbriata* may be spread via water run-off in heavy rain. This may be of higher consideration in hill country, or in the event of a heavy weather event.

## 5.5 Vector transmission (insects)

*Ceratocystis fimbriata* produces fruity odours that attract fungal feeding insects. Many insects can acquire spores of *C. fimbriata*, however most do not transmit the pathogens to new wounds and are not vectors. Wood boring ambrosia beetles may carry *C. fimbriata* on their bodies and the fungus can survive passage through the gut. However, these insects generally do not attack healthy trees and are not expected to be a common vector

## 5.6 Dispersal in plant fragments, saw dust and frass

The thick-walled aleurioconidia (type of asexual spore) can be transported with plant material and sawdust originating from infected plants. In addition, Ambrosia and other bark beetles produce frass, which like sawdust, is known to harbour inoculum which may be spread very locally in the wind and contribute to soil borne inoculum.

## 5.7 Transmission in contaminated soil

As a soil-borne pathogen *C. fimbriata* may be spread through movement of soil. If soil from an infected plant or orchard is moved, then the thick walled aleurioconidia can be transported with the soil.

## 5.8 Sporulation

*C. fimbriata* does not commonly spread through spore dispersal. While limited sporulation may occur during warm moist periods which can then be spread mechanically, or be released by boring insects or sawing activities and travel short distances by wind or rain, this is a relatively low risk vector.

# 6 Overview of market access readiness

*Ceratocystis fimbriata* is listed as a quarantine pest in the following countries; Indonesia, Korea, Russia, South Africa, Taiwan, Vietnam.

Impacts from market access restrictions are expected to be low as fruit is not considered a pathway of entry as the pathogen is not known to infect fruit (EFSA 2008).

However, this is more likely to be relevant for the movement of plant material, as opposed to produce. New Zealand is a world leader for the development of new kiwifruit cultivars and regularly sends plant material offshore, either through Zespri to support their global supply, or through other kiwifruit organisations independent of Zespri.

# Part 2- Responding to a positive detection

Part 2 identifies possible actions which may be included in any response to *C. fimbriata*. This Part may be used in an actual incursion/infection by members of the response team, particularly the Incident Controller/Response Manager, Planning and Operations workstreams.

## 7 Investigation phase (MPI accountability)

Upon receipt of information regarding a likely biosecurity incursion, an incursion investigation will be initiated by MPI. The investigation phase is outside the joint decision making of GIA. The investigation phase identifies the organism, confirms the diagnosis, assesses the risk, determines the extent of the incident and may include urgent measures to limit organism movement prior to the formal joint decision to stand up a response.

For a pathogen with significant implications such as *C. fimbriata*, a precautionary approach will be adopted to preserve response options. Actions may include:

- MPI to arrange for prompt field investigation, mobilising experienced incursion investigators;
- Providing information and explanation to property owners of the process and actions required, as well as assistance available to cope with the incident;
- Putting urgent measures in place to preserve response options;
- Gaining an understanding of diagnostics, such as degree of confidence in current identification, time frame to achieve validation of identification, and any complications related to strains and projected pathogenicity;
- Making decisions on property status and declaring property/properties to be infected if necessary;
- Preparing diagnostic facilities for high through-put sample processing if necessary.

## 8 Decision making beyond the investigation phase (Joint accountability)

If this pathogen is confirmed in kiwifruit, actions to manage the response will follow commitments entered into under GIA. MPI will notify any potentially affected GIA signatories if presence of this organism is suspected (and likely to be confirmed) in New Zealand (Deed 3.2.2). Depending on diagnostic outcomes and implications, the joint decision to initiate a response will be made and, if agreed, Response Governance is established.

All strategic decisions of a response will be made by Response Governance, which includes both MPI and industry. The decision to respond and how to respond sits with Response Governance. This group must make that decision based on the information collected within the investigation phase. Responding to eradicate may be the preferable option, however where evidence indicates that this is not feasible, containment or area freedom may become better options in return for response investment.

It is recommended that the Response Controller provides Governance with response options as soon as possible, that reassessment of the strategic direction is regularly made, and all decision-makers are aware of the appropriate courses of action.

## 8.1 Decision to stand down

The decision to stand down an investigation or response may occur if the infection is no longer present during the investigative phase or not confirmed. The decision to stand down may also occur when the cost of responding is outweighing the benefit of doing so or if no response options exist to take action. The decision will be made in joint discussion.

Note: The "standing down" of an investigation or response is different to a response being "closed out". A response is closed out when the response is complete (response objectives achieved).

## 8.2 Decision to transition to long term management

Long term management may need to be considered in the event that multiple orchards are affected across multiple regions, or when additional host plants are discovered to be susceptible to the *C. fimbriata* strain. This may occur immediately instead of initiating a response, or when all eradication options have been explored during a response and proven to be ineffective. In this instance the MPI process for transition into long term management will be followed (developing this process is under progress).

# 9 Mitigating risks of spread

## 9.1 On-orchard biosecurity

Industry practices such as tool hygiene provide an opportunity to mitigate the spread in the early stages of a response and in the long-term management phase. KVH is working on orchard biosecurity plans to establish industry best practice for mitigating risks during pruning and other activities. *C. fimbriata* will be considered as a target organism as part of this program development.

Theoretically, on-orchard hygiene practices could be very effective in preventing long distance spread as the modes of travel are primarily human assisted. KVH is working on improving overall uptake of best practice on orchards.

## 9.2 Nursery biosecurity controls

Controlling risk across the nursery pathway will mitigate the risk of spread in the early stages of a response and be effective in the long-term management of the organism. The Kiwifruit industry has already implemented such a scheme for kiwifruit rootstock material, the Kiwifruit Plant Certification Scheme (KPCS, www.KVH.org.nz/KPCS), and has made the decision to include *C. fimbriata* as a target organism within this scheme. Nurseries have been provided with symptom guides and are monitoring for all target organisms on a monthly basis, providing a means for early detection for this pathogen. It is likely that similar schemes will be developed for other plant material such as budwood in the future.

# 10 Response phase (Operational phase, Joint accountability)

Response management and workstreams will be structured using MPI's Single Scalable Response Model which is based on the Coordinated Incident Management System (CIMS; see Appendix 2).

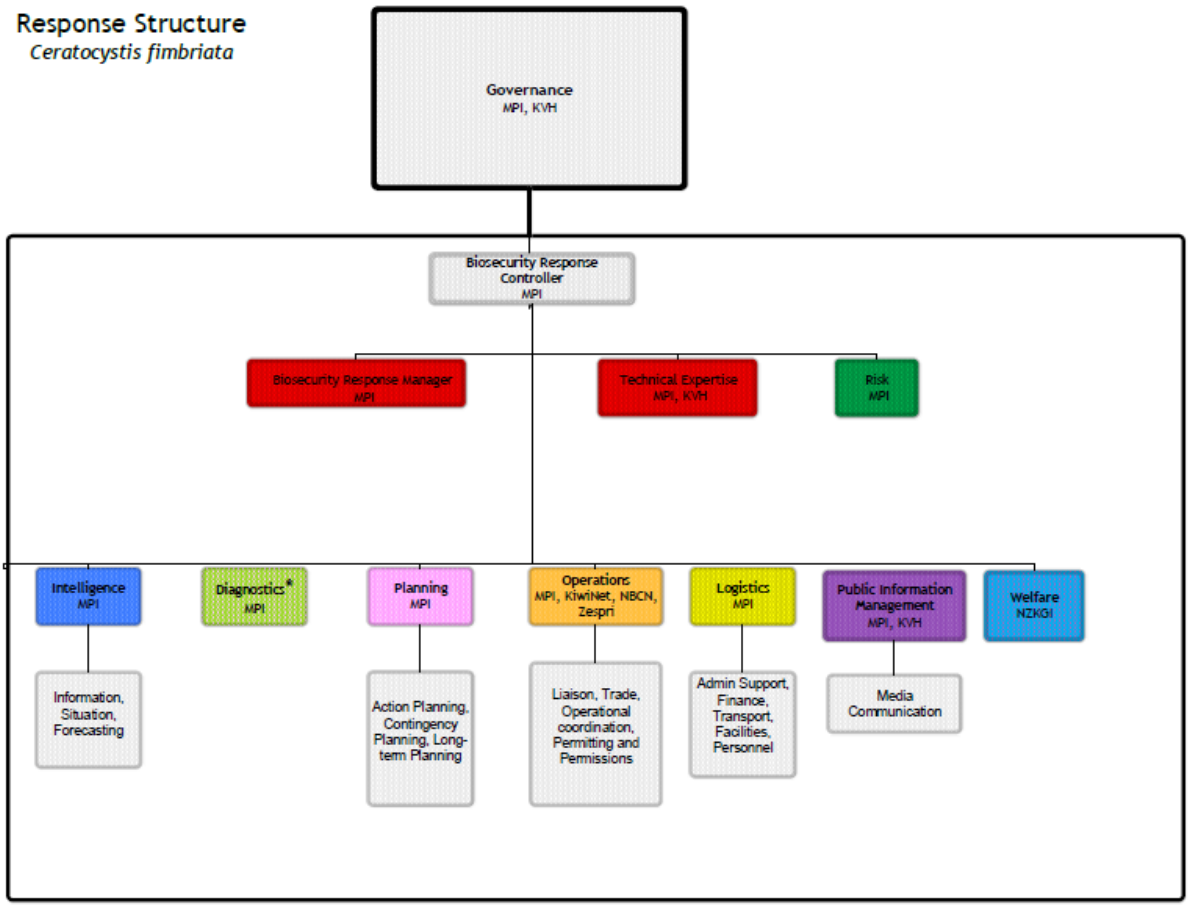


**Figure 2**. Proposed response structure for a positive detection of *Ceratocystis fimbriata*

* Diagnostic may be a function in its own right in a large response. In some cases, Diagnostics is more appropriate to sit under the Intelligence or Operations workstreams to suit the response.

Response Structure

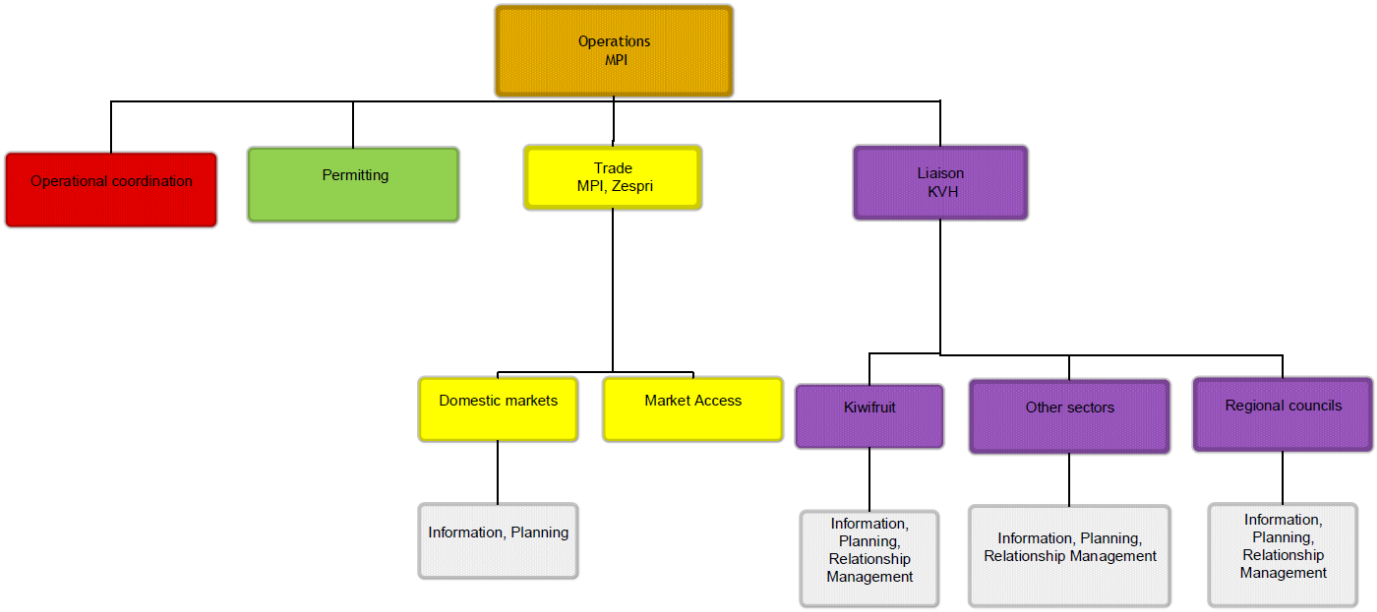


**Figure 3**. Proposed Operations workstream structure

## 10.1 Summary response strategy

The detection of *C. fimbriata* on a kiwifruit orchard may result in the following actions in the first instance (*distances identified are indicative only based on an initial assessment by KVH staff. Testing distances and strategies with an expert panel would be useful*):

- Delimiting survey to determine extent of infection. Testing would include asymptomatic and symptomatic vines. Intensive sampling and testing may be carried out to 500m and less intensive to 1 km plus any high-risk sites identified through tracing activities
- Constructing two layers of trenches 1.5m deep and lined with plastic around the infected trees, constructing the inner layer around the infected trees and the outer layer including a ring of healthy trees surrounding the infection site
- Establishing movement controls to either the orchard boundary or 500m (depending on what is closer). Other high risk sites, such as source nurseries, may also need movement controls applied until testing can verify absence of the pathogen
- Minimising risk of spread by removing infected vines and sanitising tools. Other orchards should halt pruning activities until the delimiting survey is complete, especially those orchards within 1 km of the infection site
- Carrying out enhanced surveillance at all other nurseries and monitoring of orchards

## 10.2 Response options

Essentially, two broad response options for the damaging strain for kiwifruit of *C. fimbriata* in New Zealand are:

- Eradication- eradication from New Zealand
- Containment or area freedom- containment of *C. fimbriata* to areas where it cannot be eradicated, prevention of further spread

### 10.2.1 Eradication

Eradication may be feasible in the event that the infection is detected early, found to be localised and limited. Given the longevity of this organism in soil and plant material, eradication may only be achieved under a long-term management plan.

### 10.2.2 Containment

Where eradication is not considered feasible, measures may be implemented to contain the pathogen and limit its spread. Containment may need to be considered when infection extends to multiple orchards, particularly if these orchards are not within close proximity of each other.

Aiming for containment may lead to long term management, however it may also provide for a second window of eradication with the development of new technology or tools should these be identified.

Within these overall options, the general principles for the management of *C. fimbriata* include:

- rapid detection and confirmation of infection
- rapid identification of the extent of the problem
- rapid selection and implementation of response control measures
- prevention of pathogen spread by controlling movements of plants, tolls and equipment and contaminated soil within and between orchards and other sites considered susceptible to infection
- maintenance of appropriate plant health management practices and high standards of hygiene
- minimize water run-off where possible

The most appropriate option will depend on:

- geographical location of the issue
- effective treatment
- chances of successful *C. fimbriata* eradication
- level of risk accepted for any future spread of infection
- short-term costs of response control measures and disruption to kiwifruit production
- long-term costs to kiwifruit production in the presence or absence of *C. fimbriata*
- long-term management costs should *C. fimbriata* become endemic.

# 11 High-Level Response Action Plan

A high-level response action plan needs to be drafted when a response is initiated (see Appendix 1). The details will depend on the specific circumstances but the below provides guidance to what actions may be necessary. Each function/workstream may need to complete their own response action plan which will cover items in more detail.

The response to a strain of *Ceratocystis fimbriata* harmful to kiwifruit may include the components/actions and tasks listed below. Individual response components may be mapped on a high-level timeline.

**Surveillance & Testing:**

a) A delimiting survey will be undertaken to determine the current extent and spread of the harmful *C. fimbriata* strain.
b) Analysis and testing will be undertaken at MPI's Plant Health and Environment Laboratory (PHEL), Tamaki.
c) Surveillance & testing to reduce risk of spreading *C. fimbriata* from infected sites will be undertaken.

**Movement Controls:**

a) Controlled Area and/or Restricted Place Notices may be used to control the movement of kiwifruit plants and products to other orchards.
b) Controlled Area Notices may also be used to explore the imposition of other rules to manage the risk of spread of *C. fimbriata* with other vectors (e.g., equipment and soil).
c) A permitting process may be developed to manage the movement of vectors in relation to the requirements of the Controlled Area Notice.

These movement controls would be subject to the approval and sign-off of the MPI Chief/ Deputy Chief Technical Officer (CTO).

**Organism Management:**

- Applying treatments to reduce and/or eliminate natural dispersal of the disease via wind, water or biological vectors (may include insects, birds and other animals);
- Removal and destruction of hosts, from limited action restricted to plants with signs of disease and their neighbours to whole plantings.

**Further details on operational activities are outlined in Appendix 3.**

**Communication with Stakeholders:**

a) A liaison cascade will be developed to ensure appropriate engagement occurs across a range of key stakeholders and partners (listed as a priority project in Part 3).
b) A stakeholder matrix will be developed outlining the level of importance of each stakeholder in terms of maintaining engagement and mitigating outrage to any proposed response activity and to the incursion of a harmful strain of *C. fimbriata* (listed as a priority project in Part 3).

**Communications to Wider industry:**

- Provide all growers with best practice advice for high-risk activities (such as pruning), which includes hygiene recommendations and other measures to mitigate risk.
- Passive surveillance messages, reporting process and symptom and monitoring guides issued to the entire industry (including all growers, post-harvest organisations and nurseries).

# Part 3- Current key knowledge gaps

Part 3 is identifies key knowledge gaps and improvements that could improve readiness and can be addressed through research in subsequent work programmes. This Part may be used as a starting point for further investment and prioritisation for industry and government.

The following have been identified as priority projects:

1. Run cost benefit analyses based on a few simple response scenarios to support decision making
2. Determine the lag between infection and symptom expression for surveillance
3. Determine natural spread distances to underpin high risk area, movement control zone and size of vine removal area
4. Determine how long *C. fimbriata* can survive in the soil
5. Determine the best option to achieve eradication
6. Develop a liaison cascade
7. Develop a stakeholder matrix
8. Develop generic Operational Specifications as per the MPI template
9. Develop a case for MPI's CTO/DCTO to sign-off movement controls

## 12.1 Biology and Epidemiology

- The suitability of New Zealand climate for different *C. fimbriata* strains to cause disease.
- Understanding of all the strains of *C. fimbriata* pathogenic to kiwifruit and kiwiberry.
- Are there other potential host species of kiwifruit strains?
- What likelihood is there of different strains of *C. fimbriata* adapting to infect different hosts?
- How long is the dormancy period before the symptoms appear (particularly in kiwifruit)?
- Can the pathogen be detected in asymptomatic carriers?
- For surveillance and follow-up action; should it be detected, what other species would need to be considered besides kiwifruit?
- How long does *C. fimbriata* take to spread and become transmittable?
- In Brazil what is the annual incidence (i.e. new case of disease appearing each year) within regions, and what is the annual within orchard incidence of new vines developing symptoms. In particular, what is the incidence rate per year and has this increased each year or is it weather dependant?
- If the other risk strains were pathogenic on kiwifruit, would the field symptoms be different to *C. fimbriata* in Brazil? What would need to go onto a field diagnostics and passive surveillance guide to address this? I.e. could we detect it using the current awareness material?
- It would be useful for a small number of "first responders" from KiwiNet and MPI (Incursion Investigators and PHEL mycologists) to have seen the organism in the field in Brazil. This will help with triage of reports of disease and with the development of response surveillance protocols.

- Symptoms and distinguishing features must be clearly described and available to the industry to improve effectiveness of surveillance efforts. This could be achieved by creating a field diagnostic guide that clearly differentiates *C. fimbriata* symptoms from NZ fungal pathogens.

## 12.2 Detection and Diagnostics

- The feasibility of promptly detecting infection in an orchard and throughout a growing region
- *C. fimbriata* specific PCR assay – under development, ETA March 2018.
- The best sampling methodology for *C. fimbriata* (including the detection limit from different plant parts and plants with different infection level).
- Seasonal effect (climate) for presence of *C. fimbriata* in symptomless infection (enables reliable detection by PCR).
- Preparedness for expanded diagnostic testing should sample numbers exceed MPI capacity. What is required for another lab to begin performing the diagnostic test? Can measures be implemented in advance to fast track this?
- Given the potential for false positives from a PCR test, how do we treat an initial positive result until morphological confirmation?

## 12.3 Dispersal pathways

- What species of beetles actively feed on the phloem of sapwood of kiwifruit?
- What is the efficacy of treatments for commercial sawdust against *C. fimbriata?*

## 12.4 Response options

- The feasibility of promptly detecting infection in an orchard and throughout a growing region
- What is the best option to eradicate *C. fimbriata*?
- What is the best option to contain *C. fimbriata* on an orchard (or multiple orchards)?
- How long can *C. fimbriata* survive in the soil?
- How far can *C. fimbriata* spread in water – observations from Brazil?
- Optimising current vine disposal techniques
- What are alternative hosts?
- Cost benefit analysis based on simple scenarios
- Need to determine efficacy of soil drenches against the durable spores which are robust
- Removal of infected vines – how large of an area would need to be removed given the likelihood of short distance spread via wounds, rain splash, contaminated tools etc. Biological & economic modelling to support removal of vines/block/orchard for eradication to be effective
- Based on the likelihood of spread by various mechanisms, is the proposed 500m radius suitable for the size of a high-risk zone?
- Are there any agrichemicals that can be used to control sporulation?

## 12.5 Long term management / recovery

- Is there the potential to breed resistant kiwifruit varieties with marketable fruit?
- Is there value in developing and implement pest management plans across the wider industry?

# 13 Research

## 13.1 Current research

*Ceratocystis fimbriata* is a pathogen of international significance, impacting a range of hosts in many countries. As a result, there is an opportunity to utilise international research capability or collaborate with countries with mutual interest. For example; Australia may be a potential research partner given that Eucalyptus are one of the most susceptible hosts, and a native species of great significance to Australia.

**Table 3**. Research projects and status to improve readiness

| **Project** | **Status** |
|---|---|
| Field trips to visit infected orchards and observe symptoms in Brazil. Multiple trips to the region which have included KVH staff, Zespri staff and Board members and PFR scientists. | Complete. Trip report on KVH website, (www.kvh.org.nz/emerging_risks) |
| Literature review to determine the impacts of *Ceratocystis fimbriata* on kiwifruit by Professor Tom Harrington, an international expert in this field. | Complete, Harrington (2015) |
| Pathogenicity screening of the kumara *C. fimbriata* strain on New Zealand kiwifruit. Study indicated that the only strain present in New Zealand, on kumara, is not pathogenic to kiwifruit. | Complete; Tyson JL, Manning MA, Curtis CL, Wright PJ. (2015) |
| Pathogenicity screening of isolates on kiwifruit cultivars. A collaboration with a Brazilian University to determine the degree of pathogenicity of various strains on kiwifruit, and whether tolerant kiwifruit varieties exist. | Underway |
| Sequencing and primer development. The project aims to sequence and compare a number of strains of *C. fimbriata*, including the Brazilian and kumara strains, in order to provide the basis for a DNA-based detection assay that could be used to identify risk strains of the fungus and underpin an eradication strategy in the event of an incursion. | Underway. Expected completion mid-2018. |

# 14 References

CABI (2005). *Ceratocystis fimbriata* [original text prepared by TC Harrington & C Baker, revised by T.C. Harrington]. Accessed from http://www.public.iastate.edu/~tcharrin/CABIinfo.html (March 2016).

European Food Safety Authority (EFSA) (2008). Scientific Opinion of the Panel on Plant Heath on a request from the European Commission on Pest risk assessment made by France on *Ceratocystis fimbriata* considered by France as harmful in French overseas departments of Guadeloupe, Martinique, French Guiana and Réunion. The EFSA Journal (2008) 703, 1-21.

Harrington, T.C., (2013) Ceratocystis diseases. Pp 230-255 In: *Infectious Forest Diseases.* P. Gonthier and G. Nicolotti, eds. CAB International, Wallingford, UK.

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O'Neil, B. (2014) *Report on investigation of orchards in Brazil affected by Ceratocystis fimbriata.* Accessed from http://www.kvh.org.nz/emerging_risks (Feb 2016).

Tyson JL, Manning MA, Curtis CL, Wright PJ. June 2015. VI1502: Pathogenicity screening *of Ceratocystis fimbriata* on kiwifruit cultivars in New Zealand. A Plant & Food Research report prepared for: Zespri Group Limited. Milestone No. 61394. Contract No. 31725. Job code: P/345502/01. PFR SPTS No. 11649.

# 15 Appendix 1: High-Level Response Action Plan Template

## Response Name:
## RESPONSE ACTION PLAN (Version Number)

**Date:** Covering the Period:

**Security Classification:** [*e.g. general release*] **See Distribution.**

**Authorised by:** [Name] – Controller

**REFERENCES:**

1. [e.g. High-Level Timeline]
2. [e.g. Function/Workstream Response Action Plan]

**SITUATION**

[*Guidance text is placed in the document, consistent with current Biosecurity Knowledge Base templates.*]

**AIM**

[*Aim of this document, incorporating the aim(s) of the response.*]

[E.g. The aim of this document is to provide a robust and consistent action plan to protect X from incursion of X and consequent adverse effects where it is already established.]

**EXECUTION**

[E.g. The response to (…) will include the components/actions and tasks listed below. Individual response components will be mapped on a high-level timeline.]

**Surveillance & Testing:**
E.g.:

a) A delimiting survey will be undertaken to determine the current extent and spread of […] and will involve the collection and analysis of […] from specified areas.
b) Analysis and testing will be undertaken at […].
c) Surveillance & testing to reduce risk of spread of […] from infected sites will be undertaken.

**Movement Control:**
E.g.:

a) Controlled Area and/or Restricted Place Notices will be used to control the movement of specified vectors into high value areas or out of high risk areas.
b) Controlled Area Notices will also be used to explore the imposition of other rules to manage the risk of spread of […] with other vectors.
c) A permitting process will be developed to manage the movement of vectors in relation to the requirements of the Controlled Area Notice.

**Communication with Stakeholders:**
E.g.:

a) A liaison cascade and communication strategy will be developed to ensure appropriate engagement occurs across a range of key stakeholders and partners.
b) A stakeholder matrix will be developed outlining the level of importance of each stakeholder in terms of maintaining engagement and mitigating outrage to any proposed response activity and to the incursion of […].
c) A communication plan will be developed that includes an appreciation of the right messaging and collateral to connect with a range of affected stakeholders and partners.

**Transitioning, Long-term and Contingency Planning:**
E.g.:

a) Transition and long-term planning will be undertaken to address the wind-down and closure of the response once the objectives have been achieved.
b) Long-term planning will include an analysis of long-term management options that maintain the outcomes of containment and protection.
c) Long-term planning will include debriefing and a critical analysis of the response to highlight areas of improvement for future responses.
d) Contingency planning will be undertaken to develop action plans for any unanticipated consequences that have the potential to impact on the success of this response.

**Risk Management:**
E.g.:

a) Legal, trade, reputational and biosecurity risks will be considered at all stages of the response.
b) An appreciation process will be undertaken to evaluate the proposed management options identified for each risk.
c) A risk register will be developed and maintained to provide a record of all of the thinking around the identification and management of real and perceived risks.

**Function / Workstream Tasks**

**a) Controller:**

1) Set the objectives and desired outcome of the response.
2) Maintain regular interface and updates for Governance.
3) Maintain overall day-to-day coordination and direction of the response ensuring appropriate feedback on actions, costings, risks and issues to Governance.
4) Determine frequency levels of meetings, sitreps and feedback processes throughout all phases and advice work-streams accordingly.
5) Provide guidance on an authorization process for transfers from controlled places or controlled areas.

**b) Response Manager:**

1) Provide cover for, and act as Controller as and when required and develop a workstream action plan.
2) Maintain oversight and high-level management of response staffing numbers and ensure effective management of all resources in both support of response and release to BAU activities.
3) Provide oversight of the Incident Management Team (IMT) and Workstream Leads, and chair regular IMT meetings.
4) Develop and maintain a lessons learned/continual improvement register in order to support end of response update and any subsequent audit requirements.
5) Develop and maintain a risk register is developed to enable effective risk management to occur throughout the response.

**c) Intelligence:**

1) Develop a workstream roster to support all response phases through to close-down, and develop a workstream action plan.
2) Gather, collate and analyse response information.
3) Inform the Planning Lead of intelligence that forecasts how the incident may develop.
4) Develop and distribute intelligence as situation reports, situation maps and other outputs.
5) Initiate tracing of human mediated movements that may have spread […] to new sites;
6) Initiate passive surveillance to identify possible spread events;
7) Initiate zone surveillance
8) Investigation of entry pathway

**d) Planning:**

1) Develop a workstream roster to support all response phases through to close-down, and develop a workstream action plan.
2) Develop and maintain the Response Action Plan and subsequent supplementary plans as and when required.
3) Collate and maintain oversight of individual workstream action plans.
4) Develop and implement plans
5) Develop and test contingency plans with trigger points to address the highest risk adverse events that may impact on the response.
6) Develop long-term plans for the wind-down and closure of the response.
7) Develop and document a decision process for the approval of transfers and then manage the process.

**e) Operations:**

1) Develop a workstream roster to support all response phases through to close-down, and develop a workstream action plan.
2) Plan and undertake surveillance & testing operations to determine current extent of the infection
3) Plan for an extended surveillance & testing programme to provide 'proof of freedom' from infection
4) Plan for and undertake monitoring of other orchards.
5) Identify, prioritise and align with the communications strategy and plan to carry out liaison with internal and external stakeholders.

**f) Public Information Management (PIM):**

1) Develop a workstream roster to support all response phases through to close-down, and develop a workstream action plan.
2) Develop a communications strategy as to how we will keep stakeholders informed.
3) Develop and implement a communications plan and associated communications material/resources to address communications strategy and support response operations.

**Coordination**

All workstream action plans, including projected resource requirements are to be aligned to this Response Action Plan. Plans must be provided to the Planning Lead for consolidation and sign off by the Controller.

The requirement for Governance, IMT and Operational meetings will vary across each phase of the response and will be determined by Governance, Controller and Response Manager accordingly.

Individuals may be required to move between workstreams as the resourcing requirements of each workstream changes throughout the response. This will be coordinated by Workstream Leads and the Response Manager.

**ROLES AND RESPONSIBILITIES**

Incident Management Team (IMT) and Workstream Leads as below throughout the response although it is recognised that Workstream Leads will in some instances need to provide delegated responsibility to an alternative for certain time periods (e.g. leave, BAU commitments, etc.). This should be coordinated through the Controller and Response Manager.

- **Controller:** [Name, Title]
- **Response Manager:** [Name, Title]
- **Operations:** [Name, Title]
- **Planning:** [Name, Title]
- **Intelligence:** [Name, Title]
- **PIM:** [Name, Title]
- **Technical Expertise:** [Name, Title]

Authenticated by,

| | |
|---|---|
| **[Name]** | **[Name]** |
| Planning Manager | Controller |
| [Response Name] | [Response Name] |

**Distribution:**

**[Name, Director] – Sent by Response Controller**

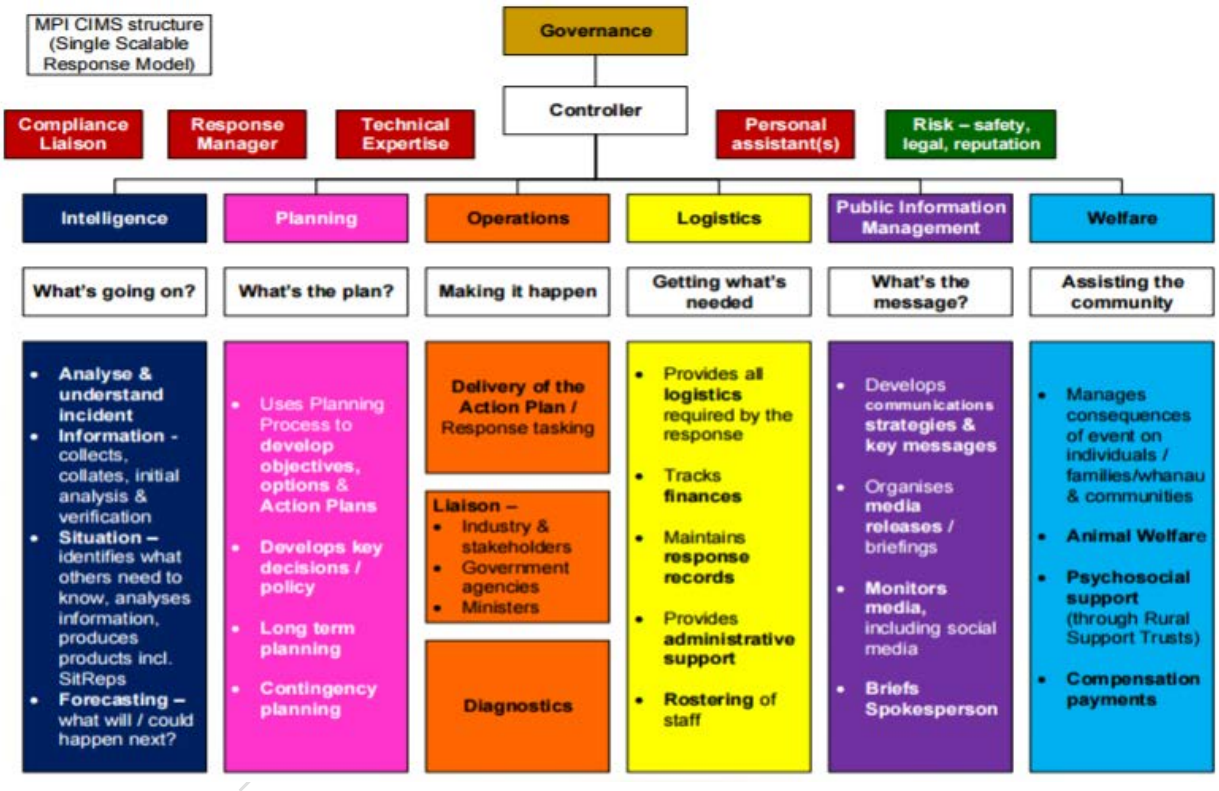
**IMT & Workstream Leads – Sent by Planning Manager**

For Information Only:

# 16 Appendix 2: MPI Response Control Structure, based on CIMS

MPI's Single and Scalable Response Model is based on the New Zealand standard for incident management, the Coordinated Incident Management System (CIMS), which is used by all major emergency services in New Zealand. This model provides a framework for responses. MPI extends CIMS to meet needs common across MPI responses which are not already addressed by CIMS.

The functions in this model may be amended or added to depending on an agency's needs, responsibilities, or the specific objectives of a particular response.



# 17 Appendix 3: Operational activities (options)

The Planning and Operations workstreams may develop and deliver the establishment of high risk zones, movement controls and organism management. Further details are included below.

### Delimiting survey, tracing and surveillance

To determine the appropriate course of action, a thorough delimiting survey should be conducted, followed by tracing of risk goods and active and passive surveillance. This may include the following:

- Intensive surveillance to determine extent of infection of symptomatic and asymptomatic vines within the immediate high-risk zone (within a 500m radius, based on an assumed natural spread distance, see Part 3)
- Passive surveillance to detect other potential focal points of infection
- Conduct tracing based on: plant material movements, movements of pruners or other contractors, movements of soil or sites with close linkages to the infected property/properties (note fruit movements are not required to be traced)
- Tracing should be conducted to determine connectedness of infected property to other sites, which would then be prioritised for diagnostic testing
- Conduct surveillance at high risk trace sites, considering how long the risk item has been there and therefore the probability of detecting a latent infection

## 17.1 Movement Controls

### 17.1.1 Declare a Restricted Place (s130 of the Biosecurity Act 1993)

Infected properties and suspected properties may be declared restricted places as per the case definition below:

- Case definition of an Infected Place (IP): Any property with a MPI validated or confirmed diagnosis of *C. fimbriata*
- Case definition of a Suspected Place (SP): Any property immediately adjacent to an IP, or currently under investigation of having received a high-risk trace item

### 17.1.2 Establish a Controlled Area (s131 of the Biosecurity Act 1993):

A Controlled Area may initially be based on the natural spread zone of *C. fimbriata*, using a precautionary approach until a delimiting survey has been completed. It may therefore include:

- Any infected place and all adjacent properties within a 500m radius
- Any properties that are at risk of water run-off from an infected place. A hydrologist can map how far the organism can spread in water based on spatial spread observed in Brazil

The Controlled Area may increase or decrease in size as delimiting survey results become available.

Things and activities subject to movement controls may include the following:

- No high risk material to leave the Area (high risk material includes all plant material except commercially harvested fruit, as hygiene protocols will apply, and soil)
- No machinery, tools and equipment used in the Area are to be removed unless under permit which will require cleaning and disinfection
- Restrict all pruning activities within the Zone, unless permission is given. This provides oversight of this high-risk activity and associated hygiene and pruning waste. A cleaning and disinfection site may be set-up within the Controlled Area
- Cleaning and disinfection is required for all IP's and SP's
- Stringent hygiene practices for movements of risk items, machinery, vehicles etc.; all movements out of the Controlled Area are only allowed under permit

### 17.1.3 Further considerations for movement controls

- Restricting movement of the infected plant material upon removal is necessary, therefore burning the plants in place may prove effective. However, it is currently unknown whether this may facilitate spread.
- Once all plant material is removed, it is possible that fungicide may speed up the death of *C. fimbriata* in the soil – however this has not been proven. A quarantine policy and testing of the soil after the quarantine period before replanting is likely to be required, or looking at the cultivation of alternative crops resistant to the *C. fimbriata* strain.
- Research suggests that the spores can survive for years in the soil. There may be a need for the property/ properties to remain host free until the spores are no longer considered viable. The planting of an alternate crop is an option, but it may not be a crop that requires tilling or disturbance of the soil, or which could potentially move soil to new sites
- Nurseries that have recently supplied rootstock to the infected site(s) should be quarantined until testing verifies absence of the pathogen. However due to the nature of the pathogen, proving absence may prove challenging and therefore a conservative approach of destroying nursery stock may be required. Consideration as to the best method for managing a nursery stock infection will need to be carefully considered in regards to the confidence of this pathway being the cause
- The kiwifruit growing regions used in the Psa-V response are familiar boundaries that could be used as the basis for movement controls for *C. fimbriata*

## 17.2 Organism management

Organism management on all confirmed infected places is vital in managing the infection. **To date, no proven effective treatments exist to eradicate the pathogen**. However, activities to contain the infection and mitigate the impacts may include the following:

- Removal of infected vines: symptomatic vines, and their surrounding asymptomatic neighbours may be fully removed as a priority
- To help contain the organism, two layers of trenches may be constructed around the infected trees.
- If a suitable product could be found, an agrichemical may also be used to control sporulation

Research suggests that the following practices may be implemented to manage the organism and/or mitigate spread:

### Treatment and removal of infected vines, plant material and soil

- In general, symptomatic plants should be completely removed. Asymptomatic neighbours will also need to be removed to manage root transmission, which has been observed in infected kiwifruit in Brazil. In kiwifruit, it is typical to see a discrete area of infected vines with symptomatic plants at the edge of the expanding infection centre
- Cutting a ring of healthy vines around the infected margin and applying a herbicide treatment (e.g. Tordon Brushkiller which is commonly used on kiwifruit) to all plants within this ring may help kill the root systems. This may be beneficial because it is believed that the fungus can spread within living root tissue. Care needs to be taken to remove as much of the root system as possible
- All sawdust generated should be collected in tarps and properly disposed through deep burial or burning. Diseased plants should not be sawn on a windy day. Removal of vines may occur only after the application of herbicide and once the material is dead, but before leaves and shoots become brittle
- Contaminated soil should be removed carefully. If soil from an infected plant or orchard is moved then the thick-walled aleurioconidia spores can be transported with the soil. The entire area will require treatment with disinfectant or fungicide, to ensure control of the pathogen, however these treatments are unlikely to eradicate the organism.
- It is unknown how effective soil drenches are against the robust aleurioconidia, however if drenches could eliminate the thin-walled and more susceptible conidia spores this would be beneficial as it would reduce inoculum spreading by water movement
- KVH maintains a list of contractors experienced in removing kiwifruit vines as this is routine practice for dealing with abandoned orchards. However, they will need to meet the pruning waste management and cleaning and disinfection requirements under biosecurity movement controls
- Destruction of the removed plant material may involve deep burial or burning. It is currently unknown which destruction would provide the least risk of spreading the organism further

- Deep burial for disposal of *C. fimbriata* infected vines may be suitable once the plant material is dead and the pathogen inactivated. However the pathogen appears to live for a long period in soil so this could contribute to the spread

### Cleaning and disinfection

- Standard biosecurity protocols for cleaning and disinfection need to be adhered to, these are available on the KVH website (www.kvh.org.nz/KVH_Protocols). Ensuring the disinfection of all tools, equipment and machinery with an effective sanitiser (such as alcohol and sodium hypochlorite) is key to managing any infection and mitigating spread

### Pruning

- Pruning wounds have been associated with *Ceratocystis* epidemics internationally. Pruning is especially risky during the warm and moist months of the year when sporulation occurs. If *Ceratocystis* is detected, pruning should cease in the immediate vicinity until delimiting surveys have been completed. The risk of pruning can be reduced by limiting these activities to cold dry periods and by applying a fungicide or appropriate sealant to the pruning wound. Care needs to be taken not to introduce sawdust from pruned material into the sealant and to use a clean applicator

### Trenching

- Trenching may be used to reduce the risk of spread of the pathogen to healthy plants within the area
- Trenching involves putting a primary barrier outside the healthy ring of trees, and a secondary barrier inside the healthy trees. This protects healthy plants from infected vines by preventing any contact between vines, leaves or roots, and effectively providing two layers of protection
- Trenches are usually 1.5m deep, and plastic barriers can be placed inside the trenches to increase their effectiveness

### Chemical controls

There are no chemical controls with proven effectiveness against *C. fimbriata.*

- Wilts of trees are difficult to manage with fungicides because of the large mass of xylem tissue to treat and the difficulty of delivering a sustained dose of protection throughout the tree at a reasonable cost.
- Systemic triazole compounds, such as propiconazole are the common choice for chemical control of *Ceratocystis* wilt. However, these are costly to apply, have limited effectiveness in moving into the root system where preventive doses are needed and are short lived in a living tree.
- There is potential in using propiconazole as a soil drench, but it is not clear if vines or trees pick up enough of the material to apply adequate protection of the whole tree for a significant period of time.

## Resistance

- With most *Ceratocystis* diseases, there is substantial variation in aggressiveness in the pathogen and there is substantial variation in resistance among host species and within host species or hybrids. Selection for resistance and elimination of susceptible cultivars have been major tools for managing *Ceratocystis* in many crops, such as mango, cacao and sweet potato.
- There is potential to identify and utilize resistance in kiwifruit. The three tested cultivars in Rio Grande do Sul all appear to be highly susceptible, but it may be possible to develop resistant rootstocks over the longer term (15 years +). Highly aggressive isolates should be used to select resistant rootstocks. However, resistance is not likely to be the sole answer to *Ceratocystis* wilt in kiwifruit (Harrington 2015).

# 18 Appendix 4: Legislative tools

The following legislations should be considered when formulating or implementing a plan for *C. fimbriata* (this is not an exhaustive list):

| Legislation | Reason |
|---|---|
| Biosecurity Act 1993 | • Ensuring that the actions within the plan are allowed under the powers bestowed under this Act<br>• Considering potential compensation claims<br>• Joint decision making under GIA<br>• Requirements of long term pest management |
| Conservation Act 1987 | Should native or DOC estate plants be infected, this Act may come into play |
| Hazardous Substances and New Organisms Act 1996 | Any chemical treatments will need to be used in compliance with this Act |
| Health and Safety at Work Act 2015 | MPI & GIA signatories involved in readiness and response activities need to ensure;<br>• safety of staff; and<br>• safety of contractors hired and that they have suitable health and safety procedures. |
| Local Government Act 2002 | Should Regional or District Councils be involved, this Act may need to be considered in terms of what a Council may or may not do |
| Resource Management Act | May require consulting – however certain exemptions are possible under Section 7A of the Biosecurity Act |

For further information, refer to Section 7 of the Biosecurity Act 1993

# 19 Appendix 5: Supplementary Information supplied by KVH

## Impacts to kiwifruit

Kiwifruit is a particularly susceptible crop to this pathogen with infection resulting in severe production impacts.

## Production impacts - The kiwifruit epidemic in Rio Grande do Sul (Brazil)

In 2010, *Ceratocystis* wilt was first observed in kiwifruit plants in the Farroupilha area of Rio Grande do Sul, Brazil where it is now causing significant mortality on some orchards. Since its first report, kiwifruit vine mortality has varied 10-30% per year in affected orchards and some growers are likely to cease commercial production of kiwifruit. Kiwifruit, a crop considered to have significant potential profitability for the region, may no longer be economically viable.

It is thought that Rio Grande do Sul is the first location of commercial kiwifruit within the natural range of *C. fimbriata,* explaining why impacts on kiwifruit have not been reported previously. However, the genetic diversity of strains infecting kiwifruit in Rio Grande do Sul indicates that *C. fimbriata* strains from across South America could potentially be aggressive on kiwifruit. Pathogenicity testing of eight isolates from kiwifruit, representing the maximum genetic diversity, were all found to be not only pathogenic but capable of killing vines in each of the three kiwifruit cultivars inoculated into (Elmwood, Monty and Hayward). While all three of these cultivars were highly susceptible, Elmwood showed less mortality that Monty and Hayward (Harrington 2015).

Observation of infected vines in Brazil, suggest that Hayward on Bruno rootstock is one of the most susceptible varieties (O'Neil 2014). This is extremely concerning for the New Zealand kiwifruit industry as Hayward represents over 60% of the industry by volume and the overwhelming majority is grown on Bruno rootstock.

***The conclusion of*** **these genetic and pathogenicity studies is that other kiwifruit production areas around the world are likely vulnerable to other *C. fimbriata* strains, not just Brazil.**

## Symptoms

Wilting is the first symptom, with complete vine collapse occurring as quickly as three days after infection. Dead vines are often adjacent to each other creating a circle of dead vines as the disease moves through soil and root systems. Browning of the xylem can be seen in infected vines moving from canes to leaders, trunks and even down to roots. Some Psa-like leaf spotting can be present (Figure 4).

Wilting and dying plants should be inspected closely for vascular discoloration of the woody xylem. A horizontal cross section of the wood will often show a radial pattern to the staining, while longitudinally the discoloration is often in streaks. Other fungi can induce similar discoloration, although this will typically be more solid and less "streaky". If *C. fimbriata* infection is suspected diagnosis can be confirmed with microscopic examination or PCR analysis (see Section 3 Diagnostics).

**Figure 4.** Symptoms of *C. fimbriata* infection in kiwifruit (Brazil) Clockwise from top; leaf wilt and curl, cane shrivelling and vine discoloration

## Host range

In the last 15 years, new host crops and new epidemics of Ceratocystis wilt have been reported frequently, especially in Brazil and Asia (Harrington 2015). Kiwifruit is an example of a sudden appearance on a new host. Kiwifruit has been cultivated in Rio Grande do Sul (Brazil) for many years with little previous loss to Ceratocystis wilt, however recently impacts have becomes so severe that cultivation of this crop may no longer be economical in this region.

Of the four *C. fimbriata* clades, the Latin American Clade (LAC) contains the most commonly reported plant pathogens, the most aggressive strains have been detected on hosts that are not native to South America.

Over 30 types of plants are attacked by the *Ceratocystis fimbriata* complex (see Appendix 5 for a complete list). Eight hosts in particular, have been identified as being as highly susceptible to multiple genotypes of the pathogen, these are;

- Mango (*Mangifera*);
- *Eucalyptus* sp. and their hybrids;
- Pomegranate (*Punica*)
- *Acacia* spp.;
- edible figs (*Ficus*);
- taro and other *Araceae* family (a.k.a. arum family or aroids);
- *Crolotaria* (genus of herbaceous plants & woody shrubs); and
- **Kiwifruit (*Actinidia* sp.)**

## Current distribution

*Ceratocystis fimbriata* has a worldwide distribution, including a strain within New Zealand infecting kumara which is host specific and not pathogenic to kiwifruit (Tyson et al. 2015). The *Ceratocystis fimbriata* complex has caused notable losses in a diverse range of hosts on over 40 countries, a complete list is provided in Appendix 6.

Impacts on kiwifruit have only been reported in Brazil in the region of Rio Grande do Sul. This strain is of particular concern to the New Zealand kiwifruit industry along with the strains causing two other recent outbreaks in other hosts. One is in South China where a closely-related *C. fimbriata* strain has been found on *Eucalyptus*, taro, and loquat, and these strains are causing substantial mortality of pomegranate in Yunnan and Sichuan. A second population is causing extensive mortality of mango in Oman and Pakistan, pomegranate in India, and Acacia in Indonesia. These populations of *C. fimbriata* have genetic characteristics of South American populations of *C. fimbriata*, but the threat of new introductions from Asia may be greater than the threat of new introductions from South America (Harrington 2015).

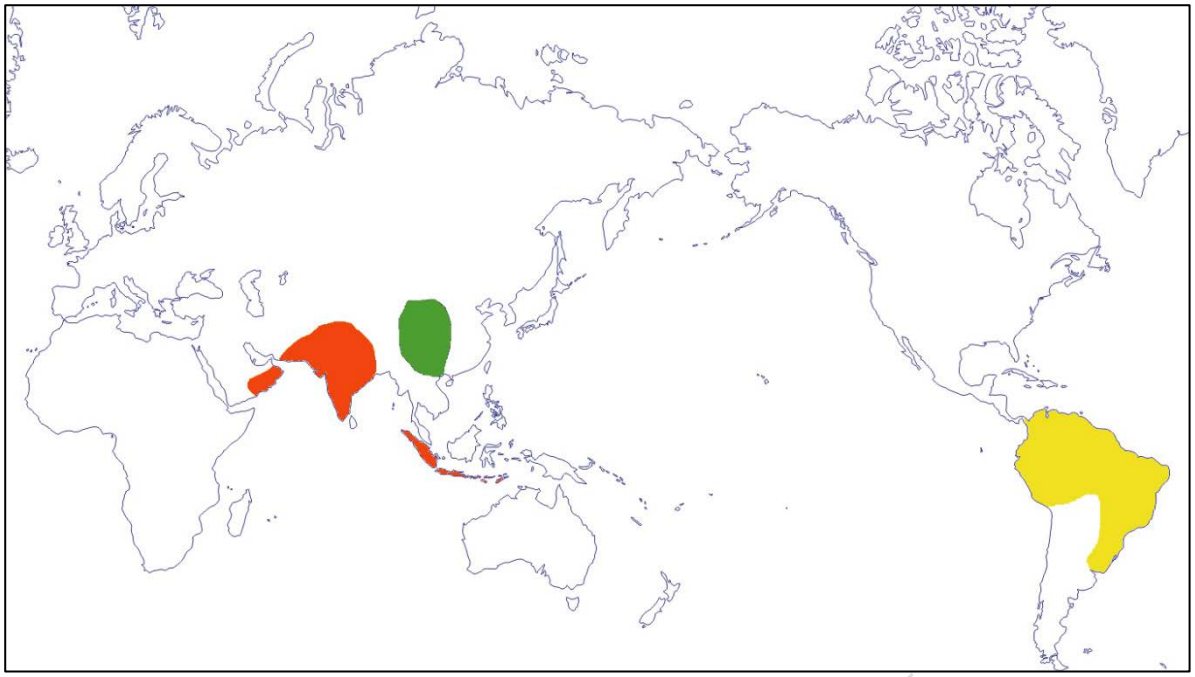


**Figure 5.** Populations of *C. fimbriata* known, or most likely, to be pathogenic to kiwifruit; South America (yellow), South China outbreak (green), and the Oman/Pakistan outbreak (orange).


**Figure 6.** Rio Grande do Sul Brazil, marked in yellow, where *Ceratocystis fimbriata* is causing significant production impacts to kiwifruit.

## Key documents on the KVH website

Unless stated otherwise, the following documents are available on the KVH website (www.kvh.org.nz/emerging_risks)

**Literature review on the threat to kiwifruit production (Feb 2015)**

Professor Tom Harrington, an international *Ceratocystis* expert, was commissioned to complete a literature review to better understand the potential impact of this pathogen to the New Zealand kiwifruit industry. A summary of this review can be found on the KVH website, the full document is available from KVH or Zespri.

***Ceratocystis fimbriata*** **fact sheet** – one page summary document

**Presentation providing overview of symptoms & research,** Joy Tyson (PFR) presented to KiwiNet (Dec 2015)

**Trip report to infected orchards in Brazil,** Barry O'Neil (Feb 2014)

## Sources of technical information and advice

| Name & organisation | Area of expertise | Contact details |
|---|---|---|
| Brett Alexander | Manager Mycology and Bacteriology | Brett.alexander@mpi.govt.nz<br>09 909 5724 |
| Joy Tyson (PFR) | Plant pathologist - visited Brazil site and conducted NZ pathogenicity trials | joy.tyson@plantandfood.co.nz<br>021 026 76200 |
| Mike Manning (PFR) | Plant pathologist - visited Brazil site and conducted NZ pathogenicity trials | Mike.Manning@plantandfood.co.nz<br>021 226 8130 |
| Tom Harrington (Iowa State University, USA) | International Expert – Author of literature review for Zespri / KVH | tcharrin@iastate.edu |

## Other sectors involved who may have an interest

Although at this time, kiwifruit (and kiwiberry) is the focus of this plan for *C. fimbriata*, should a strain enter the country, the following sectors and agencies may be affected or interested:

- Department of Conservation
- Regional Councils
- Nursery sector
- Forestry industry
- Farm forestry sector
- Citrus growers
- Other horticulture growers

# 20 Appendix 6: Host and country associations of *C. fimbriata*

Countries and host genera with notable disease losses caused by members of the Australasian (AAC), African (AFC), North American (NAC) and Latin American (LAC) Clades of the *Ceratocystis fimbriata* complex.

| **REGION / COUNTRY** | **HOSTS AFFECTED** | **CLADE AND PROBABLE SPECIES** | **REFERENCES** |
|---|---|---|---|
| **NORTH AND CENTRAL AMERICA** | | | |
| CANADA | *Populus* (poplar tree) | NAC (*C. harringtonii*) | Hinds 1985, Vujanovic et al. 1999 |
| COSTA RICA | *Theobroma* (Cacao), *Herrania* (close rel to Cacao) | LAC (*C. cacaofunesta*) | Baker et al. 2003, Engelbrecht et al. 2007a |
| | *Hevea* (rubber) | LAC (unconfirmed) | Martin 1949 |
| | *Coffea* (coffee) | LAC (*C. fimbriata*) | Baker et al. 2003, Echandi and Segall 1956, Siller 1958 |
| CUBA | *Spathodea* (African tulip tree) | LAC (*C. fimbriata*) | Herreira Isla and Ravelo 1989 |
| | *Citrus* | LAC (unconfirmed) | Rodriguez and Alfonso 1978 |
| | *Colocasia* (flowering plant) | LAC (*C. fimbriata*) | Thorpe et al. 20015, Triana and Diaz 1989 |
| DOMINICAN REP | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Schieber 1969 |
| GUATEMALA | *Coffea* (coffee) | LAC (*C. fimbriata*) | Baker et al. 2003, Schieber and Sosa 1960, Szkolnik 1951, Tejada 1983 |
| | *Hevea* (rubber) | LAC (*C. fimbriata*) | unpublished |
| HAITI | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Barker 1926 |
| JAMAICA | *Pimenta* (flowering plant) | LAC (unconfirmed) | Leather 1966 |

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|---|---|---|---|
| MEXICO | *Hevea* (rubber) | LAC (*C. fimbriata*) | Martin 1947, unpublished |
| ST VINCENT | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | BPI specimen 596219 |
| TRINIDAD | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Baker and Dale 1951 |
| | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Iton 1959 |
| UNITED STATES | *Populus* (poplar tree) | NAC (*C. harringtonii*) | Hinds 1972a, Hinds 1985, Johnson et al. 2005 |
| | *Platanus* (plane trees) | LAC (*C. platani*) | McCracken and Burkhardt 1977, Perry and McCain 1988, Walter 1946 |
| | *Prunus* (plums, cherries, peaches, nectarines, plums and apricots) | NAC (*C. variospora*) | DeVay et al. 1968, Johnson et al. 2005, Teviotdale and Harper 1991 |
| | *Quercus* (Oak) | NAC (*C. variospora*) | Johnson et al. 2005 |
| | *Carya* (Hickory) | NAC (*C. smalleyi*) | Johnson et al. 2005, Park et al. 2010, 2013 |
| | *Tilia* (aka lime tree but not citrus) | NAC (*C. variospora*) | Johnson et al. 2005 |
| | *Colocasia, Syngonium* (flowering plants) | LAC (*C. fimbriata*) | Alfieri et al. 1994, Davis1953, Thorpe et al. 2005, Uchida and Aragaki 1979 |
| | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Baker et al. 2003, Webster and Butler 1967 |
| | *Colocasia* (flowering plants) | AAC (unknown) | Hawaii Thorpe et al. 2005, unpublished |
| **SOUTH AMERICA** | | | |
| BRAZIL | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Baker et al. 2003, Bastos and Evans 1978, Bezerra 1997, Engelbrecht et al. 2007a |

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|---|---|---|---|
| | *Hevea* (rubber) | LAC (*C. fimbriata*) | Albuquerque et al. 1972, Pereira and Santos 1986, Silveira et al. 1985 |
| | *Eucalyptus* | LAC (*C. fimbriata*) | Ferreira et al. 1999, Alfenas and Ferreira 2008 |
| | *Crotolaria* (woody shrub) | LAC (*C. fimbriata*) | Batista 1947, Chardon et al. 1940, Melo-Filho et al. 2002, Muller 1937 |
| | *Gmelina* (flowering plant sp) | LAC (*C. fimbriata*) | Muchovej et al. 1978 |
| | *Acacia* (Acacia tree) | LAC (*C. fimbriata*) | Ribeiro et al. 1988, Santo and Ferreira 2003 |
| | *Annona* (sugar apple) | LAC (*C. fimbriata*) | Baker et al. 2003, Silveira et al. 2006 |
| | *Cassia* (flowering plant sp.) | LAC (*C. fimbriata*) | Galli 1958, Ribeiro et al. 1987 |
| | *Ficus* (Fig) | LAC (*C. fimbriata*) | Figueiredo and Pinheiro 1969, Valarini and Tokeshi 1980 |
| | *Mangifera* (mango) | LAC (*C. fimbriata*) | Arruda 1940, Batista 1960, Viégas 1960 |
| | *Colocasia* (flowering plant) | LAC (*C. fimbriata*) | Harrington et al. 2005 |
| | *Actinidia* (kiwifruit) | LAC (*C. fimbriata*) | Ferreira et al. 2013, Sonego et al. 2010 |
| | *Carapa* (Mahogony) | LAC (*C. fimbriata*) | Halfeld-Vieira et al. 2012 |
| | *Tectona* (teak) | LAC (*C. fimbriata*) | Firmino et al. 2012 |
| COLOMBIA | *Coffea* (coffee) | LAC (*C. colombiana*) | Marin et al. 2003, Pontis 1951, van Wyk et al. 2010, Harrington et al. 2014 |

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|---|---|---|---|
| | *Citrus* | LAC (*C. colombiana*) | Borja et al. 1995, Marin et al. 2003, Mourichon 1994, van Wyk et al. 2010, Harrington et al. 2014 |
| | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Arbelaez 1957, Garces 1944, Engelbrecht et al. 2007a |
| ECUADOR | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Desrosiers and Diaz 1956, Engelbrecht et al. 2007a, Rorer 1918 |
| GUYANA | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Bisessar 1965 |
| PERU | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Krug and Quartey-Papafio 1964, Soberanis et al. 1999 |
| | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Rada 1939 |
| SURINAME | *Coffea* (coffee) | LAC (*C. fimbriata*) | Baker et al. 2003 |
| URAGUAY | *Eucalyptus* | LAC (*C. fimbriata*) | Barnes et al. 2003b |
| VENEZUELA | *Coffea* (coffee) | LAC (unconfirmed) | Pontis 1951 |
| | *Crotolaria* (woody shrub) | LAC (unconfirmed) | Malaguti 1952a |
| | *Theobroma* (Cacao) | LAC (*C. cacaofunesta*) | Malaguti 1952b |
| **ASIA** | | | |
| CHINA | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Hu et al. 1999, Sy 1956 |
| | *Punica* (pomegranate) | LAC (*C. fimbriata*) | Harrington et al. 2015, Huang et al. 2003, Xu et al. 2011 |
| | *Eucalyptus* | LAC (*C. fimbriata*) | Chen et al. 2013, Harrington et al. 2015 |
| | *Eriobotrya* (flowering plants) | LAC (*C. fimbriata*) | Li et al. 2014a, Harrington et al. 2015 |

| | | | |
|---|---|---|---|
| | *Colocasia* (flowering plants) | LAC (*C. fimbriata*) | Harrington et al. 2015, Huang et al. 2003 |
| | *Colocasia* (flowering plants) | AAC (near *C. polychroma*) | Thorpe et al. 2005, unpublished |
| | *Eucalyptus* | AAC (near *C. polychroma*) | Li et al. 2014b, unpublished |
| INDIA | *Punica* (pomegranate) | LAC (*C. fimbriata*) | Somasekhara 1999, Somasekhara and Wali 2000, unpublished |
| | *Hevea* (rubber) | AAC (unconfirmed) | Ramakrishnan and Radhakrishna 1963 |
| INDONESIA | *Acacia* (Acacia tree) | LAC (*C. fimbriata*) | Tarigan et al. 2011, unpublished |
| | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Unpublished |
| | *Hevea* (rubber) | AAC (unconfirmed) | Leefmans 1934, South and Sharples 1925, Tayler and Stephens 1929, Wright 1925 |
| | *Coffea* (coffee) | AAC (unconfirmed) | Zimmermann, 1900 |
| | *Styrax* (large shrubs) | AAC (*C. larium*) | van Wyk et al. 2009 |
| JAPAN | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Asuyama 1938, Kajitani and Kudo 1993, Okamoto 1940 |
| | *Colocasia* (flowering plants) | AAC (unconfirmed) | Shimizu 1939 |
| | *Ficus* (fig) | AAC (*C. ficicola*) | Kajitani and Kudo 1993, Kato et al. 1982 |
| MALAYSIA | *Hevea* (rubber) | AAC (unconfirmed) | Beeley 1929, South and Sharples 1925 |

| | | | |
|---|---|---|---|
| MYANMAR | *Hevea* (rubber) | AAC (unconfirmed) | Turner and Myint 1980 |
| PAKISTAN | *Mangifera* (mango) | LAC (*C. fimbriata*) | Fateh et al. 2006, Harrington et al. 2014, van Wyk et al. 2007 |
| | *Dalbergia* (shrub) | LAC (*C. fimbriata*) | Poussio 2010, Harrington et al. 2014 |
| TAIWAN | *Crotolaria* (woody shrub) | Unknown | Lee and Kuo, 1997 |
| **OCEANIA** | | | |
| AUSTRALIA | *Syngonium* (tropical flowering plant) | LAC (*C. fimbriata*) | Thorpe et al. 2005, Walker et al. 1988 |
| FIJI | *Xanthosoma* (tropical flowering plant) | AAC (near *C. polychroma*) | Firman 1972, Graham1965, Thorpe et al. 2005, Walker et al. 1988, unpublished |
| NEW ZEALAND | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Baker et al. 2003, Slade 1960 |
| PAPUA NEW GUINEA | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Baker et al. 2003 |
| | *Hevea* (rubber) | AAC (unconfirmed) | Mann 1953 |
| WESTERN SAMOA | *Colocasia* (flowering plant) | AAC (unconfirmed) | Walker et al. 1988 |
| **MIDDLE EAST** | | | |
| OMAN | *Mangifera* (mango) | LAC (*C. fimbriata*) | Harrington et al. 2014, van Wyk et al. 2007 |
| | *Prosopis* (spiny trees & shrubs) | LAC (*C. fimbriata*) | Al-Adawi et al. 2013 |
| **AFRICA** | | | |
| CONGO | *Eucalyptus* | LAC (*C. fimbriata*) | Roux et al. 2000 |
| COTE D'IVOIRE | *Crotalaria* (woody shrub) | unconfirmed | Davet 1962 |

| | | | |
|---|---|---|---|
| KENYA | *Ipomoea* (sweet potato) | LAC (unconfirmed) | Kihurani et al. 2000 |
| UGANDA | *Eucalyptus* | LAC (*C. fimbriata*) | Roux et al. 2001 |
| | *Acacia* (Acacia tree) | AFC (*C. albifundus*) | Barnes et al. 2005 |
| SOUTH AFRICA | *Eucalyptus* | LAC (*C. fimbriata*) | van Wyk et al. 2012, Harrington et al. 2014 |
| | *Acacia* (Acacia tree) | AFC (*C. albifundus*) | Roux et al. 2000, Barnes et al. 2005 |
| **EUROPE** | | | |
| AZORES | *Ipomoea* (sweet potato) | LAC (*C. fimbriata*) | Bensaude 1927 |
| FRANCE | *Platanus* (plane trees) | LAC (*C. platani*) | Ferrari and Pechenot 1974, Grosclaude et al. 1991, Vigouroux 1986 |
| ITALY | *Platanus* (plane trees) | LAC (*C. platani*) | Panconesi 1999 |
| GREECE | *Platanus* (plane trees) | LAC (*C. platani*) | Ocasio-Morales et al. 2007 |
| POLAND | *Populus* (poplar trees) | NAC (*C. harringtonii*) | Gremmen and de Kam 1977, Przybyl 1984 |
| SWITZERLAND | *Platanus* (plane trees) | LAC (*C. platani*) | Matasci and Gessler1997 |