Importation of Fresh Bananas from the Philippines

revised Draft IRA Report

February 2004
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<td>ALOP</td>
<td>Appropriate level of protection</td>
</tr>
<tr>
<td>AQIS</td>
<td>Australian Quarantine and Inspection Service</td>
</tr>
<tr>
<td>Area</td>
<td>An officially defined country, part of a country or all or parts of several countries</td>
</tr>
<tr>
<td>Banana(s)</td>
<td>Banana fruit unless otherwise indicated in this document</td>
</tr>
<tr>
<td>Biosecurity Australia</td>
<td>an operating group within the Australian Government Department of Agriculture, Fisheries and Forestry</td>
</tr>
<tr>
<td>BPI</td>
<td>Bureau of Plant Industry (Philippines)</td>
</tr>
<tr>
<td>Control (of a pest)</td>
<td>Suppression, containment or eradication of a pest population</td>
</tr>
<tr>
<td>CSIRO</td>
<td>Commonwealth Scientific and Industrial Research Organisation</td>
</tr>
<tr>
<td>DAFF</td>
<td>Australian Government Department of Agriculture, Fisheries and Forestry: formerly AFFA (Agriculture, Fisheries and Forestry – Australia)</td>
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<tr>
<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<tr>
<td>Fresh</td>
<td>Not dried, deep-frozen or otherwise conserved</td>
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<tr>
<td>GATT</td>
<td>General Agreement on Tariffs and Trade</td>
</tr>
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<td>Imp</td>
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<td>IPPC</td>
<td>International Plant Protection Convention, as deposited in 1951 with FAO in Rome and as subsequently amended</td>
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<td>IRA</td>
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<td>Likelihood</td>
<td>Probability</td>
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<td>ISPM</td>
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<td>PBPM</td>
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Pest..................................................Any species, strain or biotype of plant animal or
pathogenic agent injurious to plants or plant products
(IPPC definition)

PQS .................................................Philippine Quarantine Service

PRA ..............................................Pest risk analysis

Probability.................................Likelihood

Quarantine pest..............................A pest of potential economic importance to the area
endangered thereby and not yet present there, or present
but not widely distributed and being officially controlled
(IPPC definition)

SPS .................................................Sanitary and Phytosanitary

SPS Agreement ................................WTO Agreement on the Application of Sanitary and
Phytosanitary Measures

TWG ..............................................Technical Working Group

WTO ..............................................World Trade Organization
EXECUTIVE SUMMARY

In June 2000, Australia initiated an import risk analysis (IRA) on Philippines bananas following provision of necessary technical information by the Philippines Bureau of Plant Industry (BPI) in May 2000.

BPI in their submission requested a risk analysis of a proposal to export fresh mature hard green banana fruit to Australia. BPI proposed exports of four varieties of Cavendish (Extra Dwarf, Giant Cavendish, Grand Nain and Williams) and Gros Michel from the Mindanao region (Davao, Cotabato and Bukidnon) in the Philippines.

An IRA team (then referred to as a Risk Analysis Panel) was established to conduct the IRA. The members are:

Dr Cheryl McRae Chair
Senior Manager — Biosecurity Development and Evaluation
Biosecurity Australia

Dr Sharan Singh Manager — Plant Biosecurity
Biosecurity Australia

Dr Rob Allen Principal Policy Officer — Plant Health
Queensland Department of Primary Industries

Dr Bryan Cantrell Principal Policy Officer — Plant Health
Queensland Department of Primary Industries

Mr Bob Paton Policy Officer — Market Access
New South Wales Agriculture

Mr David Peasley Horticultural Consultant

Mr Mike Robbins Manager — Grain, Seed and Nursery Stock
Australian Quarantine and Inspection Service

The IRA team established three technical working groups to assist its consideration of pathogen, arthropod, and horticulture, environment and operational issues relevant to the IRA. In May 2001, Biosecurity Australia released an Issues Paper on the BPI proposal for stakeholder comment. In October 2001, following stakeholder comments on the Issues Paper and discussions with the Chairs of technical working groups during their visit to the Philippines, BPI clarified that the proposed export area of Davao means Davao del Sur, Davao del Norte and Davao Oriental and Cotabato means South Cotabato, North Cotabato and Sarangani. At the same time, BPI also advised Biosecurity Australia that the cultivar Gros Michel was no longer produced in Philippines banana plantations.

In June 2002, Biosecurity Australia released a Draft IRA Report for stakeholder comment. Twenty submissions were received on the draft report, including substantial comments from the Philippines Government and industry, the Australian Banana Growers’ Council (ABGC) and the Western Australian Government. In addition to stakeholder submissions on the June 2002 Draft IRA Report, supplementary comments and reports relevant to the IRA were received from ABGC and the Philippines Government.
Given the substantial nature of the various submissions and reports, and the widely varying technical viewpoints, the IRA team considered it appropriate to undertake an extensive review of the technical information concerning each of the quarantine pests identified in the IRA. Additionally, the IRA team reviewed the various other technical issues arising from the submissions and reports.

As a consequence, the IRA team identified the need to make significant changes to the analysis as reported in the June 2002 Draft IRA Report. For this reason this report is issued as a revised Draft IRA Report that takes into account the stakeholder submissions and reports, and technical information available to the IRA team.

This revised Draft IRA Report describes the procedures followed to identify and assess the biosecurity risks associated with the importation into Australia of fresh mature hard green Cavendish banana fruit of four varieties (Extra Dwarf, Giant Cavendish, Grand Nain and Williams) from specified areas of Davao (Davao del Sur, Davao del Norte and Davao Oriental), Cotabato (South Cotabato, North Cotabato and Sarangani) and Bukidnon in the Mindanao region, the Philippines. The report also considers and evaluates, as appropriate, risk management measures. It presents recommendations on proposed biosecurity measures sufficient to ensure that Australia’s appropriate level of protection (ALOP) is maintained.

This report contains the following:

- Australia’s framework for biosecurity policy and IRAs, information on the background to this IRA, a summary of the banana industries in the Philippines and Australia, and Australia’s biosecurity policies for fresh bananas;
- An outline of the methodology and results of pest categorisation, risk assessment and risk management;
- An assessment of contaminants of banana shipments from the Philippines;
- Draft quarantine import conditions for fresh mature hard green banana fruit from the Philippines;
- Information about further steps in the IRA process.

**Australia’s current biosecurity policies for fresh bananas**

Fresh banana fruit for human consumption are not currently imported by Australia.

Fresh banana fruit may be imported for *in-vitro* laboratory work under secure quarantine conditions, and at Quarantine Approved Premises. Strict quarantine conditions are observed for these imports, including a requirement that packaging materials and containers be disposed of by incineration, autoclaving or other methods approved by the Director of Animal and Plant Quarantine. The goods in each consignment must be packaged securely and transported directly to a facility approved by AQIS for laboratory analysis. Samples must be in clean, new packaging and must be free from quarantine pests and other regulated articles (eg soil).

The importation of certain ‘banana products’ from several countries, including the Philippines, is permitted. Banana products include cooked, dried and canned or preserved product.

Movement of banana fruit and banana planting material within Australia may also be subject to intrastate and interstate quarantine restrictions dependent on State and Territory plant health concerns.
Import risk analysis

The technical component of an import risk analysis for plants or plant products is termed a ‘pest risk analysis’, or PRA. As stated in the International Plant Protection Convention’s International Standards for Phytosanitary Measures Publication Number 11 (ISPM 11 – Rev. 1) — Pest Risk Analysis for Quarantine Pests including analysis of environmental risks, a PRA comprises three discrete stages:

• initiation of the PRA;
• risk assessment; and
• risk management.

Initiation of this PRA

As described above, this IRA Report was initiated by a proposal from the Philippines to export fresh hard green Cavendish banana fruit to Australia. The following PRA flows from that proposal and is the technical component of the IRA Report. The PRA area considered in this report is Australia.

International standards to address the specific quarantine concerns associated with imports of bananas do not exist, nor has Australia completed a risk analysis of this commodity. In addition, Australia does not import fresh hard green Cavendish bananas for consumption from other countries, nor does it have existing import conditions upon which to base a response to the Philippines proposal.

In consideration of these issues, an analysis of the biosecurity risk associated with fresh hard green bananas from the Philippines was required.

A list of pests likely to be associated with fresh hard green bananas from the Philippines (i.e. the biosecurity risk pathway) was generated from information supplied by the Philippines Government and banana industry, literature searches, databases and expert consultation. This list was used in the risk assessment stage of the PRA.

Pest Categorisation

Ninety-nine pests of bananas were categorised according to their presence or absence in Australia, their association with banana fruit, their potential to become established in Australia, and the potential consequences of establishment. From these, 22 were identified as quarantine pests and were the focus of individual risk assessments.

These pests are:

• Banana bract mosaic virus
• Banana bunchy top virus
• *Ralstonia solanacearum* Race 2 (Moko)
• *Guignardia musae* (freckle)
• *Mycosphaerella fijiensis* (black Sigatoka)

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1 PRA is used throughout this document as an abbreviation of Pest Risk Analysis. The Australian Government Department of Agriculture, Fisheries and Forestry uses the term PRA to describe the technical component of an import risk analysis on plants or their products.
• *Fusarium oxysporum* f.sp. *cubense* (Panama disease)
• Mealybugs — *Dysmicoccus neobrevipes; Pseudococcus jackbeardsleyi; Rastrococcus invadens*
• Weevils — *Philicoptus demissus; P. iliganus; P. stringifrons; P. sp.1; P. sp.2*
• Hard scales — *Aspidiotus excisus; A. coryphae; Pinnaspis musae*
• Fruit flies — *Bactrocera occipitalis; B. philippinensis*
• Spider mites — *Oligonychus orthius; O. velascoi; Tetranychus piercei*

Additionally, other organisms that may enter Australia with shipments of Philippines bananas—‘contaminants of banana shipments’ (as opposed to those quarantine pests that were identified as being pests of banana fruit) were considered to be of quarantine concern. Of these, 52 weeds were classified as quarantine pests. It was considered that other quarantine pests might also be found among five groups of possible non-weed contaminants of banana shipments (mammals, amphibians, reptiles, molluscs and arthropods).

**Assessment and management of risk**

The unrestricted biosecurity risk\(^2\) was assessed by combining the estimates of the likelihoods of entry, establishment or spread of each quarantine pest or group of pests with the consequences of their entry, establishment or spread. Evaluation of consequences included harm to the environment, including impacts on native species.

In relation to Moko, freckle, and two species of *mealybugs* (*Dysmicoccus neobrevipes; Pseudococcus jackbeardsleyi*) the unrestricted biosecurity risk was assessed as being too high to meet Australia’s ALOP. For all other pests of Philippines banana fruit, the unrestricted risk was assessed as being sufficiently low as to meet Australia’s ALOP.\(^3\)

The 2002 *Draft IRA Report* assessed the unrestricted biosecurity risk of black Sigatoka as being too high to meet Australia’s ALOP. However, the IRA team, on reviewing the scientific evidence, considered that the unrestricted risk associated with black Sigatoka was in fact acceptable. Black Sigatoka is a *leaf* pathogen and not a pathogen of banana *fruit*. The finding that risk management is not required for black Sigatoka is based on a detailed assessment of, among other things, the likelihood of particulate leaf trash being associated with packed fruit, the likelihood of the fungus being on these tiny pieces of trash and the likelihood that the fungus would be viable, as well as the likelihood that the fungus, if present, would be distributed to a susceptible host.

\(^2\) Unrestricted risk estimates are those derived in the absence of specific risk management measures; or using only internationally accepted baseline risk management strategies. In contrast, restricted or mitigated risk estimates are those derived when ‘risk management’ is applied. In the case of this *Draft IRA Report*, unrestricted risk is the risk associated with fruit produced to the standard achieved through risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas, as described in documentation provided by the Philippines, as well as pre-export and on-arrival quarantine inspections.

\(^3\) Note that fruit of all kinds entering Australia is subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that may be associated with it.
Summary of risk management measures

Risk management describes the process of identifying and implementing measures to mitigate risks so as to achieve ALOP, or tolerance for loss, while ensuring that any negative effects on trade are minimised.

Various possible biosecurity measures to manage the identified risks for Moko, freckle, and mealybugs were considered, with key areas of focus being the need to reduce the risks associated with:

- symptomless infection for Moko and freckle and hence potential entry, establishment or spread of these diseases through imported fruit;
- transmission of freckle in particulate trash; and
- mealybug infestation, particularly in the spaces between banana fruit.

**Moko**

Two feasible risk management measures were identified for Moko: sourcing fruit for export from areas of low pest prevalence (ALPP); and restricting the distribution of Philippines bananas in Australia.

Bananas from the Philippines could be granted access if they were sourced from an Australian approved plantation area, which can demonstrate that the prevalence of Moko is below a level deemed acceptable by Australia – an ALPP. The low pest prevalence (LPP) level for Moko in an approved ALPP would not exceed 0.005 cases (infected mats) per hectare per week, which is about 1 case per 4 hectares per year – i.e. no more than one in 6,800 infected plants per year. This LPP level would be demonstrated by weekly surveys over a minimum period of 2 years immediately preceding harvest of fruit intended for export to Australia. If the prevalence of Moko exceeded the set LPP level, the affected area would be suspended for a minimum period of 2 years.

As an alternative to sourcing fruit from LPP areas within the Philippines, Philippines banana fruit could be granted access if the port of importation and the distribution of that fruit in Australia were restricted to those parts where commercial banana production does not occur. This measure would be in addition to the risk management practices used in the production and processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in documentation provided by Philippines Department of Agriculture and described in this Draft IRA Report. Restricting the distribution of Philippines bananas in Australia could be implemented by the Australian Commonwealth Government using the Quarantine Act 1908 and its subordinate legislation.

Each of these measures would provide security sufficient to meet Australia’s ALOP. The major difference between sourcing fruit for export from areas of LPP and restricting the port of importation and the distribution of Philippines bananas in Australia is likely to be in relation to the time required and the administrative complexity of providing for their implementation. The administration of the restriction on the movement of Philippines banana fruit would require additional arrangements and resources to address such issues as monitoring, auditing and non-compliance. The cost of these arrangements and resources would be borne by importers or wholesalers also necessitating the need to develop infrastructure for cost recovery.

It was considered that the time required to develop the suite of legal, administrative and operational arrangements that would be necessary to give the restricted distribution of Philippines banana fruit practical application in Australia is likely to be longer than the time required to demonstrate areas
with Moko prevalence at or below the specified LPP level. On this basis, the use of ALPP was considered to be the least trade restrictive of the two risk management options and is the recommended measure.

**Freckle**

Two feasible risk management measures were identified for freckle: sourcing fruit for export from areas of low pest prevalence; and restricting the distribution of Philippines bananas in Australia.

Bananas from the Philippines could be access if they were sourced from an Australian approved plantation area, which can demonstrate that the prevalence of freckle is below a level deemed acceptable by Australia – an ALPP. The low pest prevalence (LPP) level for freckle in an approved ALPP would not exceed 1 case per hectare per week – i.e. no more than one case per 1700 plants per week where a case is defined as the detection of freckle symptoms on any part of a mat from which a bunch could be harvested. This LPP would be demonstrated by weekly survey data over a minimum period of 4 weeks immediately preceding fruit harvest intended for export to Australia. If the prevalence of freckle exceeds the set level, the affected area shall be suspended for a minimum period of 4 weeks.

As an alternative to sourcing fruit from low pest prevalence areas within the Philippines, Philippines banana fruit could be granted access if the port of importation and the distribution of that fruit in Australia was restricted to those parts where commercial banana production does not occur. This measure would be in addition to the risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in documentation provided by Philippines Department of Agriculture and described in this *Draft IRA Report*. Restricting the distribution of Philippines bananas in Australia could be implemented by the Commonwealth Government using the *Quarantine Act 1908* and its subordinate legislation.

Each of these measures would provide security sufficient to meet Australia’s ALOP. The major difference between using ALPPs and restricting the distribution of Philippines banana fruit in Australia is likely to be in relation to the time required and the administrative complexity of providing for their implementation. The administration of the restriction on the movement of Philippines banana fruit would require additional arrangements and resources to address such issues as monitoring, auditing and non-compliance. The cost of these arrangements and resources would be borne by importers or wholesalers also necessitating the need to develop infrastructure for cost recovery.

It was considered that the time required to develop the suite of legal, administrative and operational arrangements that would be necessary to give the restricted distribution of Philippines banana fruit practical application in Australia is likely to be longer than the time required to demonstrate areas with freckle prevalence at or below the specified LPP level. On this basis, the use of ALPP was considered to be the least trade restrictive of the two risk management options and is the recommended measure.

**Mealybugs**

Additional packing station measures would be required to reduce the biosecurity risk associated with the mealybugs *D. neobrevipes* and *P. jackbeardsleyi* to meet Australia’s ALOP. While no individual risk management measures were identified, a combination of targeted inspection of the spaces between banana fingers by quality assurance staff and targeted sponging and brushing between banana fingers by packing station staff assigned to these duties was considered to be the
least trade restrictive risk management measure combination that would bring the risk within Australia’s ALOP.

**Weeds and other contaminants of banana shipments**

Risk assessments were carried out for the 52 weeds identified as quarantine pests. Eleven weeds were identified as requiring risk management to reduce the risks of entry, establishment or spread to an acceptable level. These risks could be managed by a suite of practical measures discussed in this report, relating to the packaging materials used and to packing and transport procedures.

Because likelihood of entry, establishment or spread of non-weed contaminant organisms of banana shipments from the Philippines was considered negligible, the overall risk was not considered sufficient to require management beyond that already proposed for weeds, except that fruit, packing materials and transport vehicles must also be free from the groups of non-weed contaminants (mammals, amphibians, reptiles, molluscs and arthropods).

**Quarantine conditions**

The *revised Draft IRA Report* outlines a set of conditions for the importation of Philippines bananas. The quarantine conditions described in the report are based on the risk assessment and risk management conclusions from this IRA. Specifically, they flow from the evaluation of risk management options. The conditions are in addition to the risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in documentation provided by Philippines Department of Agriculture.

The quarantine conditions recommended for the importation of Philippines bananas deal comprehensively with the risks identified in the IRA. A rigorous though-chain systems approach, dealing with all key points in the import pathway, is applied to protect Australia’s favourable plant health status and to verify the integrity of the measures applied.

Biosecurity Australia considers that the quarantine conditions i.e. the risk management measures recommended in this report are the least trade restrictive means of ensuring that Australia’s ALOP would be met and are commensurate with the identified risks. Biosecurity Australia invites technical comments on their economic and practical feasibility.

Alternative measures for managing risk may be accepted, generally or on a case-by-case basis if the proponent can demonstrate that they provide an equivalent level of quarantine protection. Those seeking to propose alternative risk management measures should provide a submission for consideration. Such proposals are welcome and should include supporting scientific information and describe how the alternative measures would meet Australia’s ALOP.

**Conclusion**

This *revised Draft IRA Report* recommends that import of fresh hard green bananas from the Philippines be permitted subject to certain conditions.

In accordance with the process for conducting IRAs as outlined in the *Import Risk Analysis Handbook*, established by the Australian Government Department of Agriculture, Fisheries and Forestry’s Biosecurity Australia, comments are invited on this *revised Draft IRA Report*. Submissions should reach Biosecurity Australia within 60 days of publication of this report. The
Final IRA Report will take into account any comments received on this draft as well as any new information that may come to hand. The Final IRA Report will be open to appeal for a period of 30 days after its release.
INTRODUCTION

This section outlines:

- The legislative basis for Australia’s biosecurity regime
- Australia’s international rights and obligations
- Australia’s Appropriate Level of Protection and risk management
- Import risk analysis
- Policy determination

AUSTRALIAN LEGISLATION

The Quarantine Act 1908 and its subordinate legislation, including the Quarantine Proclamation 1998, are the legislative basis of human, animal and plant biosecurity in Australia.

Some key provisions are set out below.

Quarantine Act: scope

Sub section 4 (1) of the Quarantine Act 1908 defines the scope of quarantine as follows.

In this Act, quarantine includes, but is not limited to, measures:
(a) for, or in relation to:
   (i) the examination, exclusion, detention, observation, segregation, isolation, protection, treatment and regulation of vessels, installations, human beings, animals, plants or other goods or things; or
   (ii) the seizure and destruction of animals, plants, or other goods or things; or
   (iii) the destruction of premises comprising buildings or other structures when treatment of these premises is not practicable; and
(b) having as their object the prevention or control of the introduction, establishment or spread of diseases or pests that will or could cause significant damage to human beings, animals, plants, other aspects of the environment or economic activities.

Section 5D of the Quarantine Act 1908 covers the level of quarantine risk.

A reference in this Act to a level of quarantine risk is a reference to:

(a) the probability of:
   (i) a disease or pest being introduced, established or spread in Australia or the Cocos Islands; and
   (ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and
(b) the probable extent of the harm.
Section 5D of the Quarantine Act 1908 includes harm to the environment as a component of the level of quarantine risk.

Environment is defined in Section 5 of the Quarantine Act 1908, in that it:

includes all aspects of the surroundings of human beings, whether natural surroundings or surroundings created by human beings themselves, and whether affecting them as individuals or in social groupings.

**Quarantine Proclamation**

The Quarantine Proclamation 1998 is made under the Quarantine Act 1908. It is the principal legal instrument used to control the importation into Australia of goods of quarantine (biosecurity) interest. The Proclamation empowers a Director of Quarantine to grant a permit to import.

Section 70 of the Quarantine Proclamation 1998 sets out the matters to be considered when deciding whether to grant a permit to import:

**Things a Director of Quarantine must take into account when deciding whether to grant a permit for importation into Australia**

(1) In deciding whether to grant a permit to import a thing into Australia or the Cocos Islands, or for the removal of a thing from the Protected Zone or the Torres Strait Special Quarantine Zone to the rest of Australia, a Director of Quarantine:

(a) must consider the level of quarantine risk if the permit were granted; and

(b) must consider whether, if the permit were granted, the imposition of conditions on it would be necessary to limit the level of quarantine risk to one that is acceptably low; and

(ba) for a permit to import a seed of a kind of plant that was produced by genetic manipulation -- must take into account any risk assessment prepared, and any decision made, in relation to the seed under the Gene Technology Act; and

(c) may take into account anything else that he or she knows that is relevant.

**Development of biosecurity policy**

As can be seen from the above extracts, the legislation establishes the concept of the level of biosecurity (quarantine) risk as the basis of decision-making under Australian quarantine legislation.

Import risk analyses are a significant contribution to the information available to the Director of Animal and Plant Quarantine - a decision maker for the purposes of the Quarantine Proclamation. Import risk analysis is conducted within an administrative process – known as the IRA process (described in the IRA Handbook⁴).

The purpose of the IRA process is to deliver a policy recommendation to the Director of Animal and Plant Quarantine that is characterised by sound science and by transparency, fairness and consistency. The key elements of the IRA process are covered in “Import Risk Analysis” below.

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AUSTRALIA’S INTERNATIONAL RIGHTS AND OBLIGATIONS

It is important that import risk analysis conforms with Australia’s rights and obligations as a WTO Member country. These rights and obligations derive principally from the World Trade Organization’s Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement), although other WTO agreements may also be relevant. Specific international guidelines on risk analysis developed under the International Plant Protection Convention (IPPC) and by the Office International des Epizooties (OIE) are also relevant.

The SPS Agreement recognises the right of WTO Member countries to determine the level of sanitary and phytosanitary protection they deem appropriate, and to take the necessary measures to achieve that protection. Sanitary (human and animal health) and phytosanitary (plant health) measures typically apply to trade in or movement of animal and plant based goods within or between countries. The SPS Agreement applies to measures that may directly or indirectly affect international trade and that protect human, animal or plant life or health from pests and diseases or a Member’s territory from a pest.

The SPS Agreement provides for the following:

- The right of WTO Member countries to determine the level of sanitary and phytosanitary protection (its appropriate level of protection, or ALOP) they deem appropriate;
- An importing Member has the sovereign right to take measures to achieve the level of protection it deems appropriate to protect human, animal or plant life or health within its territory;
- An SPS measure must be based on scientific principles and not be maintained without sufficient scientific evidence;
- An importing Member shall avoid arbitrary or unjustifiable distinctions in levels of protection, if such distinctions result in discrimination or a disguised restriction on international trade;
- An SPS measure must not be more trade restrictive than required to achieve an importing Member’s ALOP, taking into account technical and economic feasibility;
- An SPS measure should be based on an international standard, guideline or recommendation where these exist, unless there is a scientific justification for a measure which results in a higher level of SPS protection to meet the importing Member’s ALOP;
- An SPS measure conforming to an international standard, guideline or recommendation is deemed to be necessary to protect human, animal or plant life or health, and to be consistent with the SPS Agreement;
- Where an international standard, guideline or recommendation does not exist or where, in order to meet an importing Member’s ALOP, a measure needs to provide a higher level of protection than accorded by the relevant international standard, such a measure must be based on a risk assessment; the risk assessment must take into account available scientific evidence and relevant economic factors;
- Where the relevant scientific evidence is insufficient, an importing Member may provisionally adopt SPS measures on the basis of available pertinent information. In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the SPS measure accordingly within a reasonable period of time;
- An importing Member shall accept the measures of other countries as equivalent, if it is objectively demonstrated that the measures meet the importing Member’s ALOP.
AUSTRALIA’S APPROPRIATE LEVEL OF PROTECTION (ALOP)

The SPS Agreement defines the concept of an ‘appropriate level of sanitary or phytosanitary protection (ALOP)’ as the level of protection deemed appropriate by the WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory.

Like many other countries, Australia expresses its ALOP in qualitative terms. Australia’s ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero.

ALOP can be illustrated using a ‘risk estimation matrix’ Table 1. The cells of this matrix describe the product of likelihood^5 and consequences — termed ‘risk’. When interpreting the risk estimation matrix, it should be remembered that, although the descriptors for each axis are similar (‘low’, ‘moderate’, ‘high’ etc), the vertical axis refers to likelihood and the horizontal axis refers to consequences.

<table>
<thead>
<tr>
<th>Likelihood of entry, establishment or spread</th>
<th>High likelihood</th>
<th>Moderate</th>
<th>Low</th>
<th>Very low</th>
<th>Extremely low</th>
<th>Negligible likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negligible impact</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
<tr>
<td>Very low risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
<tr>
<td>Low risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
<tr>
<td>Moderate</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
<tr>
<td>High risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
<tr>
<td>Extreme risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
<td>Negligible risk</td>
</tr>
</tbody>
</table>

The band of cells in Table 1 marked ‘very low risk’ represents Australia’s ALOP, or tolerance of loss.

Risk management and SPS measures

Australia’s plant and animal health status is maintained through the implementation of measures to facilitate the importation of products while protecting the health of people, animals and plants.

Australia bases its national measures on international standards where they exist and where they deliver the ALOP from pests and diseases. However, where such standards do not achieve

^5 The terms "likelihood" and "probability" are synonymous. "Probability" is used in the Quarantine Act 1908 while "likelihood" is used in the WTO SPS Agreement. These terms are used interchangeably in this IRA Report.
Australia’s level of biosecurity protection, or relevant standards do not exist, Australia exercises its right under the SPS Agreement to take appropriate measures, justified on scientific grounds and supported by risk analysis.

Australia’s approach to addressing requests for imports of animals, plants and their products, where there are biosecurity risks, is, where appropriate, to draw on existing sanitary and phytosanitary measures for similar products with comparable risks. However, where measures for comparable biosecurity risks have not previously been established, further action would be required to assess the risks to Australia and determine the sanitary and phytosanitary measures needed to achieve Australia’s ALOP.

IMPORT RISK ANALYSIS

Description

In animal and plant biosecurity, import risk analysis identifies the pests and diseases relevant to an import proposal, assesses the risks posed by them and, if those risks are unacceptable, specifies the measures that could be taken to reduce those risks to an acceptable level. These analyses are conducted via an administrative process (described in the IRA Handbook) that involves, among other things, notification to the WTO, consultation and appeal.

Undertaking IRAs

Biosecurity Australia may undertake an IRA if:

- there is no relevant existing biosecurity measure for the good and pest/disease combination; or
- a variation in established policy is desirable because pests or diseases, or the likelihood and/or consequences of entry, establishment or spread of the pests or diseases could differ significantly from those previously assessed.

Environment and human health

When undertaking an import risk analysis, Biosecurity Australia takes into account harm to the environment as part of its assessment of biosecurity risks associated with the potential import.

Under the Environment Protection and Biodiversity Conservation Act 1999, the Department for Environment and Heritage (DEH) may assess proposals for the importation of live specimens and their reproductive material. Such an assessment may be used or referred to by Biosecurity Australia in its analyses.

Biosecurity Australia also consults with other Commonwealth agencies where they have responsibilities relevant to the subject matter of the IRA, e.g. Food Standards Australia New Zealand (FSANZ) and the Department of Health and Ageing (DHA).

The IRA Process in summary

The process consists of the following major steps:

- **Initiation**: This is the stage where the identified need for an IRA originates.
Scheduling and Scoping: At this stage, Biosecurity Australia considers all the factors that affect scheduling. Consultation with States, Territories and other Commonwealth agencies is involved. There is opportunity for appeal by stakeholders at this stage.

Risk Assessment and Risk Management: Here, the major scientific and technical work relating to risk assessment is performed. There is detailed consultation with stakeholders.

Reporting: Here, the results of the IRA are communicated formally. There is consultation with States and Territories. The Executive Manager of Biosecurity Australia then delivers the biosecurity policy recommendation arising from the IRA to the Director of Animal and Plant Quarantine. There is opportunity for appeal by stakeholders at this stage.

POLICY DETERMINATION

The Director of Animal and Plant Quarantine makes the policy determination, which is notified publicly.
PROPOSAL TO IMPORT BANANAS FROM THE PHILIPPINES

BACKGROUND

In June 2000, Australia initiated an IRA on Philippines bananas following provision of necessary technical information by the Philippines Bureau of Plant Industry (BPI) in May 2000 (discussed further in Method for Import Risk Analysis). In their submission, BPI requested a risk analysis of a proposal to export fresh mature hard green banana fruit to Australia. BPI proposed exports of four varieties of Cavendish (Extra Dwarf, Giant Cavendish, Grand Nain and Williams) and Gros Michel from the Mindanao region (Davao, Cotabato and Bukidnon) in the Philippines.

In May 2001, Biosecurity Australia released an Issues Paper regarding the BPI proposal for stakeholder comment. In October 2001, following stakeholder comments on the Issues Paper and discussions with the Chairs of technical working groups during their visit to the Philippines, BPI clarified that the proposed export area of Davao means Davao del Sur, Davao del Norte and Davao Oriental, and Cotabato means South Cotabato, North Cotabato and Sarangani. At the same time, BPI advised Biosecurity Australia that cultivar Gros Michel is no longer produced in Philippines banana plantations.

In June 2002, Biosecurity Australia released a Draft IRA Report for stakeholder comment. Twenty submissions were received on the draft report including substantial comments from the Philippines Government and industry, the Australian Banana Growers’Council (ABGC) and the Western Australian Government (see Appendix 3: Stakeholder submissions on the June 2002 Draft IRA Report). In addition to stakeholder submissions on the June 2002 Draft IRA Report, supplementary comments and reports relevant to the IRA were received from ABGC and the Philippines Government.

Given the substantial nature of the various submissions and reports, and the widely varying technical viewpoints, the IRA team considered it appropriate to undertake an extensive review of the technical information concerning each of the quarantine pests identified in the IRA. Additionally, the IRA team reviewed the various other technical issues arising from the submissions and reports.

As a consequence, the IRA team identified the need to make significant changes to the analysis as reported in the June 2002 Draft IRA Report. For this reason this report is issued as a revised Draft IRA Report that takes into account the stakeholder submissions and reports, and technical information available to the IRA team, as necessary.

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6 Non-confidential stakeholder submissions relating to this IRA are held at Biosecurity Australia’s office in Canberra, and documents may be accessed during business hours, by prior appointment, for perusal and copying.

7 Previously known as the Risk Analysis Panel in the 1998 version of the IRA Handbook.
ADMINISTRATION

Scope

This revised Draft IRA Report presents an assessment of biosecurity risks associated with the importation into Australia of fresh mature hard green Cavendish banana fruit of four varieties (Extra Dwarf, Giant Cavendish, Grand Nain and Williams) from specified areas of Davao (Davao del Sur, Davao del Norte and Davao Oriental), Cotabato (South Cotabato, North Cotabato and Sarangani) and Bukidnon in the Mindanao region of the Philippines. The report also considers and evaluates, as appropriate, risk management measures.

IRA team

The members of the IRA team for Philippines bananas are listed below:

Dr Cheryl McRae  Chair
Senior Manager — Biosecurity Development and Evaluation
Biosecurity Australia

Dr Sharan Singh  Manager — Plant Biosecurity
Biosecurity Australia

Dr Rob Allen  Principal Policy Officer — Plant Health
Queensland Department of Primary Industries

Dr Bryan Cantrell  Principal Policy Officer — Plant Health
Queensland Department of Primary Industries

Mr Bob Paton  Policy Officer — Market Access
New South Wales Agriculture

Mr David Peasley  Horticultural Consultant

Mr Mike Robbins  Manager — Grain, Seed and Nursery Stock
Australian Quarantine and Inspection Service

Biosecurity Australia provides a technical secretariat for the IRA team.

Technical working groups

The IRA team established the following technical working groups (TWGs) on specific aspects of the import risk analysis.

- TWG 1: Pathogens
- TWG 2: Arthropods
- TWG 3: Horticulture, Environment and Operations

An IRA team member chaired each TWG.
AUSTRALIA’S BIOSECURITY POLICIES FOR FRESH BANANAS

National quarantine policy

Fresh banana fruit for human consumption are not currently imported by Australia.

AQIS, however, conducted a risk analysis on the importation of fresh banana fruit from Ecuador in 1991. Import conditions were not subsequently developed because the access request was withdrawn. A Position Paper (AQIS, 1991) was published on this subject. The diseases ‘black Sigatoka’ and ‘Moko’, as well as several arthropod pests, were identified as of quarantine concern to Australia and further information on these pests was requested from Ecuador.

Fresh banana fruit may be imported for in-vitro laboratory work under secure quarantine conditions, and at Quarantine Approved Premises (QAPs). Strict quarantine conditions are
observed for these imports, including a requirement that packaging materials and containers be disposed of by incineration, autoclaving or other methods approved by the Director of Animal and Plant Quarantine. The goods in each consignment must be packaged securely and transported directly to a facility approved by AQIS for laboratory analysis. Samples must be in clean, new packaging and must be free from quarantine pests and other regulated articles (eg soil)\textsuperscript{8}.

The importation of certain ‘banana products’ from several countries, including the Philippines, is permitted. Banana products include cooked, dried and canned or preserved product.

**State Government arrangements**

Movement of bananas within Australia is subject to quarantine restrictions. Although the Commonwealth Government is responsible for regulating the movement of plants and their products into and out of Australia, the State and Territory Governments have primary responsibility for plant health controls within Australia. Legislation for plant health may be used by State and Territory government agencies to control intra- and interstate movement of plants and their products.

All States and the Northern Territory restrict movement of banana planting material, because of concerns over black Sigatoka, banana bunchy top disease or Panama disease, as well as various soil-borne pests. Queensland also has in place anticipatory legislation for the exotic diseases, Moko and banana bract mosaic.

Fruit flies are of concern to all Australian States and Territories. However, banana fruit may be moved into any State or Territory if in a hard green or mature green condition, if complying with an approved treatment, or if they are sourced from an approved pest-free area.

- Operational procedures for ensuring the hard green and mature green condition of bananas are described in Interstate Certification Assurance (ICA)-06 (QDPI 1997a) and ICA-16 (QDPI, 1997b), respectively. ICA is a system of plant health certification based on quality management principles.
- Under ICA, State or Territory authorities can accredit a private business to issue plant health certification for their produce. The ICA Scheme is a national scheme endorsed by the Interstate Plant Health Regulation Working Group of the Plant Health Committee of the former Standing Committee on Agricultural Resource Management (SCARM); now the Primary Industries Standing Committee (PISC).

States and Territories may also apply additional restrictions on the movement of banana fruit to address other pest and disease concerns. For example, some States and Territories imposed new restrictions following the outbreak of black Sigatoka in the Tully banana production areas of Queensland in April 2001.

Below is a brief summary of the intra- and interstate requirements for diseases that may be associated with bananas. Importantly, South Australia, Tasmania, Victoria and the Australian Capital Territory do not currently impose any disease specific restrictions on the movement of bananas.

\textsuperscript{8} The IPPC defines regulated article as " any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transporation is involved".
New South Wales

Following the outbreak of black Sigatoka in the Tully district of north Queensland, New South Wales enacted legislation to control movement of bananas and packaging materials from this district. Specifically, bananas grown or packed in parts of Queensland north of the 22nd parallel may not be taken into the New South Wales ‘Banana Protection Area’. This consists of 17 Local Government Areas (areas) of northern New South Wales — Ballina, Bellingen, Byron Bay, Coffs Harbour, Copmanhurst, Grafton, Great Lakes, Greater Taree, Hastings, Lismore, Kempsey, Kyogle, MacLean, Nambucca, Pristine Waters, Richmond Valley and Tweed. Bananas from parts of Queensland north of the 22nd parallel can be moved to other parts of New South Wales, subject to conditions approved by NSW Agriculture. These are that:

- Fruit must be commercially packed;
- Packaging must be free of any banana leaf material or trash; and
- Packaging must be clearly marked with the Interstate Produce Number (IPN) under the Interstate Certification Scheme.

Bananas originating from areas of Queensland south of the 22nd parallel may be taken into any part of New South Wales without restrictions, providing that packaging is adequately labelled.

Further requirements for transporting banana plants, fruit and associated materials from Queensland into New South Wales are available in Proclamation – P119 published in the New South Wales Government Gazette on 1 February 2002.

Northern Territory

Under the provisions of the Plant Diseases Control Act 1979 (as amended and as in force from December 2000), banana fruit grown within 50km of a known case of black Sigatoka is not permitted entry into the Northern Territory.

Queensland

Six Pest Quarantine Areas for banana pests have been established in Queensland, and movement of banana plants and their products, including fruit, may be controlled within and between these areas. Queensland legislation provides a contingency for outbreaks of quarantine pests. Black Sigatoka and bacterial wilt (blood disease and bugtok, or Moko) are among the notifiable pests, and legislation is in place for preventing movement of banana fruit and other plant material if an outbreak were recorded. An Inspector’s approval would be required for removing banana fruit and other plant material from an outbreak area.

Intrastate restrictions may be applied for movement of banana fruit within Queensland from areas where black Sigatoka has been recorded. These provisions may also be invoked for any unforeseen detections of exotic diseases and may be applied to an affected pest site. A “pest site” is defined as an area within approximately 50 km of a place where a banana pest has been found. The chief executive of the State officially declares the boundaries of an area in a pest quarantine area to be a pest area. A pest area so declared would be subject to intrastate restrictions relating to movement of bananas, among other things as necessary, originating from it.

Such restrictions would also apply to movement of bananas into Queensland from other areas if any of the above diseases or other pests of quarantine concern to Queensland were recorded there.
Further information on the Queensland requirements for intra- and interstate movement of banana plants and plant products is available in the *Plant Protection Regulation 2002* of the *Plant Protection Act 1989*.

**Western Australia**

Banana fruit grown in an area where Panama disease occurs is prohibited entry to the banana growing areas of Western Australia (Kununurra and Carnarvon), unless that fruit is inspected and found free from soil and plant debris.

In April 2001, following the outbreak of black Sigatoka in the Tully district of Queensland, Western Australia imposed new restrictions on imports of banana fruit from Queensland. At this time Western Australia also developed, under Section 23B of the *Plant Disease Act 1989*, a temporary alternative to Schedule 1 of the *Plant Diseases Regulations 1989*. Bananas grown or packed within 50km of a case of black Sigatoka, or packed in a premise that handled bananas grown within 50km of a case of black Sigatoka, are prohibited entry into Western Australia, except under conditions approved by Western Australia’s Department of Agriculture.

A risk analysis conducted by Western Australia’s Department of Agriculture has subsequently recommended that fruit originating within 50km of a case of black Sigatoka could be marketed in the State, south of the 26th parallel (Kumar *et al.*, 2002). Western Australia accepted this recommendation and has accepted fruit into Perth and the southern areas since August 2003.

Further information concerning the Western Australian requirements is available in the alternative procedure to Schedule 1 of the *Plant Diseases Regulations 1989* under section 23B of the *Plant Disease Act 1989*.

**Industry initiative**

The Australian banana industry and Plant Health Australia are working on a National Banana Industry Biosecurity Plan. The plan aims to deliver a nationally consistent way to identify serious incursion risks, develop emergency plant priority lists and contingency plans, and to define roles and responsibilities and conduct regular reviews to maintain effective industry biosecurity measures. The first draft of this plan was released in February 2003 and the finalised plan is due in February 2004.

**BANANA INDUSTRIES IN THE PHILIPPINES AND AUSTRALIA**

The information provided in the following sections derives from a variety of sources, including BPI and the Philippines and Australian banana industries. In addition, IRA team members have inspected field operations and banana fruit packing stations in both the Philippines and Australia. A technical delegation from the Philippines also met with Biosecurity Australia officials and the IRA team in Canberra on 10 and 11 April 2002.

This information was used, as necessary, in various parts of the risk assessments presented in the section *Risk Assessment for Quarantine Pests*. 
Production and trade

Global

Dessert bananas of the Cavendish variety, produced in both tropical and subtropical climes, are traded globally. Between 1995 and 2000, total trade ranged from approximately 10 to 12 million tonnes (Table 2). Ecuador supplies more than one-third of the global trade in dessert bananas. Costa Rica, Columbia and the Philippines each supply between 10% and 20%. Other significant exporters include Panama, Guatemala and Honduras.

Table 2  Worldwide production of Cavendish dessert bananas (1995-2000)

<table>
<thead>
<tr>
<th>Exporter</th>
<th>Production (kilotonnes) for the years:</th>
<th>% of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecuador</td>
<td>3,737</td>
<td>3,840</td>
</tr>
<tr>
<td>Costa Rica</td>
<td>2,033</td>
<td>1,933</td>
</tr>
<tr>
<td>Columbia</td>
<td>1,336</td>
<td>1,407</td>
</tr>
<tr>
<td>Philippines</td>
<td>1,213</td>
<td>1,271</td>
</tr>
<tr>
<td>Others</td>
<td>1,264</td>
<td>1,369</td>
</tr>
<tr>
<td>Panama</td>
<td>693</td>
<td>634</td>
</tr>
<tr>
<td>Guatemala</td>
<td>636</td>
<td>611</td>
</tr>
<tr>
<td>Honduras</td>
<td>522</td>
<td>574</td>
</tr>
<tr>
<td>Total</td>
<td>11,434</td>
<td>11,639</td>
</tr>
</tbody>
</table>

Source: FAO, 2001

Philippines

In the Philippines, about 400,000 hectares are planted to bananas. This comprises Cavendish and local varieties, including Lakatan, Latundan, Bungulan and Saba (Seaton, 2001). Philippines production is approximately 4 million tonnes, and increasing annually. Almost half of this production is Cavendish, of which most is exported.

A large proportion of export Cavendish is grown in southern Mindanao, both on the lowlands near Davao province (altitude 10–20 metres) and in the highlands near Bukidnon (altitude 500–700 metres). Each of these areas is characterised by relatively uniform monthly temperatures and rainfall (Figure 2). The flat land and optimal climate provide yields of 50–75 tonnes per hectare with at least 35 tonnes per hectare of export quality fruit (Philippines Scientific Delegation, 2002). The Pilipino Banana Growers and Exporters Association Inc (PBGEA) comprises 26 plantations with a total productive area of 20,000 hectares. It employs more than 45,000 workers in banana growing and packing.

According to PBGEA, exports of Cavendish bananas from the Philippines have increased from 0.860 million tonnes in 1991 to 1.362 million tonnes in 2000 (Table 3). Japan was the major
market, although the Middle East, Korea, China and several other countries also imported bananas. New Zealand imported 7,208 tonnes from the Philippines in 2000.

The Philippines Government reported that Japan imported 1.598 million tonnes of bananas in 2000. This represents approximately 63% of Japanese banana imports (Armstrong, 2001). Japanese statistics indicate this figure had risen to 78% in the first half of 2001 (PBGEA, 2001). Exports to China rose to 0.172 million tonnes in 2000, a 13% share of the banana market in China (Armstrong, 2001).

### Table 3 Exports of Cavendish bananas from the Philippines (1991–2000)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Japan</td>
<td>586,418</td>
<td>539,250</td>
<td>661,999</td>
<td>692,487</td>
<td>877,374</td>
<td>613,513</td>
<td>650,038</td>
<td>603,736</td>
<td>702,638</td>
<td>790,250</td>
</tr>
<tr>
<td>Middle East</td>
<td>118,325</td>
<td>115,220</td>
<td>229,693</td>
<td>182,076</td>
<td>212,039</td>
<td>189,798</td>
<td>147,976</td>
<td>142,905</td>
<td>121,761</td>
<td>113,472</td>
</tr>
<tr>
<td>Korea</td>
<td>125,526</td>
<td>69,959</td>
<td>109,080</td>
<td>122,107</td>
<td>102,124</td>
<td>111,158</td>
<td>118,168</td>
<td>82,966</td>
<td>154,642</td>
<td>170,055</td>
</tr>
<tr>
<td>China</td>
<td>0</td>
<td>0</td>
<td>1,461</td>
<td>16,587</td>
<td>99,731</td>
<td>202,826</td>
<td>104,020</td>
<td>170,401</td>
<td>128,184</td>
<td>233,413</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>28,058</td>
<td>27,783</td>
<td>35,226</td>
<td>27,957</td>
<td>25,316</td>
<td>26,819</td>
<td>26,596</td>
<td>25,017</td>
<td>29,093</td>
<td>37,024</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0</td>
<td>19</td>
<td>0</td>
<td>14,676</td>
<td>13,389</td>
<td>8,134</td>
<td>10,706</td>
<td>4,212</td>
<td>5,278</td>
<td>7,208</td>
</tr>
<tr>
<td>Russia</td>
<td>0</td>
<td>0</td>
<td>971</td>
<td>4,651</td>
<td>13,666</td>
<td>12,838</td>
<td>9,689</td>
<td>4,741</td>
<td>1,737</td>
<td>2,913</td>
</tr>
<tr>
<td>Singapore</td>
<td>2,080</td>
<td>2,187</td>
<td>2,052</td>
<td>1,832</td>
<td>2,057</td>
<td>4,244</td>
<td>4,256</td>
<td>3,938</td>
<td>5,166</td>
<td>7,272</td>
</tr>
<tr>
<td>Others</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>131</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>860,407</td>
<td>754,418</td>
<td>1,040,482</td>
<td>1,062,373</td>
<td>1,145,696</td>
<td>1,169,461</td>
<td>1,071,449</td>
<td>1,037,916</td>
<td>1,148,499</td>
<td>1,361,607</td>
</tr>
</tbody>
</table>

Source: PBGEA, 2001

### Australia

Approximately 95% of Australian banana production is Cavendish. Lady Finger (genotype AAB) accounts for about 5%. The remaining proportion is made up of a range of dessert and cooking varieties, and experimental plantings, including Dacasse (genotype ABB) and Goldfinger (genotype AAAB) (Smith, 2002; ABGC, 2003). Australia has approximately 2000 banana farms, and a total of 14,397 hectares planted (Table 4). Approximately 10,000 workers are employed in production and packing (Daniells, 2001b).

Approximately two-thirds of Australia's banana industry is concentrated on the tropical Queensland coast, between Babinda and Cardwell (designated ‘north Queensland’ in this analysis). Other banana production areas are southeast Queensland, northern New South Wales, Carnarvon and Kununurra in Western Australia, and Darwin in the Northern Territory. Climatic conditions for these areas are presented in Figure 2 and summarised in Table 4. The area of land planted to bananas, production in tonnes, gross value and the number of Australian farms are also summarised in Table 4. This information was derived from composite data sources — some additional notes are provided below:
• **North Queensland**: figures are for the year 2000. Figures were collected from Innisfail and Tully, and not all banana transporters contributed. (Allen and Janetzki, 2000; McMeekin, 2002; Lindsay, 2001).

• **Southeast Queensland**: industry characterised by many small growers, and a significant volume sold locally outside the major city markets (Allen and Janetzki, 2000; McCarthy, 2002).

• **New South Wales**: Queensland Fruit and Vegetable Growers have estimated that 23,621 tonnes of banana fruit from New South Wales were sold through major markets from October 2000 to November 2001. However, transport companies, New South Wales Agriculture and the Banana Industry Committee of New South Wales have estimated that local sales, and direct sales to buyers outside central markets, may account for as much as 40–50% of total production (Shoobridge, 2001).

• **Carnarvon and Kununurra, Western Australia**: figures represent production for the year 1999 to 2000 (AgWest, 2000; Kesavan, 2001a; Kesavan, 2001b).

• **Northern Territory**: data collected to 2001. Since that time, a large plantation has been destroyed as a part of measures to control Panama disease (Walduck, 2002b).

• **Number of farms**: Figures extracted from ABGC industry statistics up to October 2002 (ABGC, 2003).

### Table 4 Characteristics and value of banana production in Australia

<table>
<thead>
<tr>
<th>Banana production area</th>
<th>Climate type</th>
<th>Area planted (ha)</th>
<th>Production (tonnes)</th>
<th>Gross value (A$ million)</th>
<th>Number of farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Queensland</td>
<td>Wet/dry tropical</td>
<td>9,548</td>
<td>207,926</td>
<td>238.4</td>
<td>568</td>
</tr>
<tr>
<td>Southeast Queensland</td>
<td>Humid subtropical</td>
<td>850</td>
<td>9,000</td>
<td>10.0</td>
<td>396</td>
</tr>
<tr>
<td>New South Wales</td>
<td>Humid subtropical</td>
<td>3,450</td>
<td>40,000</td>
<td>45.0</td>
<td>947</td>
</tr>
<tr>
<td>Carnarvon</td>
<td>Semiarid subtropical</td>
<td>220</td>
<td>8,278</td>
<td>9.3</td>
<td>133</td>
</tr>
<tr>
<td>Kununurra</td>
<td>Semiarid monsoon</td>
<td>129</td>
<td>4175</td>
<td>5.2</td>
<td>25</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>Semiarid monsoon</td>
<td>200</td>
<td>4,105</td>
<td>13.0</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>14,397</td>
<td>273,484</td>
<td>320.9</td>
<td>2073</td>
</tr>
</tbody>
</table>

In contrast to the Philippines, virtually all bananas produced in Australia are consumed within Australia (99.9%). Information supplied by the Australian Banana Growers’ Council (ABGC) indicates that only negligible quantities of Australian bananas are exported, and that these are to a specialty market. ABGC also reported that 0.240 million tonnes were supplied to the major domestic markets in 2001 (Table 5), with Queensland the largest supplier. Production is year-round (Figure 1).
The data presented in Table 5 and Figure 1 does not take account of the bananas sold through subsidiary markets, including Hobart (Tasmania), Darwin (Northern Territory) and some markets in major cities. Table 6 provides independent estimates of the distribution of north Queensland bananas, including estimates of the fruit marketed in Tasmania and the Northern Territory.

Local sales and consignments outside the major central markets constitute a significant percentage (40–50%) of total production in southeast Queensland and northern New South Wales (Shoobridge, 2001). Local growers supply the coastal areas from the Sunshine Coast north of Brisbane to Kempsey on the mid north coast of New South Wales, and also rural New South Wales. Similarly, north Queensland growers directly supply the major cities of Townsville and Cairns. Regional sales may amount to 30,000 tonnes annually.

Accurate information on the volume of bananas bought from major markets and transported into the production area is not available and would be difficult to estimate precisely because of the number of secondary wholesalers and the unknown volume of tourist traffic carrying fruit. Use of second-hand cartons for a wide variety of domestic purposes is common and uncontrolled outside the supermarket chains in metropolitan areas.

Figure 1  Banana production for Australian States and Territories (2001)

Source: McMeekin, 2002

Note: These data do not include banana fruit sold through smaller markets, which may represent up to half of the total production in New South Wales and south–eastern Queensland.
Table 5  Monthly banana sales in Australia (2001)

<table>
<thead>
<tr>
<th>Month</th>
<th>Sydney</th>
<th>Melbourne</th>
<th>Queensland</th>
<th>Adelaide</th>
<th>Newcastle</th>
<th>Perth</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>6,596</td>
<td>4,986</td>
<td>3,110</td>
<td>1,825</td>
<td>181</td>
<td>2,041</td>
<td>18,739</td>
</tr>
<tr>
<td>Feb</td>
<td>5,176</td>
<td>4,494</td>
<td>2,793</td>
<td>1,563</td>
<td>205</td>
<td>1,794</td>
<td>16,025</td>
</tr>
<tr>
<td>Mar</td>
<td>7,398</td>
<td>5,515</td>
<td>3,133</td>
<td>1,816</td>
<td>196</td>
<td>2,101</td>
<td>20,159</td>
</tr>
<tr>
<td>Apr</td>
<td>5,558</td>
<td>5,985</td>
<td>3,042</td>
<td>1,931</td>
<td>182</td>
<td>1,551</td>
<td>18,249</td>
</tr>
<tr>
<td>May</td>
<td>8,344</td>
<td>7,096</td>
<td>3,320</td>
<td>2,436</td>
<td>177</td>
<td>2,082</td>
<td>23,456</td>
</tr>
<tr>
<td>Jun</td>
<td>6,524</td>
<td>7,058</td>
<td>3,804</td>
<td>1,985</td>
<td>189</td>
<td>1,959</td>
<td>21,520</td>
</tr>
<tr>
<td>Jul</td>
<td>6,840</td>
<td>5,932</td>
<td>5,181</td>
<td>1,877</td>
<td>173</td>
<td>2,085</td>
<td>22,089</td>
</tr>
<tr>
<td>Aug</td>
<td>6,156</td>
<td>5,561</td>
<td>3,683</td>
<td>2,136</td>
<td>220</td>
<td>2,037</td>
<td>19,792</td>
</tr>
<tr>
<td>Sep</td>
<td>6,063</td>
<td>5,518</td>
<td>3,532</td>
<td>1,995</td>
<td>220</td>
<td>2,258</td>
<td>19,585</td>
</tr>
<tr>
<td>Oct</td>
<td>7,493</td>
<td>6,066</td>
<td>3,903</td>
<td>2,110</td>
<td>273</td>
<td>1,945</td>
<td>21,789</td>
</tr>
<tr>
<td>Nov</td>
<td>6,446</td>
<td>5,448</td>
<td>3,455</td>
<td>2,004</td>
<td>244</td>
<td>1,870</td>
<td>19,466</td>
</tr>
<tr>
<td>Dec</td>
<td>5,097</td>
<td>6,515</td>
<td>3,713</td>
<td>2,271</td>
<td>215</td>
<td>1,748</td>
<td>19,560</td>
</tr>
<tr>
<td>Total</td>
<td>77,692</td>
<td>70,174</td>
<td>42,667</td>
<td>23,949</td>
<td>2,475</td>
<td>23,471</td>
<td>240,428</td>
</tr>
</tbody>
</table>

Source: ABGC, 2001

Table 6  Consignment of north Queensland bananas to Australian states (2000)

<table>
<thead>
<tr>
<th>Market destination</th>
<th>Bananas (tonnes)</th>
<th>Percentage of total</th>
</tr>
</thead>
<tbody>
<tr>
<td>New South Wales</td>
<td>83,180</td>
<td>40.00</td>
</tr>
<tr>
<td>Victoria</td>
<td>57,236</td>
<td>27.53</td>
</tr>
<tr>
<td>Queensland</td>
<td>36,026</td>
<td>17.33</td>
</tr>
<tr>
<td>South Australia</td>
<td>18,790</td>
<td>9.04</td>
</tr>
<tr>
<td>Western Australia</td>
<td>11,016</td>
<td>5.30</td>
</tr>
<tr>
<td>Tasmania</td>
<td>1,582</td>
<td>0.76</td>
</tr>
<tr>
<td>Northern Territory</td>
<td>96</td>
<td>0.05</td>
</tr>
<tr>
<td>Total</td>
<td>207,926</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Note: reassigning of produce by agents and merchants is not reflected in this table.

Source: QDPI, 2000
Growing conditions

This section summarises the climate, topography and soils, and production characteristics of the major banana growing areas of Australia, and the Philippines Province of Mindanao, from which export bananas would be sourced.

Figure 2 Climate of banana growing areas in Australia and the Philippines

Australia

1. North Queensland

2. Southeast Queensland

3. Northern New South Wales

4. Carnarvon, Western Australia

5. Kununurra, Western Australia

6. Darwin, Northern Territory
The Philippines

Lowland Davao

Highland Bukidnon

Source: ABM, 2002; World Climate, 2002

Growing conditions in the Philippines

The main production areas for the export marketing of Cavendish are the broad lowlands of Mindanao. Limited areas on the undulating highland area around Bukidnon commenced production for export in 1998. Pest and disease pressure is significantly less in these highland areas where rainfall and humidity are lower than in the coastal lowlands. Bunch filling time is, however, 18–20 weeks, compared with 10–13 weeks in the coastal lowlands (Philippines Scientific Delegation, 2002).

Climate

The Philippines climate enables even production of bananas throughout the year (Figure 2) (PCARRD, 1988). The proposed export area is compact, but there are differences between the lowland and highland areas. The new production area in Bukidnon is elevated (>500 metres) with the cooler and drier conditions providing slower growing and bunch filling than in coastal lowlands.

Topography and soils

Soils are generally heavier in the coastal lowlands, with drainage systems designed to promote root growth by quickly removing excess water to prevent flooding and waterlogging of plantations (Peasley, 2001a). The highlands and plateau areas of Bukidnon are located on well-drained basaltic krasnozem soils with variable slopes. Plantations in Bukidnon are not as extensive as those in the coastal lowlands, and tend to be separated by gullies or land that is generally too steep for mechanised cultivation.

Production and handling systems

Production and handling on Cavendish plantations are large-scale and labour-intensive (Figure 3). Plantations are corporately owned and managed. Plantation sizes range from about 70 to 6,250 ha. There is little field mechanisation as such in ratoon plantations, except for the use of cable ways to
transport bunches to permanent (cf. mobile) packing stations, and the use of machinery to remove annual crops and prepare fields for new annual crops.

**Figure 3  Propping and drainage at south Cotabato (the Philippines)**

![Propping and drainage at south Cotabato (the Philippines)](image)

Photograph: D. Peasley

**Growing conditions in Australia**

The Australian market is supplied year-round from the six areas of Australia that produce bananas (Table 4, Table 5 and Table 6). The rainfall, temperature and topography in each of these parts are distinct, resulting in a range of production and management practices, and a range of key pests and diseases.

In Australia, geographic isolation of each growing area also provides some protection against the dramatic dislocation of supply caused by cyclones and pest outbreaks from time to time.

**North Queensland**

**Climate**

The climate in north Queensland is tropical, with a pronounced wet season in summer and early autumn (December – March) when rainfall, under the influence of cyclonic disturbances, can be extreme (Figure 2), and a dry season in winter and spring (June – October). Conditions during the summer wet season are ideal for many leaf diseases, and 20–22 spray cycles each year are needed to keep these in check (Peterson, 2001). Conversely, under-canopy irrigation is required in most areas to supplement rainfall during the dry season.

**Topography and soils**

Light-to-medium alluvial clays are dominant on the flood plain of the Tully Valley (99% of bananas are grown on this soil type), and are a significant component of the soils on the Innisfail plain. Basaltic krasnozem soils are found in approximately 40% of the plantations on the
undulating slopes of the Innisfail area (Lindsay, 2002a). Following severe cyclonic or rainfall depressions, plains of the Tully and Innisfail area are subject to regular and widespread flooding. Soil temperatures are also high during this period, creating highly favourable conditions for the spread of nematodes and soil-borne diseases. Lindsay (2002a) estimated that, in the severe flood of 1999, 70% of banana plantations in the Tully Valley and 10–15% of the Innisfail production area were flooded.

**Production and handling systems**

North Queensland is made up of 568 farms of varying sizes, the average being 16 ha and the largest 700 ha. Most of the holdings are family-operated. Pest, disease and agronomic advice is readily available from consultants and government agencies. Centralised packing prevails and group marketing is increasing. This area is characterised by mechanised production, the degree of mechanisation being determined principally by farm size. On large farms, field operations, including de-leafing, bagging, pruning, harvesting, weed and pest spraying and monitoring, nematicide application, fertilising and irrigation monitoring, are all conducted from vehicles (see: for example, Figure 4).

Because of the high rainfall, heavy soils, and flat topography, bananas are planted on mounded rows. This achieves drainage necessary for high productivity. Row length is a function of farm size and configuration, as well as of the cost-effective distance for management operations such as harvesting, spraying, monitoring and irrigation. Rows may be up to 800 metres long. The inter-row area acts as the drain for excess water from irrigation, or from rainfall and flooding during periods of cyclonic or prolonged high rainfall. The inter-row drains are also the sole access for all vehicles. Mounds prevent vehicle access between rows.

Even during “dry” periods, the inter-row is constantly muddy in most plantations due to irrigation and the accumulation of spent banana stems, leaves and organic matter following harvesting, de-leafing and pruning operations. Under these conditions, four-wheel drive vehicles with specially designed tyres are used. Such vehicles tend to spread large amounts of mud rapidly throughout the inter-row drains, headlands and access roads. Rows are generally travelled at least three times each week by a variety of vehicles, including four-wheel drive motor bikes, purpose-built four-wheel drive bagging machines, tractors, harvesting trailers, fertiliser spreaders and spray rigs.

Table 7 provides an example of row travel frequency for one large farm in the Tully district of north Queensland (Lindsay, 2002a; Mackay, 2002).
Table 7  Row travel frequency on a large banana farm in the Tully district of north Queensland

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Frequency</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>4WD motor bike</td>
<td>At least once per week</td>
<td>Monitoring for leaf disease and mites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Irrigation and bell injection</td>
</tr>
<tr>
<td>4WD ‘cherry picker’</td>
<td>Every week</td>
<td>Bagging, dusting, spraying bunches, tying bunched plants (bunch support)</td>
</tr>
<tr>
<td>4WD tractor and trailer</td>
<td>Every week (every 4th row)</td>
<td>Harvesting (crew carries bunches across 2 rows to trailer, every row every week)</td>
</tr>
<tr>
<td>Fertiliser bin and tractor</td>
<td>Every 4 weeks</td>
<td>Fertiliser application</td>
</tr>
<tr>
<td>Tractor and spraying rig</td>
<td>5-7 times a year</td>
<td>Weed, mite and insect control</td>
</tr>
<tr>
<td></td>
<td>2-3 times a year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1-2 times a year</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4  Motorised bagging machine in north Queensland

Photograph: D. Peasley
Southeast Queensland and northern New South Wales

**Climate**

Both southeast Queensland and northern New South Wales have humid subtropical climates with a cooler and drier winter and spring. Rainfall is predominantly (approximately 70%) in the summer and early autumn (December – March) (Figure 2), and tends to be less extreme than in north Queensland. Prior to the 1980s, these were the principal banana production areas in Australia.

Infection pressure for leaf diseases is high during the wet summer and early autumn, requiring the application of 4–6 spray cycles to provide effective control. Irrigation is used in some cases to supplement rainfall during drier periods, but is not always available because of topography and site limitations (Peasley and Baker, 2001).

**Topography and Soils**

Production is limited to wind-protected, frost-free slopes, with isolated plantations located on the frost-free plateau areas. Aside from specially constructed roadways, mechanisation is limited by the gradient. This has the effect of reducing the movement of surface soil and hence reducing the rate of the transfer of soil-borne pests. Soil-borne pests can, however, be transferred during periods of high rainfall with soil run.

Soils are generally podsolic clays or shales, with well-drained basaltic krasnozems on plateau areas and isolated slopes, and in pockets scattered throughout.

**Production and handling systems**

Production is characterised by a large number of small plantings; approximately 1,343 farms with an average size of 3–4 ha. The holdings are largely family-operated, with size limited by topography. Climate limits year-round production, as well as the quality of Cavendish dessert bananas.

Carnarvon, Western Australia

**Climate**

Carnarvon is a semi-arid, subtropical area with high summer temperatures and mild temperatures in winter and spring (Figure 2). Humidity is low all year. Conditions are not favourable for infection and spread of leaf diseases, and no control spraying is required. Irrigation is essential all year.

**Topography and soils**

Banana production is restricted to the sandy loam, alluvial floodplain of the Gascoyne River. In this situation, under-canopy irrigation provides favourable conditions for infection and spread of soil-borne diseases and nematodes. Use of wheeled vehicles further increases the likelihood of spread of soil-borne pests.
Production and handling systems

This production area covers about 220 ha and is made up of 133 family-run farms averaging about 2 ha of bananas each. Small holdings limit the economy of mechanisation, although the flat topography is suitable. Group marketing of fruit is increasing.

Kununurra, Western Australia

Climate

Kununurra has a semi-arid, monsoonal climate with wet and dry seasons. The area receives 82% of its annual rainfall between December and March (summer wet season), with 18% falling between April and November (Figure 2). The combination of high temperatures, high rainfall and high humidity favours disease and pest development, rapid phenological growth, high plant respiration rates and high soil temperatures (Richards, 2001).

High temperatures during November and December cause climatic stress and consequent fruit quality problems in bananas. Concentrated rainfall from November to March, and the likelihood of high winds and humidity, can cause significant localised damage to bananas. Leaf disease control is needed during the wet season.

Topography and soils

Most production occurs on the sandy loams of the plains and higher land near sandstone ridges. Twenty-five percent of the production area is on cracking clays along river banks, levies and plains (Richards, 2001). Conditions are favourable for spread of soil-borne diseases during the hot or wet season, and when irrigation is used.

Production and handling systems

This area consists of 25 family-run farms averaging about 6 ha each. Field operations are limited by hot weather, and storms and flooding in the wet season. Many farms cease operation during the wet season because of transport difficulties. Mechanisation is very limited.

Darwin, Northern Territory

Climate

Darwin has a semi-arid monsoon climate (Figure 2), with distinct wet (December – March) and dry (April – November) seasons. During the wet season, the rainfall is characterised by very high intensity falls of short duration, causing localised run-off even on well-drained and relatively level soils. The wet season is more intense than in Kununurra, and the dry season is humid. Temperatures during summer are more conducive to banana production than they are in Kununurra.

Topography and soils

Topography is flat to very slightly undulating. Banana production is on the tops and side slopes of very low plateaus, which are generally dissected by drainage lines. Fall across the tops of plateaus
is less than 2%, and across the side slopes is 2–3%. During the dry season, there is no surface movement of soil or water. During the wet season, when there are the frequent short periods of very high intensity rainfall, there is significant lateral movement of water, soil and surface organic matter (Walduck, 2002a).

**Production and handling systems**

This production area is similar to the Kununurra production area. There are currently four farms totalling about 200 ha. While mechanised operations are feasible, the area has been exposed to Panama disease (*Fusarium oxysporum* f.sp. *cubense* tropical Race 4) and consequently mechanised operations have been limited to reduce the risk of spreading this disease.

Additional information regarding many features of the Australian and the Philippines banana industries is provided in a comparison table in Appendix 4.
The technical component of an import risk analysis for plants or plant products is termed a ‘pest risk analysis’, or PRA\(^9\). As stated in the International Plant Protection Convention’s (IPPC) International Standards for Phytosanitary Measures Publication Number 11 (ISPM 11 – Rev. 1) — *Pest Risk Analysis for Quarantine Pests including analysis of environmental risks*, a PRA comprises three discrete stages:

- Stage 1: initiation of the PRA;
- Stage 2: risk assessment; and
- Stage 3: risk management.

**STAGE 1: INITIATION OF THIS PRA**

As described in the background section of *Proposal to Import Bananas from the Philippines*, this IRA Report was initiated by a proposal from the Philippines to export fresh hard green Cavendish banana fruit to Australia. The following PRA flows from that proposal and is the technical component of the IRA Report. The PRA area considered in this report is Australia.

International standards to address the specific quarantine concerns associated with imports of bananas do not exist, nor has Australia completed a risk analysis of this commodity. In addition, Australia does not import fresh hard green Cavendish bananas for consumption from other countries, nor does it have existing import conditions upon which to base a response to the Philippines proposal.

In consideration of these issues, an analysis of the biosecurity risk associated with fresh hard green bananas from the Philippines was required.

A list of pests likely to be associated with fresh hard green bananas from the Philippines (i.e. the biosecurity risk pathway) was generated from information supplied by the Philippines Government and banana industry, literature searches, databases and expert consultation. This list was used in the risk assessment stage of the PRA.

**STAGE 2: METHOD FOR RISK ASSESSMENT**

Risk assessment describes the process of identifying pests of biosecurity concern, and estimating the risk (the probability of entry, establishment or spread, and the magnitude of the potential consequences) associated with each.

This risk assessment was carried out in accordance with IPPC standards and reported in the following steps:

- Pest categorisation;
- Assessment of probability of entry, establishment or spread; and

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\(^9\) PRA is used throughout this document as an abbreviation of Pest Risk Analysis. DAFF uses the term PRA to describe the technical component of an import risk analysis on plants or their products.
• Assessment of potential consequences (including environmental impacts).

**Pest categorisation**

Pest categorisation is a phase wherein pests identified in Stage 1 (Initiation of the PRA) are classified as either ‘quarantine pests’, or not. The objective of pest categorisation is to screen efficiently a ‘complete’ list of potential quarantine pests, and thus to identify those that require in-depth examination in the ensuing risk assessments.

It is stated in ISPM 11 – Rev. 1, that a ‘quarantine pest’ is a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled. An ‘endangered area’ is an area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss.

On the basis of these definitions, the process of pest categorisation is summarised by the IPPC in the five elements outlined below:

• **Identity of the pest.** The identity of the pest should be clearly defined to ensure that the assessment is being performed on a distinct organism, and that biological or other information used in the assessment is relevant to the organism in question. If this is not possible because the causal agent of particular symptoms has not yet been fully identified, then it should have been shown to produce consistent symptoms and to be transmissible.

The taxonomic unit for the pest is generally species. The use of a higher or lower taxonomic level should be supported by scientifically sound rationale. For levels below the species, this should include evidence demonstrating that factors such as differences in virulence, host range or vector relationships are significant enough to affect phytosanitary status.

Where a vector is involved, the vector may also be considered a pest to the extent that it is associated with the causal organism and is required for transmission of the pest.

• **Presence or absence in the endangered area.** The pest should be absent from all or part of the endangered area.

• **Regulatory status.** If the pest is present but not widely distributed in the PRA area, it should be under official control.

• **Potential for establishment or spread in the PRA area.** Evidence should be available to support the conclusion that the pest could become established or spread in the PRA area. The PRA area should have ecological/climatic conditions including those in protected conditions suitable for the establishment or spread of the pest where relevant, host species (or near relatives), alternate hosts and vectors should be present in the PRA area.

• **Potential for economic consequences in the endangered area.** There should be clear indication that the pest is likely to have an unacceptable economic impact (including environmental impact) in the PRA area.

Pest categorisation was conducted in two stages.

• A list of pests likely to be associated with fresh hard green bananas from the Philippines was categorised according to the presence or absence of each pest in Australia, and the association of each pest with banana fruit (compared with leaves, roots, etc). Where there was any doubt or

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10 Under IPPC and FAO terminology, ‘official control’ means the active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests.
contention regarding the occurrence of a pest or its association with banana fruit, that pest was
retained on the list of quarantine pests.

• The second stage of pest categorisation involved the categorisation of each pest absent from
Australia and associated with banana fruit according to: (a) its potential to become established
in Australia; and (b) the potential for consequences. Categorisation of establishment potential
and potential for consequences was dichotomous and was expressed using the terms ‘feasible’ /
‘not feasible’, and ‘significant’ / ‘not significant’, respectively.11

The outcome of pest categorisation was a list of quarantine pests for which individual in-depth
assessments are required (see Table 16 and Table 17).

Assessment of probability of entry, establishment or spread

Stages in the entry, establishment or spread of a pest are illustrated in Figure 5 below.

Under this terminology, the ‘probability of entry’ describes the probability that a quarantine pest
will enter Australia as a result of trade in a given commodity, be distributed in a viable state to an
endangered area and subsequently be transferred to a suitable host. The probability of entry may be
divided for administrative purposes into the following components:12

• The probability of importation: the probability that a pest will arrive in Australia when a given
commodity is imported; and

• The probability of distribution: the probability that the pest will be distributed (as a result of
the processing, sale or disposal of the commodity) to the endangered area, and subsequently be
transferred to a suitable site on a susceptible host.

The probability of importation and the probability of distribution are obtained from pathway
scenarios depicting necessary steps in: (a) the sourcing of the commodity for export; (b) its
processing, transport and storage; (c) its utilisation in Australia; and (d) the generation and disposal
of waste. Scenarios for importation and distribution are described in detail in separate discussions
(see: Probability of Importation, and Probability of Distribution).

The ‘probability of establishment or spread’ encompasses biological factors associated with the
likelihood that a pest will successfully invade an exposed host, propagate on or in that host, and
disperse from there to other populations of susceptible hosts. The probability of establishment or
spread is not obtained from a scenario or pathway analysis, but from an examination of biological
factors associated with compatibility of the host and environment, and the availability of necessary
extraneous mechanisms for dispersal. These factors are summarised in ISPM 11 – Rev. 1, and will
be described in detail separate discussions (see: Probability of Establishment and Probability of
Spread).

11 Categorisation should not be confused with the more detailed assessments of establishment or spread
potential and of economic consequences that were carried out for each quarantine pest.
12 In breaking down the probability of entry into these two components, Biosecurity Australia has not altered
the original meaning. The two components have been identified and separated to enable onshore and
offshore pathways to be described individually.
Evaluating and reporting likelihood

In this import risk analysis, likelihood was evaluated and reported qualitatively using the terms described in Table 8.

Table 8  Nomenclature for qualitative likelihoods

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Descriptive definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>The event would be very likely to occur</td>
</tr>
<tr>
<td>Moderate</td>
<td>The event would occur with an even probability</td>
</tr>
<tr>
<td>Low</td>
<td>The event would be unlikely to occur</td>
</tr>
<tr>
<td>Very low</td>
<td>The event would be very unlikely to occur</td>
</tr>
<tr>
<td>Extremely low</td>
<td>The event would be extremely unlikely to occur</td>
</tr>
<tr>
<td>Negligible</td>
<td>The event would almost certainly not occur</td>
</tr>
</tbody>
</table>

In order to ensure consistency in the usage and interpretation of these six terms and definitions, and to provide a framework under which they could be logically and transparently combined, the 0–1
interval for likelihood was also divided into six categories. Events considered virtually certain to occur were assigned a likelihood of 1.

<table>
<thead>
<tr>
<th>Category</th>
<th>Likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>0.7</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.3</td>
</tr>
<tr>
<td>Low</td>
<td>0.05</td>
</tr>
<tr>
<td>Very low</td>
<td>0.001</td>
</tr>
<tr>
<td>Extremely low</td>
<td>$10^{-6}$</td>
</tr>
<tr>
<td>Negligible</td>
<td>0</td>
</tr>
</tbody>
</table>

The boundaries adopted for qualitative likelihoods were those described in the Biosecurity Australia Guidelines for Import Risk Analysis.\(^{13}\) In choosing these boundaries, it was important for Biosecurity Australia to provide a system that could be adopted by those experts whose task it was to review scientific evidence and estimate likelihoods. It was also important to ensure that the categories were neither overly precise nor constrictive, nor so broad as to lose the precision that may have been present in the original body of scientific evidence. Accepting these requirements, it was not critical that the categories be of equal width, or that they be assigned according to a predefined arithmetic or logarithmic scale. Overall, the emphasis was on useability and, once defined, a system that would enable experts to use the corresponding terms and definitions (Table 8) consistently.

For example, an expert might consider ‘the likelihood that fruit harvested for export will be infected’ to be ‘Low’. In making this choice, the expert would have considered the likelihood to be less than the broad band representing an approximately even (moderate) probability, but not so low as to be in a range dominated by small fractions of a percent.

Likelihoods described under this nomenclature were subsequently combined using a spreadsheet-based simulation model.\(^{14}\) This was achieved by representing each of the six likelihood categories as a ‘Uniform probability distribution’ (abbreviated ‘Uniform distribution’).\(^{15}\) The parameters of each of these six Uniform distributions (their maximum and minimum values) were obtained from the boundaries of the corresponding probability category.

<table>
<thead>
<tr>
<th>Category</th>
<th>Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$L \sim \text{Uniform}(0.7, 1)$(^{16})</td>
</tr>
<tr>
<td>Moderate</td>
<td>$L \sim \text{Uniform}(0.3, 0.7)$</td>
</tr>
<tr>
<td>Low</td>
<td>$L \sim \text{Uniform}(0.05, 0.3)$</td>
</tr>
<tr>
<td>Very low</td>
<td>$L \sim \text{Uniform}(0.001, 0.05)$</td>
</tr>
<tr>
<td>Extremely low</td>
<td>$L \sim \text{Uniform}(10^{-6}, 0.001)$</td>
</tr>
<tr>
<td>Negligible</td>
<td>$L \sim \text{Uniform}(0, 10^{-6})$</td>
</tr>
</tbody>
</table>


\(^{14}\) The model was run using the spreadsheet add-on software, @Risk (2001), Palisade Corporation, USA.

\(^{15}\) A Uniform probability distribution (also called a Rectangular probability distribution) is one that has a maximum and minimum value, but for which the continuous spectrum of values in between these limits each occurs with the same probability.

\(^{16}\) This abbreviated syntax for likelihood (L) should be read as “L is distributed uniformly between 0.7 and 1”.
Thus, a likelihood described by an expert presented with the descriptors and probability ranges shown above as ‘Low’, would be represented using a Uniform probability distribution with parameters, minimum = 0.05 and maximum = 0.30.

This implies that the true likelihood might fall anywhere in the range 0.05 to 0.30, but that no particular value in this range is considered by the analyst to be more likely than any other.

The combination of likelihood descriptors using a spreadsheet-based simulation provides for the four important facilities outlined below.

A framework upon which to base the logical structure of each assessment

Assessments in this import risk analysis were carried out according to carefully described importation and distribution scenarios, and a rigorous evaluation of consequences. Consequently, the assessments were complex and multifaceted, and required a framework that ensured that all elements were combined in a transparent and consistent manner. The spreadsheet-based model provided a rigid framework. When this model was used in the context of the six general Uniform distributions, these benefits were retained without the need for more precise probability distributions or point estimates.

Evaluation of the effect of the ‘volume of trade’ during a specified period

It was expected that, as the volume of trade during a prescribed period increases, so too would the likelihood of at least one introduction of a pest. Because the volume of trade in a prescribed period affects likelihood, it will also affect risk and, by extension, will be important to the concept of ALOP, the benchmark against which risk is compared. Although this principle is explained in greater detail elsewhere (see: Risk Estimation) it is important that without a quantitative framework it would have been difficult to investigate and to demonstrate transparently or consistently the effect that projected volume of trade may have on the risks associated with imported bananas.

Accommodation of ‘uncertainty’ or ‘natural variation’ in the likelihood estimate assigned to individual steps in pathways

One of the requirements of an assessment, in which elements are quantified, is that any ‘uncertainty’ or ‘variation’ in individual estimates can be incorporated. This is important because the assessments might otherwise convey a degree of ‘precision’ that is not present in either the underlying science, or in the model parameter being estimated.

Biosecurity Australia has identified six incremental categories for likelihood and assigned a broad probability range to each. This ensures that each of the likelihoods contributing to an assessment is not expressed in unrealistically precise terms. Simulating these likelihoods as Uniform variables subsequently enables the variance within each to be incorporated directly into the outcome. A large number of iterations (n=2000) will ensure that all combinations of the possible values for each of the likelihoods are considered.

When simulation is used, the outcome is a distribution, rather than the point estimate obtained from non-random ‘deterministic’ models. Distributions obtained from simulations of this model were fitted retrospectively to the most appropriate probability range using the median value (or 50th percentile). The 50th percentile was chosen as it provides the most robust measure of central tendency for skewed (unsymmetrical) distributions.
The use of ‘sensitivity analysis’ to identify critical steps in each scenario, and thus focus information needs and (where relevant) risk management

Sensitivity analysis is a procedure that can be performed using the output from a simulation model. Sensitivity analysis ranks the model variables (in this case, either step likelihoods, or other variables such as test sensitivity that are used to calculate step likelihoods) according to their correlation with the output.

Estimates for variables that are highly correlated with the output should be as robust as possible. In this analysis, variables that were highly correlated with the output but could not be estimated with assurance were re-entered using an estimate in: (a) the lower; and (b) the higher likelihood categories. These manual manipulations were termed ‘sensitivity simulations’, and provided a means by which to determine whether a lack of precise knowledge was likely to have led to misrepresentation of the final risk.

Units for reporting likelihood and risk

An important consideration in the assessment of risk is the volume of fresh Philippines bananas that might be imported into Australia during a discrete period of trading — a measure termed ‘trade intensity’. It was expected that as trade intensity increased, so too would the likelihood of at least one pest incursion during that period.

In consideration of the effect of trade intensity, the unit chosen by Biosecurity Australia to estimate and report risk is:

... the likelihood that at least one incursion of a given pest will occur as a result of importing a projected volume of fresh bananas from the Philippines for a period of 12 months, and the likely impact of such an incursion ...

This statement of risk was adapted from Biosecurity Australia’s Guidelines for Import Risk Analysis (Draft September 2001). In these Guidelines, a period of 12 months was chosen because it allowed for the estimation of seasonal effects, but did not require long-range predictions regarding trading practices, plant or commodity production factors or pest biology.

Integral to calculations based on trade volume is the basic unit of the analysis. The unit chosen for this import risk analysis was a tonne of fresh bananas. This unit incorporates cartons, carton liners or other packaging materials. A tonne is sufficiently small as to enable probabilistic events to be visualised, but not so small as to confer an unreasonable degree of precision. A tonne is slightly larger than a large pallet, and thus also allowed the relevance of contaminants between cartons to be considered.

Probability of importation

Importation scenario for fresh bananas from the Philippines

The ‘biological pathway’\(^\text{17}\) , or ordered sequence of steps undertaken in producing and exporting fresh bananas from the Philippines is termed the ‘importation scenario’. The initiating step in the importation scenario is the selection of source plantations and the end-point is the release of a tonne of fruit (of which some are infected or infested) by AQIS at the Australian border.

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\(^{17}\) ‘Pathway’: defined in ISPM 11 Rev. – 1 as “any means that allows the entry or spread of a pest”
A conceptual representation of the importation scenario for fresh bananas is presented in Figure 6. The scenario was repeated for each of the quarantine pests identified through pest categorisation. The individual steps are defined in summary form in Table 9, immediately after the scenario pathway diagram. In this diagram and table, and elsewhere in this analysis, the term ‘Imp’ is an abbreviation for ‘importation step’.
Figure 6  Importation scenario for fresh bananas from the Philippines

- **Imp1**: Is the pest present on the source plantation?
  - Yes
  - No

- **Imp2**: Is the pest present in/on a tonne of harvested fruit?
  - Yes
  - No

- **Imp3**: Will the tonne of harvested fruit be infested or infected during transport to the packing station?
  - Yes
  - No

- **Imp4**: Will the tonne of harvested fruit be infested or infected within the packing station?
  - Yes
  - No

- **Imp5**: Will the pest or affected fruit within the tonne be detected and removed at inspection in packing station?
  - Yes
  - No

- **Imp6**: Will the pest be destroyed or removed through routine procedures within the packing station?
  - Yes
  - No

- **Imp7**: Will the pest or affected fruit within the tonne be detected and removed at quarantine inspection?
  - Yes
  - No

- **Imp8**: Will the pest remain viable in the tonne of vacuum packed cartons during transport / storage at wharf?
  - Yes
  - No

- **Imp9**: Will the pest remain viable within the tonne of vacuum packed cartons during transport to Australia?
  - Yes
  - No

- **Imp10**: Will the pest or the tonne of affected fruit be detected and the fruit removed at AQIS inspection?
  - Yes
  - No

- **Imported tonne of cartons contaminated**
- **Imported tonne of cartons not contaminated**
Table 9  Steps in the importation of fresh bananas from the Philippines

<table>
<thead>
<tr>
<th>Importation step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp1</td>
<td>The likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced</td>
</tr>
<tr>
<td>Imp2</td>
<td>The likelihood that a tonne of harvested fruit will be infected or infested with the pest</td>
</tr>
<tr>
<td>Imp3</td>
<td>The likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station</td>
</tr>
<tr>
<td>Imp4</td>
<td>The likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station</td>
</tr>
<tr>
<td>Imp5</td>
<td>The likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station</td>
</tr>
<tr>
<td>Imp6</td>
<td>The likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station</td>
</tr>
<tr>
<td>Imp7</td>
<td>The likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf</td>
</tr>
<tr>
<td>Imp8</td>
<td>The likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export</td>
</tr>
<tr>
<td>Imp9</td>
<td>The likelihood that the pest will remain viable during transport to Australia</td>
</tr>
<tr>
<td>Imp10</td>
<td>The likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia</td>
</tr>
</tbody>
</table>

Steps and likelihoods in this table correspond to those in Figure 6.

Steps in the importation scenario are discussed below. For each of the quarantine pests discussed in the analysis, it was important to identify the ‘risk scenario’ of particular concern.

The risk scenarios identified included:

- **Symptomless infection** — internal fruit or crown infection or surface infection of the peel without visible external symptoms of disease;
- **Infestation** — surface contamination with an arthropod pest;
- **Particulate trash associated with fruit** — fine leaf trash particles on the banana surface or in spaces between fingers.

‘Symptomless infection’ and ‘surface contamination’ are routinely reported characteristics of pest epidemiology and do not require clarification. ‘Particulate leaf trash’ is less well documented.

Particulate leaf trash is encountered in the harvesting, packaging and transport of many types of fruit. In the case of bananas, leaf trash particles can be introduced by nesting rodents, by entanglement of bunches with banana leaves during windstorms or as a result of leaf growth from suckers beneath bunches that penetrate under the bunch cover. In addition, small pieces of leaf trash can, under dry windy conditions become airborne, and lodge in exposed areas of banana bunches — either prior to bagging, or through holes in the bunch covers (bags). It should, however,
be recognised that most leaf trash will be removed by washing and decontamination procedures in the packing station, and that packed fruit will be largely free of trash. This assumption was borne out in the results of an intensive banana leaf trash survey conducted by NSW Agriculture quarantine inspectors at the Sydney markets on cartons of north Queensland bananas during July – November 2001 (Lazar, 2003). In these surveys, fruit were removed from cartons, and the hands and packaging carefully examined. No leaf material was found in a total of 6,100 cartons from 330 consignments. Because the procedures and quality standards used in Philippines packing station are at least comparable to those used by north Queensland banana growers and packers, it is reasonable to surmise that the amount of particulate leaf trash associated with Philippines bananas will be, at most, very small.

Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

This step describes the prevalence of affected plantations in the Philippines. In particular, it was important to consider that the prevalence of affected plantations is a dynamic variable, with substantial seasonal variation between plantations as well as variation from one year to another.

This step in the importation scenario was approached conservatively, modelling the pest-specific likelihood on the highest likely prevalence of affected plantations, rather than the prevalence at the time of writing.

Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

This step incorporates factors that contribute to the presence of the pest in or on a tonne of fruit harvested for export. Two statistics are important:

- Bananas are grown in the Philippines at a density of approximately 1700 to 2400 mats per hectare; and
- Because each bunch yields approximately 20kg of export quality fruit, a tonne will constitute approximately 50 bunches.

Important to the contamination of a tonne of bananas are aspects of the epidemiology of the pest and the pathogenesis of the disease syndrome it results in. Relevant epidemiological factors include the means by which the pest is transmitted, the route(s) of infection or infestation, any requirement for vectors, etc. Factors relevant to the pathogenesis of disease include the nature or expression of the disease syndrome, the time between infestation or infection and visible signs, the relevance of asymptomatic infection, etc.

Each of these factors was interpreted in the light of routine practices or procedures undertaken in the selection and harvesting of banana fruit that were outlined in the Philippines Department of Agriculture responses to the IRA team questions regarding the proposal to import Philippines bananas and submission in response to the June 2002 Draft IRA Report (Philippines Dept. Agriculture, 2001; Philippines Dept. Agriculture, 2002a; 2002b).

Of particular relevance to many pests are weekly phytosanitary inspections carried out in the Philippines by plantation staff. In some cases, identification of a pest or disease symptoms will result in the culling of the affected plant and others in the vicinity. In other cases, the affected plant, or parts of the affected plant, may be removed or a treatment applied. The relevance of inspection and culling to the likelihood of infection or infestation of harvested fruit is discussed within each of the pest risk assessments.

Other important management practices include:
• Regular application of fungicides to plants including at least 3 fungicide sprays before bunches are covered;
• Injection of young peduncle tissue with an insecticide;
• Removal of male flowers (de-belling);
• Removal of female flowers prior to covering the bunches;
• Insecticide spray of the immature bunch prior to covering the bunch; and
• The use of bunch covers, most of which are impregnated with the insecticide chlorpyrifos, for the 8–11 weeks prior to harvest.\(^{18}\)

Bunches are generally identified for maturity by colour tags attached to bunch covers, although in-field tests of finger diameter may also be used. Bunches are rejected in the field if they are over-mature (13 weeks from bunch emergence in the lowlands, or 20 weeks in the highlands), or if the plant has less than four functional leaves.

**Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station**

This step describes factors that may contribute to the likelihood that hitherto un-infested or uninfected fruit that has been harvested will be exposed to the pest during transport to the packing station. Such factors typically encompass aspects of the epidemiology of the pest, each of which were interpreted in the light of routine practices undertaken in the transport of harvested fruit to the packing station.

The processes used in mobile and permanent packing stations differ somewhat and are summarised individually below.

**Permanent packing stations**
• Bunches are lowered onto the frame or pad carried on the shoulder of a plantation worker, and taken to the nearest cableway where the bunch is attached to a chain on the cableway.
• Bunches are rejected if they drop to the ground and make contact with the soil at any stage from the plant to the packing station.
• Bunch covers remain on the bunch until they reach the receiver patio at the packing station.
• Bunches with severely torn bunch covers are rejected.

**Mobile packing stations (approximately 10% of plantations)**\(^{19}\)
• Bunch covers are removed in the field and bunches de-handed directly onto stretcher carrier tables.
• Two plantation workers then take hands to the packing station.
• Hands are rejected if they drop to the ground and make contact with the soil at any stage from the plant to the packing station.

\(^{18}\) Bunch covers are installed 2–3 weeks after the appearance of the first hand. Bunches remain covered for a longer period under cooler climatic conditions at higher altitudes.

\(^{19}\) The Philippines Department of Agriculture indicated in their submission to the June 2002 Draft IRA Report that field de-handing for mobile packing stations is being discontinued, contrary to earlier advice (Philippines Scientific Delegation, 2002) that the use of mobile packing stations is increasing in the Philippines.
**Imp4** — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

This step describes the potential for exposure of hitherto uninfected or uninfested fruit to the pest within the packing station. Assessment of this likelihood required that routine practices carried out in the packing station be interpreted in the light of the epidemiology of the pest, and its ability to both survive and infect or infest banana fruit.

The following steps are carried out within the packing station:

- Bunches are received on cableways (permanent facility), or hands are received on padded trays (mobile facility);
- Bunch covers and plastic sleeves are removed (permanent facility);
- Bunches with evidence of rodents’ nests, faeces, etc are discarded;
- Bunches/hands are washed with a hose using clean high-pressure water;
- Bunches/hands with evidence of pests and diseases, damage, leaf trash and dirt are rejected;
- Bunches/hands with fruit exceeding the set diameter calibration, or with a colour break, are rejected;
- Remnant female flower ends are removed;
- Bunches are de-handed into a de-handing tank of continuously flowing water containing 20ppm available chlorine and 200ppm alum;\(^\text{20}\)
- Marketable hands are selected from the tank; misshapen, damaged, pest-affected or yellowed fruit rejected;
- Hands are trimmed with knife to remove peduncle tissue and to trim the crown tissue, and to break into clusters if required;
- Visible pests, leaf tissue or sooty mould are removed by wiping with a sponge or brush plus detergent;
- Trimmed hands are placed in a flotation tank containing 20ppm available chlorine and 200ppm alum — hands remain in tank for 25 minutes at a permanent packing station, or for a shorter time at mobile packing stations;
- Hands are checked by quality inspector — unmarketable fruit removed;
- Hands are placed in a new polyethylene bag inside a new carton — polystyrene pads placed between hands to prevent blemish;
- Packed carton is weighed and marked to identify packer number, packing line number, date of packing, packing station identification number and the plantation/block where the bunch was harvested;
- Carton packed to correct weight — most air is removed using vacuum hose and polyethylene bag is constricted by tie or elastic band to maintain the seal;
- Cartons are packed on a fumigated or new wooden pallet, strapped, and then loaded into a refrigerated container or covered truck — break bulk cartons are loaded loosely on pallets until arrival at the wharf.

\(^{20}\) See **Imp6** for discussion of chlorine and alum concentration and efficacy.
Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Routine visual quality inspection is noted above in the steps undertaken in the packing station. Although quality assurance regimes vary among banana companies, each is targeted at ensuring the removal of fruit with blemishes, obvious distortion in shape, premature ripening and visible splits. It is proposed by the Philippines that quality assurance would be done on a lot basis where a ‘lot’ is the quantity of bananas packed for export to Australia by a packing station on one day.

The implications of quality assurance for this analysis will depend on the visibility of each pest, or the visibility of lesions each pest generally produces on green bananas. The likelihood that one or other of these indicators will lead to the detection and removal of infested fruit will also depend on the prevalence of the pest or of affected fruit. These issues are discussed within the individual risk assessments.

Imp6 — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

This step describes the effect of routine procedures undertaken in the packing station on the viability or removal of the pest. The routine procedures include hosing fruit bunches with water, immersion of de-handed fruit in water treated with chlorine and alum and, finally, sponging and brushing of visibly contaminated fruit.

Washing

Hosing with water is intended to remove dirt and admixed organic matter. This is relevant for pests loosely attached to the surface of fruit or associated with soil or organic matter. It is not relevant to pests carried internally in the fruit tissue. Immersion in water following de-handing will, however, disperse any remaining pests loosely attached to the fruit surface or in sap that exudes from freshly cut surfaces. Any pest dispersed in this manner could become suspended in the water, and some may even be absorbed into the exposed cut surfaces (Johnson, 1945; Zhuang et al., 1995), and therefore all fruit passing through the packing station could be universally exposed to these pests.

Sponging or brushing

Sponging or brushing is used to clean fruit, and to remove common surface contaminants such as sooty mould and arthropod pests. Although sponging or brushing will effectively remove most pests from the accessible surfaces of fruit, those lodged in spaces between fingers may be protected. In the case of pests present in sap, however, sponging and brushing would most probably only assist in dislodging dried sap and therefore increase the likelihood of the pest being suspended in tank water.

Chlorine and alum

Information provided by BPI (Philippines Dept Agriculture, 2002a, Philippines Scientific Delegation, 2002) indicates that all banana fruit exported to Australia will be treated in a solution of 20ppm chlorine plus 200ppm alum. This solution will be maintained at the stated concentration in the de-handing tanks and also in the flotation tanks through which the fruit move over a 25-minute period.

- It is understood that the 20ppm refers to free available chlorine as measured by the starch-iodine titration method for elemental chlorine, or an equivalent internationally accepted testing procedure (AOAC, 1984; Dychdala, 1991).
- It is further understood that the 200ppm alum is added in the form of potassium aluminium...
sulphate (KAl(SO₄)₂·10H₂O), which constitutes 12ppm of tri-valent aluminium (Al³⁺) in the treatment solution.

Chlorine is known to have strong biocidal properties against a wide range of living organisms (Dychdala, 1991). It is used as a disinfectant in drinking water and washing applications, for reducing microbial contamination of food products and for general surface disinfection. In relation to post harvest handling of fruit and vegetables, chlorine treatments are usually targeted against spoilage causing organisms and organisms that impact on human health. Chlorine is highly effective against non-sporo forming bacteria but also, to a lesser extent, against spore forming bacteria, fungi, algae, protozoa and viruses (Sykes, 1958; Dychdala, 1991).

The composition of chlorine in water is a complex mixture of hypochlorous acid (HOCl), hypochlorite ion (OCl⁻) and elemental chlorine (Cl₂), but it also combines with ammonia and other nitrogenous compounds to produce chloramine compounds that are also biocidal to some extent (Dychdala, 1991). The efficacy of chlorine disinfection can be increased by increasing the chlorine concentration, increasing the time of exposure, increasing the temperature, reducing the organic matter content, or by reducing the pH (more acid) (Sykes, 1958; Smith, 1962; White, 1999). Its biocidal effect is correlated most strongly with the concentration of un-dissociated hypochlorous acid. However, the biochemical basis for the biocidal properties of chlorine are not well understood (Dychdala, 1991).

Experimental research on chlorine indicates that, under standard conditions of pH, temperature and excess of chlorine over the organic matter (including organisms), the disinfection process follows first-order kinetics (the ‘Chick-Watson law’, as in Driedger et al., 2000). In its simplest form, there is a relationship between the logarithm of the number of organisms, and the product of chlorine concentration and exposure time, as expressed in the equation below.

\[ \log_{10} \left( \frac{N_0}{N_t} \right) = k(CT) \]

In this equation: \( N_0 \) and \( N_t \) are the numbers of viable organisms before and after treatment, respectively; \( C \) is the concentration of disinfectant; \( T \) is the contact time; and \( k \) is a constant characteristic of the disinfectant, the pH and the temperature (Sykes, 1958; Dychdala, 1991; Von Guten et al., 2001). This relationship has been used as a basis for regulatory standards for disinfection (USEPA, 1999) and, while modifications are necessary to account for complex biological systems (Sykes, 1958; Driedger et al., 2000), the CT concept has proven to be a useful guide for chlorine-based disinfection. If the concentration variable (\( C \)) is measured in ppm (mg l⁻¹) and the exposure time variable (\( T \)) in minutes, then the product (CT) can be expressed in units of ppm-minutes. The commercial disinfection treatment of bananas in the Philippines would then be described as \( CT_{\text{chlorine}} \, 500 \text{ppm-minutes} \) (i.e. 20ppm x 25 minutes).

Available evidence suggests that a chlorine treatment maintained at \( CT_{\text{chlorine}} \, 500 \text{ppm-minutes} \) would be an effective biocide against bacterial and fungal cells in suspension (Bartz et al., 2001; Dychdala, 1991; Holmes and Harrup, 2003; Ritenour et al., 2002; Robbs et al., 1995; Sanz et al., 2002; Zhuang et al., 1995). Such a treatment would serve to prevent fruit being universally exposed to bacteria and fungi in the de-handing and flotation tanks. However, the chlorine treatment would be unlikely to be effective against infection carried internally in the tissue.

The presence of banana sap in the de-handing and flotation tanks in commercial packing stations in the Philippines would be expected to deplete the chlorine concentration, and, therefore, its biocidal effect (US FDA, 2001). A non-replicated trial conducted under Australian commercial conditions (Lindsay, 2002b) showed that chlorine levels in a banana wash tank decreased rapidly in the presence of banana sap and organic matter. Although this trial was conducted in the absence of
alum, which would bind with the sap (see below), it did confirm the necessity for continual monitoring of chlorine levels and regular replenishment to maintain its biocidal effect. The Philippines BPI submission did not specify the method of chlorine maintenance. Rather, it indicated that whilst on some plantations, automatic chlorine assay and injection systems are used (Philippines Dept Agriculture, 2002), on others, chlorine concentration is assessed manually by colorimetry, and adjusted manually by adding concentrated chlorine and alum solutions to the tank(s). Systems for controlling pH of the de-handing and flotation tanks were not described by BPI.

Alum is added to de-handing and flotation tanks primarily to inhibit sap flow from the freshly cut surfaces of the de-handed banana fruit.

Tri-valent aluminium is known to coagulate colloidal organic impurities in drinking water (Gregor et al., 1997), either by forming soluble complexes at pH less than 4.5 or by the adsorption on aluminium hydroxide crystals formed at pH of 5 to 7 (Lu et al., 1999). In treatment of low turbidity drinking water, alum is used at concentrations of up to 2ppm Al+++ (Gregor et al., 1997). Given this, a solution of 12ppm Al+++ as used in Philippines de-handing and flotation tanks, would be expected to assist in the coagulation of banana sap.

It remains to be determined whether or not the coagulant effect of Al+++ on sap exudation assists the efficacy of chlorine by simply limiting the amount of sap or by denaturing exuded sap so that it does not react with hypochlorites in solution. Lu et al. (1999) reported that, as much aluminium would be required to remove organic matter, as there is organic matter present. In other words, 12ppm Al+++ would be rapidly depleted from the solution and would require regular replenishment. Consideration will also have to be given to the removal of alum-organic matter complexes to maximise the effects of alum treatment, and also to prevent accumulation of chlorinated organic compounds (USEPA, 1999).

Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

This step describes the efficacy of inspection procedures carried out at the packing station by BPI and the Philippines Quarantine Service (PQS), prior to the loading of vehicles, or containerisation. Although quarantine inspection may be tailored to suit the requirements of individual importing countries, the following parameters were suggested by the Philippines and will be used in the assessment of unrestricted risk.

- The inspection would occur on a ‘consignment’ basis, with a ‘consignment’ being that quantity of fruit that would be imported under a single phytosanitary certificate. This volume would vary among exporters;
- 600 clusters (approximately 46 cartons) would be selected randomly from each consignment, and examined for pests and disease symptoms;
- Detection of a pest of quarantine concern would result in the disqualification of the consignment for export to Australia; and
- Optical enhancements (magnification and spot lighting) would not be used.

Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

This step describes the ability of the pest to survive within (partially) vacuum-packed cartons during the period taken for transport to the wharf and storage prior to export.
Contamination of packaged cartons during transport to the wharf was also considered. However, given that cartons will be transported either by covered truck, or in shipping containers on an open truck, this pathway was not considered further.

**Imp9** — the likelihood that the pest will remain viable during transport to Australia

This step describes the ability of the pest to survive within (partially) vacuum-packed cartons and cool storage (13°C) during transport to Australia. Transport time is variable but may be as long as 2 weeks.

**Imp10** — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

This step describes the efficacy of on-arrival AQIS inspection. Although AQIS inspection is commonly tailored to meet the requirements of particular phytosanitary protocols, the following parameters were used to provide a measure of ‘unrestricted’ risk.

- The inspection would occur on a ‘lot’ basis, with a lot being all fruit processed by a particular packing station on a single day;
- 600 clusters (approximately 46 cartons) would be selected randomly from each lot, and examined for pests and disease symptoms;
- Optical enhancements (magnification and spot lighting) would not be used.

**Calculation of the probability of importation**

The importation scenario for fresh green bananas was complicated by the potential for infestation or infection of fruit at various points during sourcing, processing and packing. This means that fruit from a plantation that does not harbour a given pest, or clean fruit harvested from a plantation that does harbour a given pest, may become infected or infested prior to being sealed within a carton.

The expanded pathway diagram shown in two parts in Figure 7 (Part A) and Figure 8 (Part B) illustrates the effect of infestation or infection at various points in the possible pathways. The diagram is necessarily more complex than Figure 6, because the identification of individual pathways provides the basis for calculating the likelihood that an imported tonne of bananas will contain infected or infested fruit; i.e. the ‘probability of importation’.

Specifically, Figure 7 and Figure 8 show that:

- Pathways 2, 6, 9, 14 and 17 describe chains of events that lead to an imported tonne containing infected or infested fruit;
- Pathways 1, 3, 4, 5, 7, 8, 10, 11, 12, 13, 15, 16, 18, 19 and 20 describe chains of events that lead to an imported tonne of fruit that is not infected or infested; and
- The remaining pathways (those that conclude with the words “no risk”) describe chains of events that lead to the removal of fruit from the overall scenario.

Likelihoods assigned to individual steps in the importation scenario were evaluated and reported using the terms and definitions in Table 8. In each case, the estimated step-level likelihood represented the probability that infection or infestation would not be detected at that step, or that the pest would otherwise be destroyed or inactivated. This likelihood is ‘conditional’, because it is based on the assumption that the fruit has remained infected or infested up until the start of the step in question.
Likelihoods ascribed to events, or importation steps, in Figure 7 and Figure 8 are labelled Imp1 to Imp10. These likelihoods were summarised in Table 9.
Figure 7  Expanded importation scenario for fresh bananas from the Philippines (Part A)

Plantation

- Is the pest present on the source plantation?
  - Yes = Imp1
  - No = 1-Imp1

Transport to packing station

- Is the pest present on fruit selected for export?
  - Yes = Imp2
  - No = 1-Imp2

Packing station

- Will fruit be infested or infected during transport?
  - Yes = Imp3
  - No = 1-Imp3

- Will the fruit be infested or infected in packing station?
  - Yes = Imp4
  - No = 1-Imp4

- Will pest or affected fruit be detected and removed?
  - Yes = Imp5
  - No = 1-Imp5

- Will pest be removed from fruit by dipping, washing, etc?
  - Yes = Imp6
  - No = 1-Imp6

Inspection and transport to wharf

- Will infested or infected fruit be detected?
  - Yes = Imp7
  - No = 1-Imp7

No risk

No = 1-Imp1

No = 1-Imp2

No = 1-Imp3

No = 1-Imp4

No = 1-Imp5

No = 1-Imp6

No = 1-Imp7
Calculation of the probability of importation is summarised in Table 10. The calculation was based on, and resulted in, specific ‘conditional’ probabilities.
In particular, it was important to estimate:

- The likelihood that a tonne of bananas will be imported, given that it contains infected or infested fruit. This is the sum of the likelihood derived for pathways 2, 6, 9, 14 and 17. These pathway likelihoods were, in turn, derived as the product of the likelihood ascribed to each of their component steps (shown in Figure 7 and Figure 8 as ‘Imp1’ to ‘Imp10’ and (‘1-Imp1’) to (‘1-Imp10’)).

- The likelihood that a tonne of bananas will be imported, given that it contains infected or infested fruit was abbreviated as \( L(\text{fruit imported, given infected or infested}) \).

- The likelihood that a tonne of fruit will be infected or infested, given that it has been imported. This is the reverse conditional form of \( L(\text{fruit imported, given infected or infested}) \), and was calculated by dividing the latter by the sum of likelihoods obtained for all pathways that lead to the importation of bananas; i.e. pathways 1 to 20.

- The likelihood that a tonne of imported fruit will be infected or infested has been abbreviated as \( L(\text{fruit infected or infested, given imported}) \). The total likelihood that bananas harvested for export would be imported into Australia was abbreviated as \( L(\text{fruit imported}) \).

### Table 10 Calculation of the probability of importation

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Description and calculation</th>
</tr>
</thead>
</table>
| \( P_{\text{importation}} \) | The likelihood that a tonne of fruit will be infected or infested, given that it has been imported  
\( = L(\text{fruit infected or infested, given imported}) \)  
\( = L(\text{imported, given infected or infested}) \div L(\text{fruit imported}) \)  
- The likelihood that a tonne of bananas will be imported, given that it contains infected or infested fruit  
\( = L(\text{imported, given infected or infested}) \)  
\( = \text{Path2} + \text{Path6} + \text{Path9} + \text{Path14} + \text{Path17} \)  
- The likelihood that a tonne of fruit harvested for export will be imported  
\( = L(\text{fruit imported}) \)  
\( = \text{Path1} + \text{Path2} + \text{Path3} + \ldots \text{Path20} \) |
| Path1       | The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 1  
\( = \text{Imp1 x Imp2 x (1-Imp5) x Imp6} \) |
| Path2       | The likelihood that a tonne of fruit that is infected or infested will be imported through pathway 2  
\( = \text{Imp1 x Imp2 x (1-Imp5) x (1-Imp6) x (1-Imp7) x Imp8 x Imp9 x (1-Imp10)} \) |
| Path3       | The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 3  
\( = \text{Imp1 x Imp2 x (1-Imp5) x (1-Imp6) x (1-Imp7) x Imp8 x (1-Imp9)} \) |
### Likelihood Description and calculation

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path 4</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 4</td>
<td>(\text{Imp}_1 \times \text{Imp}_2 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times (1-\text{Imp}_8))</td>
</tr>
<tr>
<td>Path 5</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 5</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times \text{Imp}_6)</td>
</tr>
<tr>
<td>Path 6</td>
<td>The likelihood that a tonne of fruit that is infected or infested will be imported through pathway 6</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times \text{Imp}<em>9 \times (1-\text{Imp}</em>{10}))</td>
</tr>
<tr>
<td>Path 7</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 7</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times (1-\text{Imp}_9))</td>
</tr>
<tr>
<td>Path 8</td>
<td>The likelihood that a tonne of fruit that is not infected or infested fruit will be imported through pathway 8</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times (1-\text{Imp}_8))</td>
</tr>
<tr>
<td>Path 9</td>
<td>The likelihood that a tonne of fruit that is infected or infested will be imported through pathway 9</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times (1-\text{Imp}_3) \times \text{Imp}_4 \times (1-\text{Imp}_5) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times \text{Imp}<em>9 \times (1-\text{Imp}</em>{10}))</td>
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<tr>
<td>Path 10</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 10</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times (1-\text{Imp}_3) \times \text{Imp}_4 \times (1-\text{Imp}_5) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times (1-\text{Imp}_9))</td>
</tr>
<tr>
<td>Path 11</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 11</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times (1-\text{Imp}_3) \times \text{Imp}_4 \times (1-\text{Imp}_5) \times (1-\text{Imp}_7) \times (1-\text{Imp}_8))</td>
</tr>
<tr>
<td>Path 12</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 12</td>
<td>(\text{Imp}_1 \times (1-\text{Imp}_2) \times (1-\text{Imp}_3) \times (1-\text{Imp}_4))</td>
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<tr>
<td>Path 13</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 13</td>
<td>((1-\text{Imp}_1) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times \text{Imp}_6)</td>
</tr>
<tr>
<td>Path 14</td>
<td>The likelihood that a tonne of fruit that is infected or infested will be imported through pathway 14</td>
<td>((1-\text{Imp}_1) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times \text{Imp}<em>9 \times (1-\text{Imp}</em>{10}))</td>
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<tr>
<td>Path 15</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 15</td>
<td>((1-\text{Imp}_1) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times \text{Imp}_8 \times (1-\text{Imp}_9))</td>
</tr>
<tr>
<td>Path 16</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 16</td>
<td>((1-\text{Imp}_1) \times \text{Imp}_3 \times (1-\text{Imp}_5) \times (1-\text{Imp}_6) \times (1-\text{Imp}_7) \times (1-\text{Imp}_8))</td>
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</table>
**Likelihood Description and calculation**

<table>
<thead>
<tr>
<th>Path</th>
<th>Description</th>
<th>Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Path17</td>
<td>The likelihood that a tonne of fruit that is infected or infested will be imported through pathway 17</td>
<td>$(1-I_{\text{Imp}1}) \times (1-I_{\text{Imp}3}) \times I_{\text{Imp}4} \times (1-I_{\text{Imp}5}) \times (1-I_{\text{Imp}7}) \times I_{\text{Imp}8} \times I_{\text{Imp}9} \times (1-I_{\text{Imp}10})$</td>
</tr>
<tr>
<td>Path18</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 18</td>
<td>$(1-I_{\text{Imp}1}) \times (1-I_{\text{Imp}3}) \times I_{\text{Imp}4} \times (1-I_{\text{Imp}5}) \times (1-I_{\text{Imp}7}) \times I_{\text{Imp}8} \times (1-I_{\text{Imp}9})$</td>
</tr>
<tr>
<td>Path19</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 19</td>
<td>$(1-I_{\text{Imp}1}) \times (1-I_{\text{Imp}3}) \times I_{\text{Imp}4} \times (1-I_{\text{Imp}5}) \times (1-I_{\text{Imp}7}) \times (1-I_{\text{Imp}8})$</td>
</tr>
<tr>
<td>Path20</td>
<td>The likelihood that a tonne of fruit that is not infected or infested will be imported through pathway 20</td>
<td>$(1-I_{\text{Imp}1}) \times (1-I_{\text{Imp}3}) \times (1-I_{\text{Imp}4})$</td>
</tr>
</tbody>
</table>

**Probability of distribution**

The ‘biological pathway’, or ordered sequence of steps describing the distribution of a pest from its point of entry into Australia to a susceptible host, is termed a distribution scenario.

In the context of this assessment:

- The *initiation point* for a distribution scenario is the release of a tonne of fruit, of which some is infested or infected with a given pest, by AQIS at the Australian border; and
- The *endpoint* for a distribution scenario is the delivery of a sustainable number of pests, or sufficient dose of a pest, to a suitable site on a susceptible host.

A conceptual representation of the distribution scenario is presented in Figure 9. The scenario will be repeated for each of the quarantine pests identified in pest categorisation.

The distribution scenario for fresh bananas from the Philippines has substantially fewer (and more general) steps than the importation scenario. This is because the relevant processes involved in the storage, ripening, distribution and human consumption of bananas in Australia, and the generation and disposal of banana waste (fruit and peel) are less understood, or less able to be estimated with precision, than the steps undertaken in sourcing and importing fruit.

The distribution scenario is concerned only with the bananas used by, or intended for use by, households or people; i.e. the distribution scenario does not include pathways for the use of bananas by the food service industries (restaurants, the catering industry, etc) or by fruit processors. There are two reasons for this:

- *Firstly*, the IRA team established that the pathway of highest risk for all identified quarantine pests was the distribution and sale of fruit for direct human consumption, and the random disposal of spoiled fruit and banana waste (fruit and peel); and
- *Secondly*, it is very likely that bananas, if imported, would be distributed through supermarket...
outlets in Australia\(^{21}\). Consequently, it is extremely unlikely that a substantial proportion of fruit used by the food service industries or by food processors would be purchased through supermarkets.

Groups of susceptible hosts

The term, ‘group of susceptible hosts’, denotes a category of plant (whether based on its species or the conditions in which it lives or is managed) that may be susceptible to one or more of the pests considered in this import risk analysis.

Three groups of susceptible hosts are considered relevant to the distribution of pests of bananas (Figure 9):

- Commercially cultivated banana plants;
- Household (non-commercial) banana plants or other susceptible garden plants (including weeds); and
- Susceptible wild (native and feral) plants including wild banana plants or susceptible cultivated plants other than bananas.

These groups were considered separately because factors relevant to their exposure to a pest associated with imported Philippines bananas, and the likely impact of exposure, were likely to differ.

\(^{21}\) ABGC industry statistics report that banana sales may be as high as 70\% through supermarket chains (ABGC, 2003)
Figure 9  Distribution scenario for fresh bananas from the Philippines

Dist1
Will a tonne of imported bananas contain infested or infected fruit?

Yes = probability of importation

Dist1
Will pest survive storage, ripening and distribution to wholesalers?

Dist2
Distribution of imported fruit within Australia

Dist2
Will pest be discarded with waste or otherwise enter the environment?

Dist2
Will pest be discarded with waste or otherwise enter the environment?

Dist2
Will pest be discarded with waste or otherwise enter the environment?

Dist2
Will pest be discarded with waste or otherwise enter the environment?

Dist3
Will commercial banana plants be exposed to the pest?

Dist4
Will susceptible household plants be exposed to the pest?

Dist5
Will susceptible wild plants or susceptible cultivated plants (other than bananas) be exposed to the pest?

No exposure of susceptible species

Prop1
The proportion of fruit distributed to an area in which bananas are commercially grown

Prop2
The proportion of fruit distributed to an area in which susceptible household plants are found

Prop3
The proportion of fruit distributed to an area in which susceptible wild plants, or susceptible cultivated plants (other than bananas) are found

No exposure of commercial banana plants

No exposure of susceptible household plants

No exposure of susceptible wild plants, or susceptible cultivated plants
The conditional probability assigned to each step in a distribution scenario represents the likelihood that the pest will not be detected at that step, or that the pest will not be destroyed, if infection or infestation has persisted up until that point in the scenario. Likelihoods assigned to steps in the assessment of distribution potential were represented using the terms and definitions shown in Table 8.

### Table 11  Steps in the distribution scenario for fresh bananas from the Philippines

<table>
<thead>
<tr>
<th>Distribution step&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist1</td>
<td>The likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers</td>
</tr>
<tr>
<td>Prop1</td>
<td>The proportion of imported bananas that is likely to be distributed to an area&lt;sup&gt;2&lt;/sup&gt; in which bananas are grown commercially</td>
</tr>
<tr>
<td>Prop2</td>
<td>The proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found</td>
</tr>
<tr>
<td>Prop3&lt;sup&gt;3&lt;/sup&gt;</td>
<td>The proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found</td>
</tr>
<tr>
<td>Dist2</td>
<td>The likelihood that a pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment</td>
</tr>
<tr>
<td>Dist3</td>
<td>The likelihood that commercially cultivated bananas would be exposed to a pest discarded with banana waste (fruit and peel), or a pest that had otherwise entered the environment</td>
</tr>
<tr>
<td>Dist4</td>
<td>The likelihood that household (i.e. non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to a pest discarded with banana waste (fruit and peel), or a pest that had otherwise entered the environment</td>
</tr>
<tr>
<td>Dist5</td>
<td>The likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment</td>
</tr>
</tbody>
</table>

<sup>1</sup> Steps and likelihoods in this table correspond to those in Figure 9.

<sup>2</sup> In the context of this analysis, an ‘area’ denotes a local government area or LGA — in densely populated parts of Australia, LGAs are generally geographically smaller than in rural and remote parts

<sup>3</sup> Prop1, Prop2 and Prop3 are not mutually exclusive — i.e. a particular imported banana (or batch of bananas) could be distributed to an area in which commercial bananas and susceptible household plants and susceptible wild plants, or susceptible cultivated plants other than bananas, are found
Exposure of commercial banana plants

The pathway leading to the exposure of commercially cultivated banana plants (Figure 9) involves the completion of four key steps:

- The survival of the pest through the process of storage and ripening, and distribution to wholesalers (Dist1);
- The distribution of imported infected and/or infested bananas to an area in which bananas are grown commercially (Prop1);
- The discarding of the pest with waste, or its entry into the environment through other means (Dist2); and
- The subsequent exposure of commercial banana plants to the pest (Dist3).

Dist1 and Dist2 will depend on pest biology and epidemiology, and are discussed within the individual pest risk assessments. Storage conditions would be 13-20°C with a relative humidity of greater than 80%. The seal of the banana bag is broken for ripening. Ripening temperatures during a 5-day cycle would vary from 16.5°C for the first day, reducing to 15°C. If fast ripening is required, the maximum temperature is 17°C for day 1, reducing to 15°C (Muirhead, 2002). However, temperatures are often raised to 18°C for even faster ripening during periods of peak demand. In supermarkets and retail shops, air conditioning generally places the temperature between 20 and 22°C.

Prop1 describes the proportion of imported bananas likely to be distributed to, and consumed within, an area in which bananas are grown commercially. To obtain this proportion, local government areas in Queensland, New South Wales, Western Australia and the Northern Territory in which bananas are grown commercially were identified, and the proportion of the Australian population resident in these areas calculated from Australian demographic statistics obtained from the Australian Bureau of Statistics. This approach rests on the assumption that the proportional distribution of imported bananas within Australia would follow approximately the proportional distribution of the Australian population. This assumption is conservative, since the demand for imported bananas in some banana growing areas is likely to be lower than, in particular, urban areas removed from banana production.

The calculation showed that approximately 18% of the Australian population currently resides in areas in which bananas are grown commercially. The bulk of this can be attributed to approximately 15% of the Australian population that resides in areas of north and southeast Queensland (including the Brisbane area) and approximately 2.5% of the Australian population that resides in areas of northern New South Wales where bananas are grown commercially. The population densities in these areas are shown in Figure 10 below. The number of people living in areas of Western Australia or the Northern Territory in which bananas are grown commercially is comparatively small.

When correlated with Biosecurity Australia’s likelihood descriptors, the proportion (18%) of imported bananas that are likely to be distributed to, and consumed within, an area in which bananas are grown commercially (Prop1) was considered low.

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22 Available at: http://www.abs.gov.au
**Figure 10  Distribution of the Australian population (2003)**

Source: Australian Bureau of Statistics, 2003

**Dist3** is a complex variable that encompasses biological and epidemiological factors that contribute to the ability of a pest to move from discarded banana waste, to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of the pest in or on fruit, in discarded waste or in the soil;
- The distance between the pest’s point of entry into the environment (discarded banana waste) and a commercial banana plant;
- The mechanism(s) by which the pest could move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant to a sustainable number of arthropod pests, or sufficient dose of a pathogen.

The persistence of a pest and the conditions needed for adequate exposure of a suitable site on a susceptible plant, are characteristics of its biology, and are discussed within the individual pest risk assessments.

The distance between the point at which a pest enters the environment and a commercial banana plant, and the mechanism(s) by which it may move across this distance, will depend on whether the pest is confined to banana waste (e.g. some bacteria and viruses), or whether it is able to move from unpacked fruit by itself (e.g. most mobile arthropods) or by a biological or mechanical vector (e.g. wind-borne arthropod larvae, or some vectored viruses).

- Where a pest is confined to banana waste, it will be relevant to consider that a relatively high
The proportion of household waste from major population centres is managed through regulated refuse collection and disposal services. The importance of managed waste disposal varies among pests. In some cases, the bulk of waste may represent an important point of amplification. In other cases, hastened fruit decay and competition with saprophytes may mean that the pest’s viability in such facilities will be threatened. Likewise, the importance of unmanaged waste disposal (whether this is the random discarding of peel, or the use of garden compost systems) to the potential for exposure of commercial banana plants will vary among pests.

- Where a pest is able to move from fruit by itself, or through biological or mechanical vectors, waste disposal patterns may be less relevant than the proximity of points of sale to commercial banana plantations.

Most people within the banana growing areas of Australia live in urban or semi-rural populations (Banana TWG 3, 2002). These centres are generally well removed from commercial banana plantations. If plantation owners or workers purchased imported bananas, it is more likely that waste would be discarded near households or worker facilities, than in the plantation.

These considerations, and the overall likelihood assigned to Dist3, are discussed within the individual pest risk assessments.

**Exposure of household (non-commercial) banana plants or other susceptible garden plants (including weeds)**

The pathway leading to the exposure of susceptible household plants (Figure 9) involves the completion of four key steps:

- The survival of the pest through the process of storage and ripening, and distribution to wholesalers (Dist1);
- The distribution of imported infected and/or infested bananas to an area in which susceptible household plants can be found (Prop2);
- The discarding of the pest with waste, or its entry into the environment through other means (Dist2); and
- The subsequent exposure of susceptible household plants (Dist4).

As mentioned above, Dist1 and Dist2 are derived as a function of pest biology and epidemiology, and are discussed within the individual pest risk assessments. Storage conditions would be 13-20°C with a relative humidity of greater than 80%. The seal of the banana bag is broken for ripening. Ripening temperatures during a 5-day cycle would vary from 16.5°C for the first day, reducing to 15°C. If fast ripening is required, the maximum temperature is 17°C for day 1, reducing to 15°C (Muirhead, 2002). However, temperatures are often raised to 18°C for even faster ripening during periods of peak demand. In supermarkets and retail shops, air conditioning generally places the temperature between 20 and 22°C.

Prop2 describes the proportion of imported bananas that are likely to be distributed to, and consumed within, an area (where this denotes a local government area or LGA) in which susceptible household plants are found.

Where pests are specific to bananas, Prop2 describes the proportion of areas in Australia in which households keep ornamental or productive banana plants. A survey conducted in March 2002 (see Appendix 2) indicated that a measurable proportion of households in the major population centres on Australia’s Eastern seaboard above and including Sydney, grow banana plants. Below this, the...
climate is generally more temperate, and only a very small proportion (less than 1%) of households in population centres on either the eastern and southern seabords (including Melbourne, Hobart and Adelaide) grow bananas.

In consideration of this result, the following assumptions were used to estimate the proportion of imported bananas that are likely to be distributed to, and consumed within, an area in Australia in which households keep ornamental or productive banana plants.

- **New South Wales** — coastal local government areas north of and including the coastal suburbs of Sydney (population approximately = 1.7 million)
- **Northern Territory** — all local government areas in the Northern Territory (population approximately = 0.2 million)
- **Queensland** — all local government areas within the Pest Quarantine Areas for pests of banana plants, as determined by the Queensland Department of Primary Industries (QDPI) (population approximately = 3.3 million)
- **Western Australia** — coastal local government areas in Western Australia north of and including the coastal suburbs of Perth (population approximately = 1.2 million)
- Because of the sparsity of household banana plants in Victoria, South Australia, the Australian Capital Territory and Tasmania, these States and Territories were removed.

From the above, the total number of Australians living in areas in which household bananas can be found was estimated to be 6.4 million. With a total population of 19.8 million, this equates to approximately 32% of Australians.

If it can be assumed that imported bananas would be distributed according to the distribution of the Australian population, then it follows that approximately 32% of imported bananas would be distributed to an area in which household bananas are found. Where a pest is specific to bananas, Prop2 would thus be described as **moderate**.

Where a pest is not specific to bananas — i.e. where it can infect or infest other household plants (including weed species), Prop2 will be increased to include any further areas that contain susceptible household plants other than bananas. Importantly, this will, for some pests, include some of the larger population centres in more temperate southern parts of Australia.

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable site on a susceptible household plant. Of particular relevance are:

- The persistence of the pest in or on fruit, in discarded waste or in the soil;
- The distance between the pest’s point of entry into the environment (discarded banana waste) and a susceptible household plant;
- The mechanism(s) by which the pest could move from discarded banana waste to a susceptible household plant; and
- The conditions needed for exposure of a suitable site on the plant to a sustainable number of arthropod pests, or sufficient dose of a pathogen.

The persistence of a pest and its ability to infect an exposed susceptible household plant are characteristics of its biology, and are discussed within the individual pest risk assessments.

The distance between the point at which a pest enters the environment and a susceptible household plant will depend on whether the pest is confined to banana waste (e.g. some bacteria and viruses),
or whether it is able to move from unpacked fruit by itself (e.g. most mobile arthropods) or by a biological or mechanical vector (e.g. wind-borne arthropod larvae, or some vectored viruses).

- Where a pest is confined to banana waste, it will be relevant to consider that a relatively high proportion of household waste from major production centres is managed through regulated refuse collection and disposal services. The importance of managed waste disposal varies among pests. In some cases, the bulk of waste may represent an important point of amplification. In other cases, hastened fruit decay and competition with saprophytes may mean that the pest’s viability in such facilities will be threatened. In all cases, managed waste will represent the removal of the pest from the household, and a subsequent reduction in the likelihood that susceptible garden plants will be exposed.

- Where a pest is able to move from fruit by itself, or through vectors, waste disposal patterns may be less relevant than the proximity of points of sale to a susceptible household plant.

The distance between the point at which a pest enters the environment and a susceptible household plant will also depend on the range and abundance of such plants. Importantly, this will differ in different parts of Australia. Accepting this, where common garden plants or common garden weed species are susceptible, it is more likely that a pest associated with waste from a household, or a pest that has entered the environment through vectors or under its own locomotion, would come into contact with these plants.

These considerations, and the overall likelihood assigned to Dist4, are discussed within individual pest risk assessments.

**Exposure of susceptible wild (native and feral) plants including banana plants or susceptible cultivated plants other than bananas**

The pathway leading to the exposure of susceptible wild plants, or susceptible cultivated plants other than bananas (Figure 9) involves the completion of four key steps:

- The survival of the pest through the process of storage and ripening, and distribution to wholesalers (Dist1);
- The distribution of imported infected and/or infested bananas to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found (Prop3);
- The discarding of the pest with waste, or its entry into the environment through other means (Dist2); and
- The subsequent exposure of susceptible wild plants, or susceptible cultivated plants other than bananas (Dist5).

As mentioned above, Dist1 and Dist2 are derived as a function of pest biology, and are discussed within the individual pest risk assessments. Storage conditions would be 13-20°C with a relative humidity of greater than 80%. The seal of the banana bag is broken for ripening. Ripening temperatures during a 5-day cycle would vary from 16.5°C for the first day, reducing to 15°C. If fast ripening is required, the maximum temperature is 17°C for day 1, reducing to 15°C (Muirhead, 2002). However, temperatures are often raised to 18°C for even faster ripening during periods of peak demand. In supermarkets and retail shops, air conditioning generally places the temperature between 20 and 22°C.

Prop3 describes the proportion of imported bananas that are likely to be distributed to, and consumed within, an area (where this denotes a local government area or LGA) in which susceptible wild plants, or susceptible cultivated plants other than bananas are found.
The term ‘wild plants’ includes native and feral banana plants, and amenity plants, such as those planted in public gardens and beside roadways, as well as plants (including weed species) growing naturally in these areas, in parks and preserves, or on farmland or grazing land.

The term, ‘cultivated plants’, incorporates all commercially cultivated pasture and crop species other than bananas.

Where pests are specific to bananas, Prop3 describes the proportion of areas in Australia in which wild banana plants can be found. This includes both native bananas and feral bananas.

Australia has three species of native bananas — *Musa acuminata* subsp. *Banksii* F. Muell., *Musa jackeyi* W. Hill and *Musa fitzalanii* F. Muell.— all largely restricted to tropical forests of north Queensland. The cultivation of native and seeded bananas is prohibited in banana growing States of Australia, except for registered botanical gardens. Feral bananas, however, are more widespread and common, and continue to be found in many banana-growing parts of Australia in spite of official measures to minimise the incidence of pests and diseases by the removal of such plants. Feral bananas generally originate in part from abandoned commercial farms and, in part, from plants discarded by householders.

In view of this, the following assumptions were used to estimate the proportion of imported bananas that are likely to be distributed to, and consumed within, an area (where this denotes a local government area) in Australia in which wild (native or feral) banana plants are found.

- **New South Wales** — areas in NSW in which bananas are or have been grown commercially (population approximately = 0.5 million)
- **Northern Territory** — areas in the Northern Territory in which bananas are or have been grown commercially (population approximately = 0.07 million)
- **Queensland** — QDPI has identified local government areas in Queensland where wild (native or feral) bananas are reported to occur (population approximately = 1.6 million) (Allen, 2003)
- **Western Australia** — areas in Western Australia in which bananas are or have been grown commercially (population approximately = 0.01 million)
- **Because of the sparsity of wild bananas in Victoria, South Australia, the Australian Capital Territory and Tasmanian, these States and Territories were removed.**

From the above, the total number of Australians living in areas in which wild (native or feral) bananas can be found was estimated to be 2.2 million. With a total population of 19.8 million, this equates to approximately 11% of Australians.

If it can be assumed that imported bananas would be distributed according to the distribution of the Australian population, then it follows that approximately 11% of imported bananas would be distributed to an area in which wild (native or feral) bananas are found. Where a pest is specific to bananas, Prop3 would thus be described as low.

Where a pest is not specific to bananas — i.e. where it can infect or infest other wild plants (including weed species), or commercially cultivated plants other than bananas — Prop3 will be increased. Importantly, this will, for some pests, include some of the larger population centres in more temperate southern parts of Australia.

As for Dist3 and Dist4 (see above), Dist5 is a complex variable that encompasses biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable site on a susceptible wild plant (including bananas) or a susceptible cultivated plant (other than bananas). Of particular relevance are:
• The persistence of the pest in or on fruit, in discarded waste or in the soil;
• The distance between the pest’s point of entry into the environment (discarded banana waste) and a susceptible wild plant or susceptible cultivated plant (other than bananas);
• The mechanism(s) by which the pest could move from discarded banana waste to a susceptible wild plant or susceptible cultivated plant; and
• The conditions needed for exposure of a suitable site on the plant to a sustainable number of arthropod pests, or sufficient dose of a pathogen.

The persistence of a pest and its ability to infect an exposed susceptible wild or cultivated plant (other than a banana plant) are characteristics of its biology, and are discussed within the individual pest risk assessments.

The distance between the point at which a pest enters the environment and a susceptible wild or cultivated plant (other than a banana plant) will depend on whether the pest is confined to banana waste (e.g. some bacteria and viruses), or whether it is able to move from unpacked fruit by itself (e.g. most mobile arthropods) or by a biological or mechanical vector (e.g. wind-borne arthropod larvae, or some vectored viruses).

• Where a pest is confined to banana waste, it will be relevant to consider that a relatively high proportion of household waste from major production centres is managed through regulated refuse collection and disposal services. The importance of managed waste disposal varies among pests. In some cases, the bulk of waste may represent an important point of amplification. In other cases, hastened fruit decay and competition with saprophytes may mean that the pest’s viability in such facilities will be threatened. In contrast to Dist4, however, the removal of waste from a household is likely to increase its proximity to a susceptible wild or cultivated plant (other than a banana plant).
• Where a pest is able to move from fruit by itself, or through vectors, waste disposal patterns may be less relevant than the proximity of points of sale to a susceptible wild or cultivated plant (other than a banana plant).

The distance between the point at which a pest enters the environment and a susceptible wild or cultivated plant (other than a banana) will also depend on the range and abundance of such plants. It seems sensible to assume that, if common wild plants (including weeds) or cultivated plants are susceptible, it is more likely that a pest associated with waste from a household, or a pest that has entered the environment through vectors or under its own locomotion, would come into contact with these plants.

These considerations, and the overall likelihood assigned to Dist5, will be discussed within the individual pest risk assessments.

**Calculation of the partial probability of distribution for each group of susceptible hosts**

Calculation of the probability of distribution for each group of susceptible host is illustrated in Table 12. Dist1 and Dist2 are common to each pathway. Prop1 to Prop3 and Dist3 to Dist5 are used to capture likelihoods and events that differ among the three pathways.
**Table 12 Calculation of partial probabilities of distribution**

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Description and calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>PPD Commercial</td>
<td>The likelihood that commercial banana plants will be exposed to a pest imported in a</td>
</tr>
<tr>
<td></td>
<td>tonne of infected or infested fruit</td>
</tr>
<tr>
<td></td>
<td>[ \text{PPD Commercial} = \text{Dist1} \times \text{Prop1} \times \text{Dist2} \times \text{Dist3} ]</td>
</tr>
<tr>
<td>PPD Household</td>
<td>The likelihood that susceptible household plants will be exposed to a pest imported in a</td>
</tr>
<tr>
<td></td>
<td>tonne of infected or infested fruit</td>
</tr>
<tr>
<td></td>
<td>[ \text{PPD Household} = \text{Dist1} \times \text{Prop2} \times \text{Dist2} \times \text{Dist4} ]</td>
</tr>
<tr>
<td>PPD Wild</td>
<td>The likelihood that susceptible wild plants, or susceptible cultivated plants other than</td>
</tr>
<tr>
<td></td>
<td>bananas will be exposed to a pest imported in a tonne of infected or infested fruit</td>
</tr>
<tr>
<td></td>
<td>[ \text{PPD Wild} = \text{Dist1} \times \text{Prop3} \times \text{Dist2} \times \text{Dist5} ]</td>
</tr>
</tbody>
</table>

**Probability of establishment**

Under IPPC terminology, the probability of establishment is derived from a comparative assessment of those factors in the source country and ‘PRA area’ considered pertinent to the ability of a pest to survive and perpetuate. These factors include:

- **The availability, quantity and distribution of hosts in the PRA area.** Whether hosts (or suitable near relatives) occur in sufficient numbers and geographical proximity to allow the pest to complete its life cycle, whether known vectors (or suitable alternate species) are present or likely to be introduced.

- **The environmental suitability of the PRA area.** Whether environmental factors (climate, soil conditions, pest and host competition, etc) are suitable for the pest and any identified hosts or vectors. Environmental factors in protected environment (glasshouses, etc) will be considered.

- **The potential for adaptation of the pest.** Whether the species is polymorphic, and the degree to which it has demonstrated an ability to adapt to conditions as present in the PRA area. Genetic adaptability is considered an indication of a pest’s ability to withstand environmental fluctuations, to adapt to a wide range of habitats, to develop pesticide resistance and to overcome host resistance.

- **The reproductive strategy of the pest.** Characteristics that enable the pest to reproduce effectively in the new environment. Examples include pathogenesis, self-crossing, duration of life cycle, number of generations/year, the presence of a resting stage, etc.

- **The method of pest survival.** Whether a minimum population is needed for survival.

- **Cultural practices and control measures.** Whether these differ between the area of origin and the PRA area. Pest-control programs and natural enemies of the pest will be considered. It was noted that pests for which there is no feasible control should be considered a greater threat than those that are subject to control in the area of origin.

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23 For more details see ISPM 11 Rev. – 1 section 2.2.2
Thus, in contrast to the probability of importation and the probability of distribution, the ‘probability of establishment’ does not result from a structured scenario of events, or ‘pathway’ but, rather, reflects an expert opinion derived from a comparative evaluation of the biological factors described above.

Furthermore, it will be clear that factors determining the likelihood that a pest will establish (availability and quantity of hosts, suitability of environment, etc) will differ markedly for each of the three broad groups of ‘susceptible hosts’ identified above, i.e. (a) commercially cultivated banana plants, (b) household (non-commercial) banana plants or other susceptible household plants (including weeds), and (c) susceptible wild (native and feral) plants (including bananas) or susceptible cultivated plants (other than bananas). Therefore, a separate probability of establishment (termed a ‘partial probability of establishment’, or PPE) was obtained for each group. The subsequent combination of these probabilities with other likelihoods, and with estimates of the impact of each pest, is described in the discussion of risk estimation (see: Conclusions: Risk Estimation).

**Probability of spread**

Under IPPC terminology, the probability of spread is derived from a comparative assessment of those factors in the source country and ‘PRA area’ considered pertinent to the expansion of the geographical distribution of a pest\(^\text{24}\).

These factors include:
- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- Movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

As for the probability of establishment, estimation of the probability of spread (or ‘spread potential’) was not based on a pathway but, rather, reflected expert opinion on a comparative evaluation of the biological factors described above. In addition, because spread potential will differ amongst the three identified groups of susceptible hosts, a separate estimate was derived for each. These separate estimates were termed the partial probabilities of spread, or PPS.

**Consequences of entry, establishment or spread**

**Direct and indirect criteria**

Criteria for assessing the consequences associated with a pest or disease are outlined in the relevant acts and agreements, and in the standards prepared by the international organisations.

In particular:
- The *Quarantine Act 1908* requires decision-makers to take into account the likelihood of harm being caused (to humans, animals, plants, other aspects of the environment, or economic activities) and the probable extent of the harm (Section 5D).

\(^{24}\) For more details see ISPM 11 Rev. – 1 section 2.2.3
The SPS Agreement states that:

...Members shall take into account as relevant economic factors: the potential damage in
terms of loss of production or sales in the event of entry, establishment or spread of a
pest or disease; the costs of control or eradication in the territory of the importing
Member; and the relative cost-effectiveness of alternative approaches to limiting risks.

IPPC expands the ‘relevant economic factors’ described in the SPS Agreement to differentiate
between the ‘direct’ and ‘indirect’ effects of a pest, and to provide examples of factors that will
typically be relevant to an import risk analysis\(^25\).

In each case, consequence assessments do not extend to considering the benefits or otherwise of
trade in a given commodity, nor to the impact of import competition on industries or consumers in
the importing country.

The particular direct and indirect consequences considered in this import risk analysis are
discussed below.

**Direct consequences**

These describe direct harm to:

- Animal or plant life, or health (whether native or introduced species), including animal and
  plant production losses;
- Human life or health; and
- Any other aspects of the environment not covered above (e.g. the physical environment or
  other life forms — micro-organisms, etc.).

**Indirect consequences**

Indirect consequences are the costs resulting from natural or human processes associated with the
incursion of a pest. These include:

- New or modified eradication, control, surveillance/monitoring and compensation
  strategies/programs;
- Domestic trade or industry effects, including changes in consumer demand and effects on other
  industries supplying inputs to, or utilising outputs from, directly affected industries;
- International trade effects, including loss of markets, meeting new technical requirements to
  enter/maintain markets and changes in international consumer demand; and
- Indirect effects on the environment (see below), including biodiversity, endangered species,
  the integrity of ecosystems, reduced tourism, reduced rural economic viability and loss of
  social amenity, and any ‘side effects’ of control measures.

A range of factors is relevant to the consideration of harm to the environment\(^26\). This includes harm
arising from the impact of the pest, as well as from any treatments or procedures used to control it.
The extent of harm will be evaluated taking into account the circumstances of the particular pest,
and using the following factors:

- On-site and off-site impacts;
- The geographical scope and magnitude of the impact;

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\(^{25}\) For more details see ISPM 11 Rev. – 1 section 2.3

\(^{26}\) For more details see ISPM 11 Rev. – 1 section 2.3.1.2
• The frequency and duration of the action causing the harm;
• The total impact which can be attributed to that action over the entire geographic area affected, and over time (i.e. cumulative impact);
• Any synergistic effect of hazards on impact;
• Reversibility of the impact;
• The sensitivity of the receiving environment (recognised environmental features of high sensitivity); and
• The degree of confidence with which the impacts of the action are known and understood.

The direct and indirect consequences described above collectively cover harm to human beings, animals, plants, other aspects of the environment, or economic activities. Given this, the consequences are also mutually exclusive, i.e. an effect will not be assessed more than once. In particular, the direct effects of a pest on a native or wild species were assessed under the criterion describing the ‘animal or plant life or health, including animal and plant production losses’, whereas the indirect or ‘flow-on’ effects on the environment were assessed under the last indirect criterion.

Describing the impact of a pest

Each direct and indirect consequence was estimated at four levels — local, district, regional and national — and the values derived subsequently translated into a single qualitative score (A–F). In this context, the terms ‘local’, ‘district’, ‘regional’ and ‘national’ have been defined as follows.

Local: An aggregate of households or enterprises, e.g. a rural community, a town or a local government area

District: A geographically or geopolitically associated collection of aggregates

Region: A geographically or geopolitically associated collection of districts which, for the purposes of this analysis, approximates an Australian State or Territory

National: Australia-wide

At each level, the magnitude of impact has been described as ‘unlikely to be discernible’, of ‘minor significance’, ‘significant’ or ‘highly significant’:

• An unlikely to be discernible impact is not usually distinguishable from normal day-to-day variation in the criterion.

• An impact of minor significance is not expected to threaten economic viability, but would lead to a minor increase in mortality/morbidity or a minor decrease in production. For non-commercial factors, the impact is not expected to threaten the intrinsic ‘value’ of the criterion, though the value of the criterion would be considered as ‘disturbed’. Effects would generally be reversible.

• A significant impact would threaten economic viability through a moderate increase in mortality/morbidity, or a moderate decrease in production. For non-commercial factors, the intrinsic ‘value’ of the criterion would be considered as significantly diminished or threatened. Effects may not be reversible.

• A highly significant impact would threaten economic viability through a large increase in mortality/morbidity, or a large decrease in production. For non-commercial factors, the

27 In this analysis, the term ‘State or Territory’ has been used consistently in place of the term ‘region’
intrinsic ‘value’ of the criterion would be considered as severely or irreversibly damaged.

When assessing the local, district, State or Territory and national consequences, the frame of reference was the impact of each pest on the community as a whole. This may differ from the effect of the pest on the local, district, State or Territory or national population, of directly affected parties.

A related consideration is the persistence of an effect. In general, where the effect is prolonged, as was the case if it were thought to persist for several production cycles or if regeneration would take several generations, the consequences were considered greater. If an effect was not prolonged, then consequences were likely to be less serious. In either case, it was at times necessary to place a pest in the next higher or lower category for that consequence criterion.

As mentioned at the beginning of this section, estimates of the consequences of the entry, establishment or spread of a pest or disease at the different levels were subsequently translated to an overall score (A–F) using the schema outlined in Table 13. In this table, the magnitude of impact is assessed first at the national level. If, for that particular criterion, there is no discernible impact at a national level, then, in descending order, the magnitude of impact is assessed at the State or Territory level, district level or at the local level.

<table>
<thead>
<tr>
<th>Impact score</th>
<th>National</th>
<th>State or Territory</th>
<th>District</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>F Highly significant</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>E Significant</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>D Minor</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>C Unlikely to be discernible</td>
<td>Minor</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>B Unlikely to be discernible</td>
<td>Unlikely to be discernible</td>
<td>Minor</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>A Unlikely to be discernible</td>
<td>Unlikely to be discernible</td>
<td>Unlikely to be discernible</td>
<td>Minor</td>
<td></td>
</tr>
</tbody>
</table>

- = the same or higher impact score as the next higher level

**Approach to the consequence assessment for Philippines bananas**

The assessment of consequences of entry, establishment or spread of Philippines bananas was carried out in two steps:
- The magnitude of impact of a pest on each of the direct and indirect criteria was evaluated; and
- The magnitude of impact obtained for each of the direct and indirect criteria was combined to give an overall (qualitative) estimate of the consequences of entry, establishment or spread.

The first step was undertaken using the descriptive (qualitative) system outlined in the preceding section.
The second step was undertaken by following the decision rules below. These rules are mutually exclusive, and were addressed in the order that they appeared in the list. For example, if the first set of conditions does not apply, the second set will be considered. If the second set does not apply, the third set will be considered ... and so forth until one of the rules applies:

- Where the consequences of a pest with respect to any direct or indirect criterion is ‘F’, the overall consequences are considered ‘extreme’;
- Where the consequences of a pest with respect to more than one criterion is ‘E’, the overall consequences are considered ‘extreme’;
- Where the consequences of a pest with respect to a single criterion is ‘E’ and the consequences of a pest with respect to each remaining criterion is ‘D’, the overall consequences are considered ‘extreme’;
- Where the consequences of a pest with respect to a single criterion is ‘E’ and the consequences of a pest with respect to remaining criteria is not unanimously ‘D’, the overall consequences are considered ‘high’;
- Where the consequences of a pest with respect to all criteria is ‘D’, the overall consequences are considered ‘high’;
- Where the consequences of a pest with respect to one or more criteria is ‘D’, the overall consequences are considered ‘moderate’;
- Where the consequences of a pest with respect to all criteria is ‘C’, the overall consequences are considered ‘moderate’;
- Where the consequences of a pest with respect to one or more criteria are ‘C’, the overall consequences are considered ‘low’;
- Where the consequences of a pest with respect to all criteria are ‘B’, the overall consequences are considered ‘low’;
- Where the consequences of a pest with respect to one or more criteria are ‘B’, the overall consequences are considered ‘very low’;
- Where the consequences of a pest with respect to all criteria are A, the overall consequences are considered ‘negligible’.

**Unrestricted annual risk**

Risk estimation describes the integration of the ‘likelihood’ components of each PRA with the assessment of consequences. Risk estimation also involved a consideration of the likely volume of trade in fresh Philippines bananas during a 12-month period (i.e. one year).

Risk estimation was undertaken in two steps:

- Calculation of the annual probability of entry (importation and distribution), establishment or spread; and
- Combination of the annual probability of entry, establishment or spread with the estimate of consequences, to give the *unrestricted annual risk of entry, establishment or spread*.

Risk estimation is illustrated schematically in Figure 11.
Figure 11 Schematic illustration of risk estimation

Harvest of fruit for export

Importation potential

Release of fruit from quarantine in Australia

Partial probabilities of distribution

Commercial bananas

Partial probabilities of establishment or spread

Suceptible household plants

Wild bananas, susceptible cultivated plants - not bananas

Likelihood per tonne

Annual trade volume

Likelihood per year

Likely consequences

Unrestricted risk estimate
Calculation of annual likelihood

Annual likelihood was estimated in three steps:

- Estimation of the partial probability of entry (importation and distribution), establishment or spread for a tonne of fruit, and for each group of susceptible hosts;
- Estimation of the overall probability of entry, establishment or spread for a tonne of fruit; and
- Estimation of the annual probability of entry, establishment or spread.

Calculations required for each step are illustrated in Table 14.

### Table 14 Calculation of annual likelihood

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Calculation / description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual $P_{EES}$</td>
<td>The annual probability of entry, establishment or spread $=$ $1 - (1 - P_{EES}) \cdot \text{Number of tonnes imported annually}$</td>
</tr>
<tr>
<td>$P_{EES}$</td>
<td>The probability of entry, establishment or spread for a tonne of fruit $=$ $1 - (1 - P_{\text{Commercial}}) \times (1 - P_{\text{Household}}) \times (1 - P_{\text{Wild}})$</td>
</tr>
<tr>
<td>$P_{\text{Commercial}}$</td>
<td>The probability of entry, establishment or spread through the exposure of commercial banana plants $=$ $P_{\text{Importation}} \times P_{\text{PD Commercial}} \times P_{\text{PE Commercial}} \times P_{\text{PS Commercial}}$</td>
</tr>
<tr>
<td>$P_{\text{Household}}$</td>
<td>The probability of entry, establishment or spread through the exposure of household (non-commercial) banana plants or other susceptible garden plants (including weeds) $=$ $P_{\text{Importation}} \times P_{\text{PD Household}} \times P_{\text{PE Household}} \times P_{\text{PS Household}}$</td>
</tr>
<tr>
<td>$P_{\text{Wild}}$</td>
<td>The probability of entry, establishment or spread through the exposure of susceptible wild plants (including bananas) or susceptible cultivated plants other than bananas $=$ $P_{\text{Importation}} \times P_{\text{PD Wild}} \times P_{\text{PE Wild}} \times P_{\text{PS Wild}}$</td>
</tr>
<tr>
<td>$P_{\text{Importation}}$</td>
<td>The probability of importation (see: Probability of Importation)</td>
</tr>
<tr>
<td>$P_{\text{PD Commercial}}$</td>
<td>The partial probability of distribution for commercial banana plants, for susceptible household plants and for susceptible wild plants (including bananas) or susceptible cultivated plants other than bananas, respectively</td>
</tr>
<tr>
<td>$P_{\text{PD Household}}$</td>
<td>The partial probability of establishment for commercial banana plants, for susceptible household plants and for susceptible wild plants (including bananas) or susceptible cultivated plants other than bananas, respectively</td>
</tr>
<tr>
<td>$P_{\text{PD Wild}}$</td>
<td>The partial probability of spread for commercial banana plants, for susceptible household plants and for susceptible wild plants (including bananas) or susceptible cultivated plants other than bananas, respectively</td>
</tr>
</tbody>
</table>
Because there is no existing trade in fresh bananas, the number of tonnes likely to be imported from the Philippines in a year of trading had to be estimated.

It is known, however, that Australia’s annual production of Cavendish bananas is approximately 265,000 tonnes, and that other varieties account for a further 20,000 tonnes (Banana TWG 3, 2002). It is also known that the Pilipino Banana Growers and Exporters Association (Philippines Scientific Delegation, 2002) estimate a penetration of the Australian banana market of up to 30%. Because virtually all bananas produced in Australia are consumed domestically, this represents approximately 79,506 tonnes.

To accommodate these figures, and to take account of the uncertainty around them, the annual volume of trade in bananas was modelled as a BetaPert distribution, with minimum value 20% (or 53,004 tonnes), most likely value 30% (or 79,506 tonnes) and maximum value 50% (or 132,510 tonnes). This distribution is illustrated in Figure 12.

**Figure 12**  A BetaPert distribution for the annual volume of trade in bananas

![BetaPert distribution](image)

**Combination of likelihood and consequences**

The annual likelihood of entry, establishment or spread was combined with the estimate of consequences using the ‘rules’, or logic, shown in the risk estimation matrix in Table 15. The principle underlying this matrix is that the cells are expressed in the units of consequences, and represent the ‘expected loss’ associated with a particular combination of probability and consequences. Importantly, expected loss cannot exceed the consequence that would be accrued were the event not associated with a probability. Given this, the extent to which consequence will be reduced by multiplying it by the probability of occurrence will be determined by the magnitude of that probability.

It was assumed that likelihoods greater than or equal to Biosecurity Australia’s definition of ‘Moderate’ are not sufficiently small to reduce consequences within the limits of measurement. This means that the first two rows of the matrix mirror the consequence scale on the horizontal axis. The remaining levels of probability, i.e. ‘Low’, ‘Very Low’, ‘Extremely Low’ and ‘Negligible’, reduced the consequences by one, two, three and four categories, respectively, or to ‘Negligible’.
Table 15  Risk estimation matrix

<table>
<thead>
<tr>
<th>Likelihood of entry, establishment or spread</th>
<th>High likelihood risk</th>
<th>Very low risk</th>
<th>Low risk</th>
<th>Moderate risk</th>
<th>High risk</th>
<th>Extreme risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>High likelihood</td>
<td>Negligible</td>
<td>Very low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Extreme</td>
</tr>
<tr>
<td>Moderate</td>
<td>Negligible</td>
<td>Very low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>Extreme</td>
</tr>
<tr>
<td>Low</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Very low</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Very low</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Very low</td>
<td>Low</td>
<td>Moderate</td>
</tr>
<tr>
<td>Extremely low</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Very low</td>
<td>Low</td>
</tr>
<tr>
<td>Negligible likelihood</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Negligible</td>
<td>Very low</td>
</tr>
</tbody>
</table>

Consequences of entry, establishment or spread

STAGE 3: METHOD FOR RISK MANAGEMENT

Risk management describes the process of identifying and implementing measures to manage risks so as to achieve Australia’s ALOP, or tolerance for loss, while ensuring that negative effects on trade are minimised. Appropriate level of protection is considered a societal value judgement that reflects the maximal risk (or expected loss) from a pest or disease incursion that Australia considers acceptable (see: Appropriate Level of Protection).

To implement risk management appropriately, it is necessary to formalise the difference between ‘unrestricted’ and ‘restricted’ risk estimates. Unrestricted risk estimates are those derived in the absence of specific risk management measures; or using only internationally accepted baseline risk management strategies. By contrast, restricted or mitigated risk estimates are those derived when ‘risk management’ is applied. In the case of this IRA Report, unrestricted risk is the risk associated with fruit produced to the standard achieved through normal practices of production, quality control, packing, transport and shipment from the specified areas, as described in documentation provided by the Philippines as well as pre-export and on-arrival quarantine inspections.

The result of the ‘risk assessment’ for fresh bananas from the Philippines was an unrestricted risk estimate for each of the identified pests of quarantine concern. This was then compared with Australia’s ALOP, which is shown in the risk estimation matrix (Table 15) as the band of cells associated with a ‘very low’ risk. This step is termed ‘risk evaluation’. An unrestricted risk that was either ‘negligible’ or ‘very low’ met Australia’s ALOP and was considered ‘acceptable’. In this situation, risk management was not justified. Where an unrestricted risk was ‘low’, ‘moderate’,
‘high’ or ‘extreme’ however, risk management measures needed to be identified and applied and, for each of these, the ‘restricted’ risk calculated. This process is termed ‘option evaluation’.

It is possible that some biosecurity measures will cause harm to the environment. In this analysis, biosecurity measures will not be recommended unless any potential harm to the environment has been considered. In making this judgement, relevant considerations will include local legal requirements, manufacturer’s advice on usage and national or international standards.
Pest categorisation was carried out in two stages.

Ninety-nine pests of bananas were categorised according to their presence or absence in Australia, and their association with banana fruit (compared with leaves, roots, etc) (Table 16). If the pest is absent from Australia and associated with banana fruit, the pest was considered further in the analysis. Where there was any doubt or contention about the occurrence of a pest or its association with banana fruit, that pest was also retained on the list of quarantine pests.

From this process, eight pathogens and 16 arthropods were identified.

At the second stage of pest categorisation (Table 17), the 24 pests absent from Australia and associated with banana fruit were further classified according to: (a) potential to become established in Australia; and (b) the potential for consequences. One fungus and one virus were not considered further for the following reasons:

- *Uromyces musae* (rust) is a minor disease of bananas (Jones, 2000).
- Abaca mosaic potyvirus is a major disease of abaca and enset, but not a major disease of Cavendish (Jones, 2000). This virus is not found in commercial Cavendish plantations in the Philippines (Philippines Dept Agriculture, 2002a).

This left the six pathogens and 16 arthropods listed below.

**Pathogens**

- *Ralstonia solanacearum* Race 2 (Moko)
- *Guignardia musae* (freckle)
- *Mycosphaerella fijiensis* (black Sigatoka)
- Banana bract mosaic virus
- Banana bunchy top virus
- *Fusarium oxysporum f.sp. cubense* (Panama disease)

**Arthropods**

- Mealybugs — *Dysmicoccus neobrevipes; Pseudococcus jackbeardsleyi; Rastrococcus invadens*
- Weevils — *Philicoptus demissus; P. iliganus; P. stringifrons; P. sp.1; P. sp.2*
- Hard scales — *Aspidiotus excisus; A. coryphae; Pinnaspis musae*
- Fruit flies — *Bactrocera occipitalis; B. philippinensis*
- Spider mites — *Oligonychus orthius; O. velascoi; Tetranychus piercei*
Table 16  Pest categorisation stage 1: occurrence and association with fruit

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name(s)</th>
<th>Present in Philippines</th>
<th>Present in Australia</th>
<th>Commodity association – Comment/ Reference</th>
<th>Consider further</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abgrallaspis cyanophylli (Signoret)</td>
<td>Cyanophyllum scale</td>
<td>Yes - Sugimoto, 1994;</td>
<td>Yes (Qld, NSW, Tas) - Lindsay, 1993; CSIRO-AFFA, 2001</td>
<td>Yes - Lindsay, 1993; Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Diaspididae]</td>
<td></td>
<td>Velasquez, 1971</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aleurocanthus woglumi Ashby</td>
<td>Citrus white fly</td>
<td>Yes - Martin, 1999;</td>
<td>No - Martin, 1999; Mound and Halsey, 1978</td>
<td>No - Enkerlin, 1976; Shaw, 1950</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Aleyrodidae]</td>
<td></td>
<td>1994; Waterhouse, 1993</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aphis gossypii Glover</td>
<td>Cotton aphid; melon</td>
<td>Yes - Waterhouse, 1993</td>
<td>Yes (Qld, NSW, Vic, Tas, NT, SA) – Carver and Reid, 1996; CSIRO-AFFA, 2001</td>
<td>No – Ebert and Cartwright, 1997</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Aphidae]</td>
<td>aphid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Araecerus coffeae (Fabricius) (= syn.</td>
<td>Coffee bean weevil</td>
<td>Yes - Mphuru, 1974;</td>
<td>Yes (Qld, NSW) - Zeck, 1943; CSIRO-AFFA, 2001</td>
<td>Yes - Brown, 1998</td>
<td>No</td>
</tr>
<tr>
<td>Araecerus fasciculatus (De Geer))</td>
<td></td>
<td>Waterhouse, 1993</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[Coleoptera: Anthribidae]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
<td>Present in Philippines</td>
<td>Present in Australia</td>
<td>Commodity association – Comment/ Reference</td>
<td>Consider further</td>
</tr>
<tr>
<td>-----------------</td>
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<td>--------------------------------------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Artona catoxantha (Hampson) (= syn. Brachartona catoxantha (Hampson)) [Lepidoptera: Zygaenidae]</td>
<td>Coconut leaf moth</td>
<td>Yes - Merino, 1938</td>
<td>No - Nielsen et al., 1996</td>
<td>No - Van der Vecht, 1950</td>
<td>No</td>
</tr>
<tr>
<td>Aspidiotus destructor Signoret [Hemiptera: Diaspididae]</td>
<td>Transparent scale; coconut scale</td>
<td>Yes - PCARRD, 1988; Sugimoto, 1994; Velasquez, 1971; Waterhouse, 1993</td>
<td>Yes (NT, Qld) - CSIRO-AFFA, 2001; CIE, 1966</td>
<td>Yes - Lindsay, 1993; Pines and Piper, 1994</td>
<td>No</td>
</tr>
<tr>
<td>Atherigona orientalis [Diptera: Muscidae]</td>
<td>Pepper fruit fly</td>
<td>Yes - CABI, 2002</td>
<td>Yes (NSW, Qld, NT, WA) - CABI, 2002; Miller et al., 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td>Bactrocera musae [Diptera: Tephritidae]</td>
<td>Banana fruit fly</td>
<td>Yes - CABI, 2002(^{28})</td>
<td>Yes (Qld) - CABI, 2002</td>
<td>Yes - Smith, 1977</td>
<td>No</td>
</tr>
</tbody>
</table>

\(^{28}\) CABI 2002 states only restricted distribution of banana fruit fly in the Philippines
<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name(s)</th>
<th>Present in Philippines</th>
<th>Present in Australia</th>
<th>Commodity association – Comment/ Reference</th>
<th>Consider further</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bactrocera occipitalis</strong> (Bezzi)</td>
<td>Fruit fly</td>
<td>Yes – Drew and Hancock, 1994</td>
<td>No - Drew, 1989</td>
<td>Yes – Drew and Hancock, 1994</td>
<td>Yes</td>
</tr>
<tr>
<td>[Diptera: Tephritidae]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bactrocera philippinensis</strong> Drew &amp; Hancock</td>
<td>Philippines fruit fly</td>
<td>Yes – Drew and Hancock, 1994</td>
<td>No – Drew and Hancock, 1994</td>
<td>Yes - Hamacek et al., 1997</td>
<td>Yes</td>
</tr>
<tr>
<td>[Diptera: Tephritidae]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chaetanaphthrips signipennis</strong> (Bagnall)</td>
<td>Banana rust thrips; red rust thrips</td>
<td>Yes - PCARRD, 1988</td>
<td>Yes (Qld, NSW) - CSIRO-AFFA, 2001; Williams et al., 1990</td>
<td>Yes Lindsay, 1993; Pinese and Piper, 1994; Pitkin, 1977; Williams et al., 1990</td>
<td>No</td>
</tr>
<tr>
<td>[Thysanoptera: Thripidae]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chondracris rosea</strong> [Orthoptera: Acrididae]</td>
<td>Citrus locust</td>
<td>Yes - CABI, 2002</td>
<td>No - CABI, 2002</td>
<td>No - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><strong>Chrysomphalus aonidum</strong> [Hemiptera: Diaspididae]</td>
<td>Circular scale</td>
<td>Yes - CABI, 2002</td>
<td>Yes (NT, Qld, NSW, WA) - CABI, 2002; Miller et al., 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><strong>Chrysomphalus dictyospermi</strong> [Hemiptera: Diaspididae]</td>
<td>Spanish red scale</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld) - CABI, 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><strong>Coccus hesperidium</strong> Linnaeus [Hemiptera: Coccidae]</td>
<td>Soft brown scale</td>
<td>Yes - Sugimoto, 1994; Swirski et al., 1997</td>
<td>Yes - CSIRO-AFFA, 2001; Ben-Dov, 1993</td>
<td>Yes - Lindsay, 1993; Pinese and Piper, 1994; Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
<td>Present in Philippines</td>
<td>Present in Australia</td>
<td>Commodity association – Comment/ Reference</td>
<td>Consider further</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------------</td>
<td>------------------------</td>
<td>----------------------</td>
<td>--------------------------------------------</td>
<td>-----------------</td>
</tr>
</tbody>
</table>
| *Cosmopolites sordidus* (Germar)  
[Coleoptera: Curculionidae] | Banana weevil borer; banana root weevil | Yes - Deang *et al*., 1971; PCARRD, 1988 | Yes (Qld, NSW) - CSIRO-AFFA, 2001; Pinese and Piper, 1994 | No - Lindsay, 1993; Pinese and Piper, 1994 | No |
| *Cryptothelea fuscescens* (Snellen)  
| *Dysmicoccus brevipes* (Cockerell)  
[Hemiptera: Pseudococcidae] | Pineapple mealybug | Yes - Sugimoto, 1994 | Yes (Qld, NSW, Tas, NT, WA) - CSIRO-AFFA, 2001 | Yes - Sugimoto, 1994 | No |
| *Dysmicoccus neobrevipes* Beardsley  
| *Elixothrips brevisetis* Bagnall  
<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name(s)</th>
<th>Present in Philippines</th>
<th>Present in Australia</th>
<th>Commodity association – Comment/ Reference</th>
<th>Consider further</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Ferrisia virgata</em> (Cockerell) [Hemiptera: Pseudococcidae]</td>
<td>Striped mealybug</td>
<td>Yes - Waterhouse, 1993</td>
<td>Yes (NT, Qld) - CSIRO-AFFA, 2001; Williams, 1985</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td><em>Hemiberlesia lataniae</em> (Signoret) [Hemiptera: Diaspididae]</td>
<td>Latania scale</td>
<td>Yes - CABI, 2002; Velasquez, 1971</td>
<td>Yes (Qld, NSW) - CSIRO-AFFA, 2001; Waite, 1988</td>
<td>Yes - Lindsay, 1993; Waite, 1988</td>
<td>No</td>
</tr>
<tr>
<td><em>Hemiberlesia palmae</em> (Cockerell) [Hemiptera: Diaspididae]</td>
<td>Citrus black scale</td>
<td>Yes - PCARRD, 1988; Sugimoto, 1994; Velasquez, 1971</td>
<td>Yes (Qld) - Donaldson, 2001</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
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<tr>
<td><em>Hemiberlesia rapax</em> (Comstock)</td>
<td>Greedy scale</td>
<td>Yes - Sugimoto, 1994</td>
<td>Yes (Qld, Vic, Tas, SA) - CSIRO-AFFA, 2001</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Diaspididae]</td>
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<tr>
<td><em>Hermetia illucens</em> (Linnaeus)</td>
<td>American soldier fly</td>
<td>Yes - Rueda <em>et al.</em>, 1990</td>
<td>Yes (Qld) - McCallan, 1974; Warburton and Hallman, 2002</td>
<td>Yes - Stephens, 1975(^29)</td>
<td>No</td>
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<tr>
<td>Stephens, 1975</td>
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<tr>
<td><em>Icerya seychellarum</em> (Westwood)</td>
<td>Seychelles scale</td>
<td>Yes - Sugimoto, 1994</td>
<td>Yes (NT) - CSIRO-AFFA, 2001</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
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<tr>
<td>[Hemiptera: Margarodidae]</td>
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<tr>
<td><em>Locusta migratoria</em> [Orthoptera: Acrididae]</td>
<td>Migratory locust</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld, NSW, NT, WA) - CABI, 2002; Miller <em>et al.</em>, 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
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<tr>
<td><em>Maconellicoccus hirsutus</em> [Hemiptera: Pseudococcidae]</td>
<td>Pink hibiscus mealybug</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld, NT, SA, WA) - Ben-Dov, 1994; CABI, 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
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<tr>
<td><em>Melanitis leda ismene</em> [Lepidoptera: Nymphalidae]</td>
<td>Rice butterfly</td>
<td>Yes - CABI, 2002</td>
<td>No - Braby, 2000</td>
<td>No - CABI, 2002</td>
<td>No</td>
</tr>
</tbody>
</table>

\(^29\) Stephens (1975) noted that females of *Hermetia illucens* will sometimes oviposit between young banana fingers in Panama, but the hatching larvae fall to the ground and do not penetrate the fruit. Stephens also reported that a blemish develops at the site of oviposition as the fingers mature and this resembles a patch of alligator hide.
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</thead>
<tbody>
<tr>
<td><em>Odoiporus longicollis</em> Olivier [Coleoptera: Curculionidae]</td>
<td>Banana stem weevil; banana stem borer</td>
<td>Yes - Uichanco, 1936</td>
<td>No - Robbs et al., 1995</td>
<td>No - Isahaque, 1978; Dutt and Maiti, 1972; Kalshoven, 1981</td>
<td>No</td>
</tr>
<tr>
<td><em>Oryctes rhinoceros</em> [Coleoptera: Scarabaeidae]</td>
<td>Rhinoceros beetle</td>
<td>Yes - CABI, 2002</td>
<td>No - CABI, 2002</td>
<td>No – CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><em>Philicotus demissus</em> (Heller) [Coleoptera: Curculionidae]</td>
<td>Peel-scarring weevil</td>
<td>Yes - Stephens, 1984</td>
<td>No - Stephens, 1984</td>
<td>Yes - Stephens, 1984</td>
<td>Yes</td>
</tr>
<tr>
<td><em>Philicotus iliganus</em> (Heller) [Coleoptera: Curculionidae]</td>
<td>Peel-scarring weevil</td>
<td>Yes - PCARRD, 1988; Stephens, 1984</td>
<td>No - Stephens, 1984</td>
<td>Yes - Stephens, 1984</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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30 CABI (2002) listed this species as present in Australia but gave no further details. This may be an error because the same reference (CABI, 2002) indicates that this species is absent and not established in Queensland.
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<tbody>
<tr>
<td><em>Philicoptus</em> sp.1</td>
<td>Peel-scarring weevil</td>
<td>Yes - Stephens, 1984</td>
<td>No - Stephens, 1984</td>
<td>Yes - Stephens, 1984</td>
<td>Yes</td>
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<td>[Coleoptera: Curculionidae]</td>
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<tr>
<td><em>Philicoptus</em> sp.2</td>
<td>Peel-scaring weevil</td>
<td>Yes - Stephens, 1984</td>
<td>No - Stephens, 1984</td>
<td>Yes - Stephens, 1984</td>
<td>Yes</td>
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<tr>
<td>[Coleoptera: Curculionidae]</td>
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<tr>
<td><em>Philicoptus</em> stringifrons (Heller)</td>
<td>Peel-scaring weevil</td>
<td>Yes - Stephens, 1984</td>
<td>No - Stephens, 1984</td>
<td>Yes - Stephens, 1984</td>
<td>Yes</td>
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<tr>
<td>[Coleoptera: Curculionidae]</td>
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<tr>
<td><em>Pinnapsis musae</em> Takagi</td>
<td>Hard scale</td>
<td>Yes - Sugimoto, 1994</td>
<td>No - CSIRO-AFFA, 2001</td>
<td>Yes - Sugimoto, 1994</td>
<td>Yes</td>
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<tr>
<td>[Hemiptera: Diaspididae]</td>
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<tr>
<td><em>Pinnaspis strachani</em></td>
<td>Lesser snow scale</td>
<td>Yes - CABI, 2002</td>
<td>Yes (SA) - Brookes, 1964; (WA) - Miller <em>et al.</em>, 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Diaspididae]</td>
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<tr>
<td><em>Planococcus citri</em> (Risso)</td>
<td>Citrus mealybug</td>
<td>Yes - Waterhouse, 1993</td>
<td>Yes (Qld, NSW, Vic, Tas, NT, SA, WA) - CSIRO-AFFA, 2001; Williams, 1985</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td>[Hemiptera: Pseudococcidae]</td>
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<td>Scientific name</td>
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<tr>
<td><em>Planococcus minor</em> (Maskell) (= syn. <em>P. pacificus</em> Cox) [Hemiptera: Pseudococcidae]</td>
<td>Passionvine mealybug; Pacific mealybug</td>
<td>Yes - Ben-Dov, 1994</td>
<td>Yes (Qld) - CSIRO-AFFA, 2001; Ben-Dov, 1994</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td><em>Pseudaulacapsis cockerelli</em> (Cooley) [Hemiptera: Diaspididae]</td>
<td>Mango scale; oleander scale</td>
<td>Yes - Sugimoto, 1994</td>
<td>Yes (NT, Qld, NSW) - CSIRO-AFFA, 2001</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
</tr>
<tr>
<td><em>Pseudococcus jackbeardsleyi</em> Gimpel &amp; Miller (previously as <em>P. elisae</em> Borchsenius in the Philippines) [Hemiptera: Pseudococcidae]</td>
<td>Banana mealybug</td>
<td>Yes - Ben-Dov, 1994; Lit and Calilung, 1994</td>
<td>No - Ben-Dov, 1994; Ben-Dov <em>et al.</em>, 2002</td>
<td>Yes - Sugimoto, 1994[^31]</td>
<td>Yes</td>
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<tr>
<td><em>Pseudococcus longispinus</em> (Targioni Tozzetti) [Hemiptera: Pseudococcidae]</td>
<td>Longtail mealybug</td>
<td>Yes – Lit and Calilung, 1994</td>
<td>Yes (Qld, NSW, Vic, Tas, NT, SA, WA) - CSIRO-AFFA, 2001; Ben-Dov, 1994; Williams, 1985</td>
<td>Yes - Sugimoto, 1994</td>
<td>No</td>
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</table>

[^31] *P. jackbeardsleyi* was intercepted on banana exported from the Philippines to Japan (Sugimoto 1994), under the name *P. elisae*.

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[^31]: P. jackbeardsleyi was intercepted on banana exported from the Philippines to Japan (Sugimoto 1994), under the name *P. elisae*.
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</thead>
</table>
| *Rastrococcus invadens* Williams  
[Hemiptera: Pseudococcidae] | Mango mealybug | Yes - Ben-Dov, 1994; Lit and Calilung, 1994 | No - Ben-Dov, 1994; Williams, 1985 | Yes - CABI, 2002<sup>32</sup> | Yes |
| *Rastrococcus spinosus* Robinson  
[Hemiptera: Pseudococcidae] | Mealybug | Yes - Ben-Dov, 1994; Williams, 1989 | No - Ben-Dov, 1994; Williams, 1989 | No (no records on banana fruit but being considered as a group with other mealybugs which are known to occur on fruit) | No |
| *Rhopalosiphum maidis* (Fitch) (=syn. *Aphis maidis* (Fitch))  
[Hemiptera: Aphidae] | Corn aphid; maize aphid | Yes - Waterhouse, 1993 | Yes (Qld, NSW, Vic, Tas, NT, WA) - CSIRO-AFFA, 2001; CIE, 1971 | No - CABI, 2002 | No |
| *Spodoptera exigua*  
[Lepidoptera: Noctuidae] | Beet armyworm | Yes - CABI, 2002 | Yes (Qld, NSW, Vic, NT, SA, WA) - CABI, 2002 | Yes - CABI, 2002 | No |
| *Stephanitis typica*  
(Distant)  

<sup>32</sup> This species has been recorded on species of *Musa* (Ben-Dov and German, 2002) and is recorded in the Philippines. Additionally it affects the fruits of its various hosts (CABI, 2002).
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</thead>
<tbody>
<tr>
<td><em>Thosea sinensis</em> (Walker)</td>
<td>Cup moth; Assam nettle; saddle-back nettle</td>
<td>Yes - Waterhouse, 1993</td>
<td>No - CABI, 2002</td>
<td>No - Dammerman, 1929; Kalshoven, 1981</td>
<td>No</td>
</tr>
<tr>
<td>[Lepidoptera: Limacodidae]</td>
<td></td>
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<tr>
<td><em>Thrips florum</em> Schmutz</td>
<td>Banana flower thrips; scab thrips</td>
<td>Yes – Palmer and Wetton, 1987; PCARRD, 1988;</td>
<td>Yes (Qld, NSW) - CSIRO-AFFA, 2001; Lindsay, 1993; Swaine and Corcoran, 1975</td>
<td>Yes - Lindsay, 1993; Swaine and Corcoran, 1975</td>
<td>No</td>
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<td>[Thysanoptera: Thripidae]</td>
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<tr>
<td><em>Thrips hawaiensis</em></td>
<td>Hawaiian flower thrips</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld, WA) - CABI, 2002; Miller <em>et al.</em>, 2002</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
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<td>[Thysanoptera: Thripidae]</td>
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<tr>
<td><em>Tiracola plagiata</em></td>
<td>Plague caterpillar</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld, NSW) - CABI, 2002</td>
<td>Yes - Common, 1990; Herbison-Evans and Common, 2001</td>
<td>No</td>
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<tr>
<td>[Lepidoptera: Noctuidae]</td>
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<tr>
<td><em>Tirathaba rufivena</em></td>
<td>Coconut spike moth</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld) - CABI, 2002</td>
<td>No - CABI, 2002</td>
<td>No</td>
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<td>[Lepidoptera: Pyralidae]</td>
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<tr>
<td><em>Valanga nigricornis</em> Burmeister</td>
<td>Grasshopper</td>
<td>Yes - Waterhouse, 1993</td>
<td>Yes (Qld) - Pinese and Piper, 1994</td>
<td>No - Pinese and Piper, 1994</td>
<td>No</td>
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<td>[Orthoptera: Acrididae]</td>
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<tr>
<td><em>Mites</em></td>
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<tr>
<td><em>Eutetranychus orientalis</em></td>
<td>Citrus brown mite</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld, WA) - CABI, 2002; Miller et al., 2002</td>
<td>No - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><em>Tetranychus cinnabarinus</em> (Boisduval)</td>
<td>Spider mite</td>
<td>Yes - Corpuz-Raros, 1989</td>
<td>Yes (Qld, NSW, Vic, Tas, NT, SA, WA) - Halliday, 1998; CSIRO-AFFA, 2001</td>
<td>No - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><em>Tetranychus neocaledonicus</em> André</td>
<td>Spider mite</td>
<td>Yes - Corpuz-Raros, 1989</td>
<td>Yes (Qld) - Bolland et al., 1998; Halliday, 1998</td>
<td>No – TWG 2 professional opinion</td>
<td>No</td>
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<td><strong>Bacteria</strong></td>
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<tr>
<td><em>Erwinia carotovora</em> (Jones) Bergey, Harrison, Breed, Hammer &amp; Huntoon [Enterobacteriales: Enterobacteriaceae]</td>
<td>Corm rot</td>
<td>Yes - Philippines Dept. Agriculture, 2001; San Juan, 1980</td>
<td>Yes (Qld) - Pegg <em>et al.</em>, 1974; Persley and Cooke, 1993</td>
<td>No - Jones, 2000</td>
<td>No</td>
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<td><strong>Fungi</strong></td>
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<tr>
<td><strong>Botryodiplodia theobromae</strong> Pat. (= syn. <em>Lasiodiplodia theobromae</em> (Pat.), Griff, &amp; Maubl.) [anamorph] [Mitosporic fungi: Coelomycetes]</td>
<td>Crown rot, finger rot</td>
<td>Yes - PCARRD, 1988; CABI, 2002</td>
<td>Yes (Qld, NT) - CABI, 2002; Pitkethley, 1998; Simmonds, 1966</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
</tr>
<tr>
<td><strong>Ceratocystis paradoxa</strong> (Dade) C. Moreau (= syn. <em>Thielaviopsis paradoxa</em> (De Seynes) Höhn. [anamorph]; <em>Chalara paradoxa</em> (De Seynes) Sacc. [anamorph]; <em>Ceratostomella paradoxa</em> Dade [teleomorph]; <em>Ophiostoma paradoxa</em> (Dade) Nannf. [teleomorph]; <em>Sporoschisma paradoxum</em> De Seynes [teleomorph])</td>
<td>Corm rot, black end, fingertip rot</td>
<td>Yes - CABI, 2002</td>
<td>Yes (Qld) NSW) - CABI, 2002; NSW Agriculture, 1995; Simmonds, 1966</td>
<td>Yes - CABI, 2002</td>
<td>No</td>
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</tbody>
</table>
| *Cercospora hayi* Calpouzos  
| *Colletotrichum musae* (Berk. & Curt.) von Arx (= syn. *Gloeosporium musarum* Cooke & Massee)  
| *Cochliobolus lunatus* R.R.Nelson and Hasis ( = syn. *Curvularia lunata* (Wakk.) Boedijn) [anamorph]  
[Loculoascomycetes, Dothideales] | Yes - CABI, 2002 | Yes (NSW, recorded on citrus) – Wellings and Nuzum, 1978; CABI, 2002; APDD, 2003 | Yes (with trash) - CABI, 2002 | No |
| *Cordana musae* (Zimm.) Hohnel  
[Mitosporic fungi] | Cordana leaf spot | Yes - Philippines Dept. Agriculture, 2001 | Yes (Qld, NT) - Simmonds, 1966; Pitkethley, 1998; Jones, 2000 | Yes (with trash) - Jones, 2000 | No |
| *Deightoniella torulosa* (Syd.) Ellis  
<table>
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</table>
| *Fusarium oxysporum* f. sp. *cubense* (Smith) Sny. & Han.  
[Ascomycetes, Hypocreales: Hypocreaceae] | Fusarium wilt, Panama disease | Yes (classification of strains required) - Philippines Dept. Agriculture, 2001; Jones, 2000 | Yes (Qld, NSW, NT, WA - (restricted and some Races are under official control) - McKirdy, 2002; APDD, 2003 | Yes (with soil and trash, fruit stalks on severely infected plants may be infected but fruit is not infected) - Allen, 1999; Ploetz, 2002 | Yes |
| *Fusarium moniliforme* Sheldon (= syn. *Gibberella fujikuroi* (J. Sawada) Wollenw.) [teleomorph]  
| *Fusarium pallidoroseum* (Cooke) Sacc. (= syn. *F. semitectum* auct. non.)  
<table>
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</thead>
</table>
| *Fusarium roseum* Link:Fr.  
| *Guignardia musae* Racib.  
[Dothideales: Mycosphaerellaceae] | Freckle | Yes - (clarification of strains required) Jones, 2000; Conde, 2001 | Yes (Qld, NSW, NT, WA - exotic strains are of quarantine concern)33 - Jones, 2000; Conde, 2001; APDD, 2003 | Yes - Jones, 2000 | Yes |
| *Mycosphaerella fijiensis* ( = syn. *M. fijiensis* var. *difformis* Mulder & Stover); *Paracercospora fijiensis* (Morelet) Deighton; *Cercospora fijiensis* Morelet; *Pseudocercospora fijiensis* (Morelet) Deighton)  

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33 *G. musae* recorded on the Cavendish cultivar in Western Australia in early 2001 and eradicated immediately (Conde, 2001).
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</table>
| *Uredo musae* Cummins  
[Uredinales: Pucciniaceae] | Rust | Yes - CIE, 1971 | Yes (Qld, Christmas Island) - Shivas, 1989 | Yes (in trash) - Shivas, 1989 | No |
| *Uromyces musae* Henn.  
| Several fungi | Crown rot | Yes - Philippines Dept. Agriculture, 2001 | Yes (several crown rot fungi occur in Australia) - Jones, 2000; APDD, 2003 | Yes (on crown) - Jones, 2000 | No |
| **Nematoda** | | | | | |
| *Helicotylenchus multicinctus*  
[Tylenchida: Hoploplaimidae] | Banana spiral nematode | Yes - CABI, 2002 | Yes (Qld, NSW, NT, SA, WA) - McLeod *et al.*, 1994; CABI, 2002 | No | No |
| *Hopolaimus seinhorsti* Luc  
[Tylenchida: Hoploplaimidae] | Lance nematode | Yes - CABI, 2002 | No (Qld, NT) - McLeod *et al.*, 1994; CABI, 2002 | No | No |
| *Meloidogyne arenaria* Neal  
[Tylenchida: Meloidogynidae] | Root knot nematode | Yes - Taylor *et al.*, 1982 | Yes (Qld WA) -Taylor *et al.*, 1982; McLeod *et al.*, 1994 | No | No |
<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name(s)</th>
<th>Present in Philippines</th>
<th>Present in Australia</th>
<th>Commodity association – Comment/ Reference</th>
<th>Consider further</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Meloidogyne incognita</em> (Kofoid &amp; White)</td>
<td>Root knot nematode</td>
<td>Yes - Timm, 1965</td>
<td>Yes (Qld, NSW, NT) - Simmonds, 1966; McLeod <em>et al.</em>, 1994</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><em>Radopholus similis</em> (Cobb) Thorne</td>
<td>Burrowing nematode</td>
<td>Yes - Booth and Stover, 1974</td>
<td>Yes (Qld, NSW, NT, WA) - Persley and Cooke, 1993; McLeod <em>et al.</em>, 1994; Pitkethley, 1998</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td><em>Rotylenchus reniformis</em> Linford &amp; Oliveira</td>
<td>Reniform nematode</td>
<td>Yes - CABI, 2002</td>
<td>Yes (WA) - McLeod <em>et al.</em>, 1994; CABI, 2002</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Viruses**

<table>
<thead>
<tr>
<th>Abaca mosaic potyvirus</th>
<th>Abaca mosaic, sugarcane mosaic</th>
<th>Yes - Jones, 2000</th>
<th>No - Jones, 2000</th>
<th>Yes - TWG1 Professional opinion</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana bract mosaic potyvirus</td>
<td>Banana bract mosaic virus</td>
<td>Yes - Jones, 2000</td>
<td>No - Jones, 2000</td>
<td>Yes - CABI, 2002</td>
<td>Yes</td>
</tr>
<tr>
<td>Banana bunchy top nanavirus</td>
<td>Banana bunchy top</td>
<td>Yes - Jones, 2000</td>
<td>Yes (SE Qld, NSW - under official control) - Jones, 2000</td>
<td>Yes - CABI, 2002</td>
<td>Yes</td>
</tr>
<tr>
<td>Banana streak badnavirus</td>
<td>Banana streak</td>
<td>Yes - Jones, 2000</td>
<td>Yes (Qld) – Persley and Cooke, 1993; Jones, 2000</td>
<td>Yes - CABI, 2002; Jones, 2000</td>
<td>No</td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
<td>Present in Philippines</td>
<td>Present in Australia</td>
<td>Commodity association – Comment/ Reference</td>
<td>Consider further</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------------------</td>
<td>---------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td>Cucumber mosaic cucumovirus</td>
<td>Mosaic, infectious chlorosis, heart-rot, virus sheath rot</td>
<td>Yes - Philippines Dept. Agriculture, 2001</td>
<td>Yes (Qld, NSW) - Persley and Cooke, 1993; NSW Agriculture, 1995; Jones, 2000</td>
<td>Yes - Jones, 2000</td>
<td>No</td>
</tr>
</tbody>
</table>
### Table 17  Pest categorisation stage 2 - potential for establishment and economic consequences

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name(s)</th>
<th>Potential for establishment in Australia? (Feasible/Not feasible)</th>
<th>Potential for consequences? (Significant/ Not significant)</th>
<th>Comments</th>
<th>Quarantine pest? (Yes / No)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Insects</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspidiotus coryphae</td>
<td>Hard scale</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Aspidiotus excisus</td>
<td>Hard scale</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Bactrocera occipitalis</td>
<td>Fruit fly</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Bactroceraophilippines</td>
<td>Philippines fruit fly</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Dysmicoccus neobrevipes</td>
<td>Annona or Grey pineapple mealybug</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Philicoptus demissus</td>
<td>Peel scarring weevil</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Philicoptus iliganus</td>
<td>Peel scarring weevil</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Philicoptus sp.1</td>
<td>Peel scarring weevil</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Philicoptus sp.2</td>
<td>Peel scarring weevil</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Philicoptus stringifrons</td>
<td>Peel scarring weevil</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Pinnapsis musae</td>
<td>Hard scale</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
<td>Potential for establishment in Australia? (Feasible/Not feasible)</td>
<td>Potential for consequences? (Significant/ Not significant)</td>
<td>Comments</td>
<td>Quarantine pest? (Yes / No)</td>
</tr>
<tr>
<td>-----------------</td>
<td>-------------------------</td>
<td>-----------------------------------------------------------------</td>
<td>-----------------------------------------------------------</td>
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<td>-----------------------------</td>
</tr>
<tr>
<td><em>Pseudococcus</em></td>
<td>Jack Beardsley mealybug</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>jackbeardsleyi</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Rastrococcus</em></td>
<td>Mango mealybug</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>invadens</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mites</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Oligonychus</em></td>
<td>Spider mite</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>orthius</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>velascoi</em></td>
<td>Coconut spider mite</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>Tetranychus</em></td>
<td>Spider mite</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>piercei</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Bacteria</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Ralstonia</em></td>
<td>Moko/Bugtok</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>solanacearum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Race 2</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fungi</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Fusarium</em></td>
<td>Panama</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>oxysporum</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>sp. Cubense</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Race 4</em></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Guignardia</em></td>
<td>Freckle</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>musae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Mycosphaerella</em></td>
<td>Black Sigatoka</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td><em>fijiensis</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scientific name</td>
<td>Common name(s)</td>
<td>Potential for establishment in Australia?</td>
<td>Potential for consequences? (Significant/ Not significant)</td>
<td>Comments</td>
<td>Quarantine pest?</td>
</tr>
<tr>
<td>---------------------</td>
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<td>-------------------------------------------</td>
<td>------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------</td>
<td>------------------</td>
</tr>
<tr>
<td><em>Uromyces musae</em></td>
<td>Rust</td>
<td>Feasible</td>
<td>Not significant</td>
<td>A minor disease of bananas (Jones, 2000)</td>
<td>No</td>
</tr>
<tr>
<td><strong>Viruses</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abaca mosaic potyvirus</td>
<td>Abaca mosaic</td>
<td>Feasible</td>
<td>Not significant</td>
<td>Is a major disease of abaca and enset, which are not grown to any extent in Australia and are not likely to be in the future - not a major disease of Cavendish (Jones, 2000). This virus is not found in commercial Cavendish plantations in the Philippines (Philippines Dept. Agriculture, 2002a).</td>
<td>No</td>
</tr>
<tr>
<td>Banana bract mosaic potyvirus</td>
<td>Banana bract mosaic</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
<tr>
<td>Banana bunchy top nanavirus</td>
<td>Banana bunchy top</td>
<td>Feasible</td>
<td>Significant</td>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>
The following risk assessments commence with a brief introduction to the pest. More information about the pests is provided in Appendix 1: Pest Data Sheets. Additionally, a summary of environmental issues considered in these assessments is provided in Appendix 5.

PATHOGENS

Banana bract mosaic virus

Banana bract mosaic virus (BBrMV) is a potyvirus generally considered specific to plants of the genus *Musa* (Thomas *et al.*, 2000). Although BBrMV does not occur in Australia, potential *Musa* host species, including native and feral bananas, as well as commercial bananas of all cooking and dessert varieties, are found.

The virus affects all plant parts, and leads to a range of symptoms. Symptom expression depends upon the mode of transmission, the plant part affected, the variety of banana and the strain of BBrMV (Thomas *et al.*, 2000). However, mosaic patterns on flower bracts are diagnostic and distinct from all other symptoms caused by other known viruses of banana (Thomas *et al.*, 2000). The severity of disease caused by BBrMV in banana fruit is generally correlated with the stage of plant growth at the time of infection (Thomas *et al.*, 2000).

- Three-week-old fingers from Cavendish cultivars have spindle-shaped brown streaks and a distorted shape. The bunch will not develop normally and is generally unsaleable.
- When fully developed Cavendish banana plants are infected, symptoms may not be evident or may be limited to dark green streaks and minor distortion of the fingers.

BBrMV is considered widespread amongst native bananas and smallholdings in Mindanao Province from where export bananas are sourced (Magnaye and Espino, 1990), and is known to occur on commercial plantations (Thomas, 1993). In 1988, the disease reached epidemic proportions around the General Santos City, where 25,000 mats were destroyed (CABI, 2002). Commercial companies note a strong correlation between a high incidence of BBrMV and a high rejection rate for malformed bunches and low hand-class ratings. Yield losses have been estimated to be as high as 40% in the popular Cardaba and Saba (ABB) cultivars (Kenyon *et al.*, 1996; Sharman *et al.*, 2000).

BBrMV can be transmitted by the aphids *Aphis gossypii*, *Rhopalosiphum maidis* and *Pentalonia nigronervosa* (Thomas *et al.*, 2000), all of which are endemic and common in Australia. By analogy to other potyviruses (Hull, 2002), there is potential for transmission by many additional aphid vector species. Transmission is considered ‘non-persistent’, in that aphids must feed on a healthy banana plant within 3 hours of feeding on an infected plant. A feeding time of a few seconds is considered sufficient to transmit the virus. The virus will be lost within minutes, however, if the aphid feeds on a non-host plant. BBrMV can also be spread by the translocation of planting materials, such as suckers, bits or corms and micro-propagated plantlets (Thomas *et al.*, 2000).
The Importation of Philippines bananas: Draft IRA Report

Probability of importation

The risk scenario of particular relevance to BBrMV is that associated with symptomless infection of banana fruit. Symptomless infection means that infection occurs internally in the tissue but has not developed to the stage of visible symptom expression. This form of infection would not be detected by visual inspection; nor would it be affected by chlorine treatments or subject to desiccation.

Another pathway that was considered was the contamination of fruit surfaces with viruliferous aphids. However, whilst this pathway might be relevant to the transmission of virus in the field, it is expected that free aphids would be either removed from fruit in the packing station through the cleaning action of washing and brushing, or killed by the solution of chlorine and alum in the de-handing and flotation tanks (see: Method for Import Risk Analysis for a discussion of the efficacy of the chlorine and alum treatment).

Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

BBrMV is considered widespread among native bananas and smallholdings in Mindanao (Magnaye and Espino, 1990). Although it is maintained that commercial plantations are currently free of the disease (Philippines Dept. Agriculture, 2002a), Thomas (1993) reported that BBrMV was causing increasingly serious problems for banana production in the Philippines, with many but not all commercial plantations affected. Thomas (1993) noted that the aphid vectors were ubiquitous and growers had difficulty in recognising early symptoms of disease.

Given these considerations, Imp1 was rated high.

Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

As in other potyvirus infections (Hull, 2002), BBrMV is expected to invade the plant systemically and to be found in all parenchymatous tissues produced after infection. It is known, however, that the concentration of virions is low and not easily detected by direct electron microscopy (Thomas et al., 2000).

There are no recent estimates of the incidence of BBrMV in commercial Cavendish plantations of Mindanao Province, from where export bananas are to be sourced. Thomas (1993) reported that the disease occurred in patches and that it is not in every plantation. Where it did occur however, between 4 and 14% of mats were eradicated each year. Routine weekly inspections for evidence of BBrMV have been carried out in commercial plantations since 1993, and diseased mats have been destroyed in the same way as for banana bunchy top disease (Philippines Dept Agriculture, 2002a). Philippine authorities report that BBrMV is now rarely encountered. The issue that remains is whether BBrMV can be detected when symptoms are mild or transient. It is axiomatic that plants in a symptomless condition will not be detected.

There appears to be little information on the incubation period for BBrMV. It could be expected, however, that this will be similar to that for banana bunchy top disease, which generally appears on the second leaf to emerge after aphid inoculation (Magee, 1927; Allen, 1987). There is also some evidence that symptom expression is more variable than is the case for banana bunchy top disease (Thomas, 1993; Thomas et al., 2000).

Overall, variation about incubation period and expression of visible symptoms of disease, in conjunction with the report that BBrMV is rarely seen in commercial Cavendish plantations in the
Philippines, led to the consideration that the likelihood of infection within a tonne of export fruit was very low.

**Imp3** — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete. Infection of harvested green bananas would require aphids to penetrate the ventilation holes or inspection windows of bunch covers, many of which are impregnated with the insecticide, chlorpyrifos, and then complete a transmission before arrival at the packing station. Additionally, aphids must have fed only on an infected plant within 3 hours prior to penetrating the bunch. The likelihood of this scenario was considered negligible.

**Imp4** — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

BBrMV is carried internally in the fruit and is transmitted during a very short feeding period by viruliferous aphids. On arrival at the packing station, fruit are subjected to washing and immersion in a solution of chlorine and alum for at least 25 minutes. These conditions are not conducive to either the feeding activities of aphids or to their survival. Overall, the likelihood of transmission within the packing station was considered negligible.

**Imp5** — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Fruit are inspected within the packing station for adherence to basic quality parameters. Fruit are removed on the basis of blemishes, obvious distortion in shape, premature ripening and visible splits or other lesions. As previously noted, early infections with BBrMV lead to spindle-shaped brown streaks on banana fruit, and a distorted shape. Any fruit that is harvested in this condition would be detected and removed. It was stated at the start of this discussion, however, that the pathway of concern relates to symptomless infection, and thus it is clear that the likelihood that affected fruit of this sort would be detected is negligible.

**Imp6** — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

While it is likely that any free aphids would be removed or destroyed as a result of washing, scrubbing, sponging and immersion in the chlorine and alum solution, virus within the fruit would not. Given that symptomless infection of fruit was considered the risk pathway, the likelihood assigned to this step was rated as negligible.

**Imp7** — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Quarantine inspection would detect fruit blemishes, obvious distortion in shape, premature ripening and visible splits. By definition, however, symptomless infection would not be detected by visual inspection by BPI quarantine officers, so the likelihood of detection at this stage was considered negligible.
Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Although there are no reports on the persistence of BBrMV, the accepted scientific position (Hull, 2002) is that potyviruses will remain viable in fruit or in discarded fruit waste while the fruit tissue is not completely necrotic. On this basis, it was considered virtually certain that BBrMV would survive and remain viable during this step in the pathway.

Imp9 — the likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. However, because BBrMV is considered tolerant of this temperature, and because other environmental factors are constant within the fruit, it was considered virtually certain that the virus would remain viable during this step in the pathway.

Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

BBrMV produces visible lesions only when infection occurs early in the development of the fruit. In other words, symptoms would not express in fully developed fruit during the period of transport to Australia. By definition, symptomless infection of fruit would not be detected by visual inspection by AQIS officers regardless of the proportion of the consignment that was inspected. Imp 10 was thus rated as negligible.

Conclusions — probability of importation

When these likelihoods were inserted into the simulation model, the overall probability that BBrMV would be present in a tonne of hard green bananas was found to be very low.

Probability of distribution

The initiating step for distribution of BBrMV in Australia is the presence of virus particles in the peel or crown of banana fruit imported from the Philippines. The endpoint is the exposure of tissue of a susceptible banana plant in Australia to virus via an aphid vector.

Dist1 — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers

It was explained above that while there are no reports on the persistence of BBrMV, the accepted scientific position (Hull, 2002) is that potyviruses will remain viable in fruit or in discarded fruit waste while the fruit tissue is not completely necrotic On this basis, it was considered virtually certain that the virus would remain viable during the storage and ripening of fruit, and its distribution to wholesalers.

Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.
Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

The host range of BBrMV is restricted to native and commercial banana genotypes that are found in households in tropical and subtropical areas, and, to a lesser extent, the temperate areas of Australia.

It was stated in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, approximately 32% of imported bananas would be consumed in an area in which household banana plants are found. Thus, for pests such as BBrMV that are known to be specific to bananas, Prop2 is considered moderate.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was stated in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, approximately 11% of imported bananas would be consumed in an area in which wild (native or feral) bananas are found. Thus, for pests such as BBrMV that are specific to bananas, Prop3 is considered low.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Although not documented, it is very likely that BBrMV, if present in the flesh of a banana, would also be present in the skin and crown tissue. The skin and crown tissue are discarded in the normal course of the consumption of banana fruit.

From these observations it was considered virtually certain that BBrMV, if present in an imported banana, would be discarded with banana waste.

Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of BBrMV to move from discarded banana waste to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of BBrMV in or on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which BBrMV can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

Persistence. Although there are no reports on the persistence of BBrMV, the accepted scientific position (Hull, 2002) is that potyviruses will remain viable in fruit or in discarded fruit waste while the fruit tissue is not completely necrotic. In tropical climates, this period may be in the order of a day. In cooler and drier climates, decay may take 1-3 days. The virus does not persist more than about 3 hours in the saliva of the aphid vector.

Distance. BBrMV would enter the environment through the disposal of infected waste, whether this is peel and associated flesh or whole spoiled bananas, or by aphids feeding directly on fruit at
the point of sale or after purchase. The implications of waste disposal patterns are discussed in the following bullet points. Aphid transmission is discussed under the heading of Dispersal mechanisms below.

- Individuals (rather than food service industries or food processors) consume the vast majority of bananas, and most of these individuals reside within the major population centres.
- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities. Bulk waste disposal will place virus associated with banana waste a substantial distance from commercial banana plants. Refuse disposal facilities frequently bury waste. Buried waste is likely to decay rapidly under Australian climatic conditions. This would lead to the rapid inactivation of BBrMV. Buried waste is in any event inaccessible to vectors.
- The balance of banana waste will be diverted to home composting, or discarded randomly in the form of peel and uneaten flesh, or whole spoiled fruit. Home composting will place the virus at some distance from commercial banana plants. In addition, the rapid decay of composted material will lead to rapid inactivation of BBrMV. Random waste disposal is more likely to result in slow spoilage. There is some chance that random waste disposal would place infected peel or fruit at roadsides adjacent to commercial banana plantations.

**Dispersal mechanisms.** The following points from Thomas *et al.* (2000) are relevant to the dispersal of BBrMV:

- The species of aphid known to vector this virus are endemic and common in Australia. Other Australian aphids may also be competent vectors.
- These aphids are considered itinerant, in that their natural behaviour is to move through the environment in search of suitable host plants. They are not generally associated with a discrete home range, and are able to sustain populations without a large number or density of individuals.
- Although a single aphid could transmit the virus, it would need to feed on a commercial banana plant within 3 hours of feeding on discarded banana waste. Feeding on another plant(s) prior to the commercial banana would result in rapid inactivation of the virus.
- Aphids are not capable of rapid, long-range movement and, thus, contact with fruit or fruit waste must occur in reasonably close proximity to a commercial banana plantation if commercial bananas are to be exposed directly.

**Exposure of a susceptible host.** As for other potyviruses (Hull, 2002), it is expected that aphids could transmit BBrMV after feeding on any surface of a susceptible host plant. Although it will take only a few seconds to acquire the virus from an infected banana or banana waste, aphids must then feed on a susceptible plant within 3 hours (without feeding on any other plant in between) if transmission is to occur. The effectiveness of aphid transmission is likely to be in the order of 20% when an aphid finds a suitable host immediately after feeding on an infected plant, but much lower if these conditions are not satisfied (Hull, 2002).

When these points were collated, the scenarios of highest concern were considered contact between an aphid vector and either: (a) infected banana waste discarded in proximity to commercial banana plantations; or (b) infected banana fruit on sale, or purchased and awaiting consumption, in close proximity to a commercial banana plantation.

The likelihood that either of these scenarios would occur was considered extremely low.
**Dist4** — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden banana plant.

The persistence of BBrMV in or on banana fruit and peel and the means by which it may be vectored from infected fruit to a susceptible plant, were discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants are the following:

- BBrMV infects only *Musa* spp. (Thomas *et al.*, 2000).
- The distance likely to lie between discarded waste and a susceptible garden plant is determined by waste disposal patterns. It is known that most bananas will be consumed in the major population centres, and that most waste generated in these centres is managed through refuse disposal facilities. The balance is managed through garden compost, or discarded randomly into the environment. BBrMV is unlikely to survive either managed refuse disposal sites or composting, and banana waste that is discarded randomly is more likely to lie in the general environment within a household or garden.
- The variable distance likely to lie between fruit at the point of sale or in households, and a susceptible garden plant. Aphids that feed on fruit at the point of sale are less likely to contact a susceptible household plant than those that feed from purchased fruit in or near households. Bananas are not generally refrigerated, and opportunity would exist for aphids to subsequently move from the household to its immediate environment, which may include susceptible plants. However, the proportion of banana plants amongst other potential feeding sites in household situations is very low.

When these points were collated, the scenarios of highest concern were considered contact between an aphid vector and either: (a) infected banana waste discarded in close proximity to household banana plants; or (b) infected banana fruit on sale, or purchased and awaiting consumption, in close proximity to household bananas.

From these observations and discussions regarding BBrMV persistence, the conditions needed for exposure of susceptible host plants, and dispersal mechanisms, the likelihood that susceptible household bananas would be exposed to BBrMV (Dist4) was rated as extremely low.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) banana plants. In banana growing parts of Australia, feral banana plants occur as frequently as household banana plants, whereas native banana species are restricted largely to the wet tropical areas of north Queensland. As previously noted, only *Musa* spp. are hosts of BBrMV.

Technical issues associated with the persistence of BBrMV, the conditions needed for infection of susceptible host plants, and its means of dispersal, need not be reiterated. Specific to Dist5 is the physical distance that may lie between discarded waste and a susceptible wild banana plant. Because the definition of a ‘wild’ plant includes native and feral bananas, amenity plants, and those that grow beside roadways and urban streets, the physical distance between discarded waste
and a plant is likely to be less than considered for either Dist3 (the exposure of commercial plants) or Dist4 (the exposure of household plants). Offsetting this, however, is the observation that susceptible native and feral banana plants are significantly less abundant. Further, the cultivation of native and seeded bananas is prohibited except for registered botanical gardens and official controls are exercised to minimise the incidence of pests and diseases in feral bananas (Queensland Plant Protection Regulation 2002). On balance, the likelihood that susceptible wild (native or feral) banana plants would be exposed to BBrMV (Dist5) was considered extremely low.

Conclusions — probability of distribution

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible commercial plants (other than bananas) would be exposed to BBrMV that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Extremely low
- Partial probability of distribution for susceptible household plants = Extremely low
- Partial probability of distribution for susceptible wild/commercial plants = Extremely low

Probability of establishment

The probability of establishment examines factors relevant to successful multiplication of the pest, and establishment of disease amongst the exposed plant, or group of plants. The initiation point for establishment of BBrMV in Australia is its transmission to a banana plant following the feeding of a viruliferous aphid. The end-point is the development of a systemic infection within the banana plant in which infectious BBrMV particles are present in sufficient concentration for aphid vectors to acquire them.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

Commercially cultivated banana plants

It is clear that the availability, quantity and distribution of hosts in an Australian banana plantation, and the suitability of the tropical or subtropical environments would favour the establishment of BBrMV in Australia. Adaptation would not be necessary, and the pest’s amplification within affected plants would only serve to enhance the likelihood of successful establishment. In regard to

the final criterion, ‘cultural practices and control measures’, it is unlikely that differences between Australian and Philippines banana production practices (in particular, the management of aphid vectors) would reduce the ability of the virus to become established in commercial Australian banana plants.

Based on this evidence, it was considered very likely that BBrMV would establish within exposed commercial banana plants, that is, the establishment potential was rated **high**.

**Susceptible household plants**

Whilst the availability, quantity and distribution of household bananas is less than would be the case in a commercial plantation, the aphid vectors of BBrMV are mobile and itinerant, and are likely to feed sufficiently on an exposed group of plants to ensure local establishment of the virus. A cultural practice of relevance in this context is the household control of aphids, but this is unlikely to be so effective as to hinder establishment. Similarly, it is possible that a diseased plant will be removed by cultural methods already practiced for banana bunchy top virus in subtropical banana areas but this is generally unlikely to occur before BBrMV has spread to other plants.

Overall, it was considered very likely that BBrMV would establish within exposed household banana plants. The potential for establishment amongst susceptible household plants was therefore considered **high**.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

While the availability, quantity and distribution of wild (native or feral) hosts is likely to be even lower than would be the case if susceptible household plants were exposed, viral multiplication in exposed plants and the ample opportunity for the reinfection of aphid vectors, result in a **high** likelihood of establishment within exposed wild plants.

**Probability of spread**

The probability of spread examines factors relevant to the movement of BBrMV from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. The initiation point for spread is acquisition of BBrMV by an itinerant aphid species and the end point is the distribution of an infective dose of BBrMV to other banana plants.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

Similarities between the natural and built environment in banana plantations in the Philippines and those in Australia, would suggest that conditions in Australia are suitable for spread of BBrMV.
While the movement of the commodity (fruit) and its intended use are not directly relevant to this pest, the relative abundance of vectors would favour spread. Viruses do not have natural enemies as such, and it is clear that aphids are able to sustain stable populations in Australia despite predation. The spread of cucumber mosaic virus throughout Australia by non-persistently infected aphid vectors illustrates that this mechanism is effective. This virus is also known to be carried long distances through the translocation of infected planting or propagation materials.

Overall, it was considered very likely that BBrMV would spread from a point of establishment within exposed commercial banana plants. The potential for spread from a point of establishment in commercially cultivated plants was therefore considered high.

**Susceptible household plants**

The spread of BBrMV from a point of establishment in exposed household banana plants will be determined largely by the availability of aphid vectors, and the proximity of other susceptible plants.

The following points are relevant:

- The aphid species known to vector BBrMV are endemic in most areas of Australia, and common in the tropical and subtropical areas in which banana plants are kept as household plants.
- Although population studies have not been carried out, it is likely that these aphids would be less abundant in urban centres, and particularly in larger urban centres.
- Spread from an exposed banana plant, or group of plants, to another susceptible banana plant would require that the aphids feed on both plants within a space of 3 hours. Feeding on a third plant in between the two would result in a rapid decline in transmission.
- Banana species are perennial plants and BBrMV persists indefinitely in infected plants.

Overall, it was considered very likely that BBrMV would spread from a point of establishment among exposed household plants. Spread potential was therefore rated as high.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Although conditions for spread will vary substantially, spread from exposed wild (native or feral) banana plants would be dependent on the factors discussed above. In this situation, however, a larger and more freely moving population of itinerant aphid vectors may offset a relatively lower abundance of susceptible plants.

- In some cases, aphids may not be able to travel the distance between hosts within the 3 hour period required for transmission and the virus would die out before an aphid transmits it to a susceptible host.
- In other cases, aphids may be able to move from a point of establishment in wild banana plants to other wild bananas, to household bananas or to commercial banana plants, and spread would be rapid.

Further, banana species are perennial and BBrMV persists indefinitely in infected plants. Moreover, BBrMV can be spread very effectively in infected plant material.

Overall, it was considered very likely that BBrMV would spread from a point of establishment in exposed wild (native or feral) banana plants, that is, the rating is high.
Consequences

The consequences to the Australian community of the entry, establishment or spread of BBrMV were assessed by considering its potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of BBrMV was assessed on the basis of its potential effect on the entire local, district, State or Territory, or national community. For some criteria, the effect of BBrMV could be estimated by considering the scale of likely economic impact. For others, its affect could only be assessed in more subjective terms, such as the loss of social amenity.

The direct impact of BBrMV

**Animal or plant life, or health**

This criterion describes the production losses associated with BBrMV in commercial bananas. The direct effects of BBrMV have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

The direct impact of BBrMV on commercial bananas will be determined by the stage of development at which infection occurs, and the speed and extent to which the disease spreads to other farms. At the start of this risk assessment the following points were made:

- Three-week-old fingers from Cavendish cultivars have spindle-shaped brown streaks and a distorted shape. The bunch will not develop normally and is generally unsaleable.
- When fully developed Cavendish bananas are infected, symptoms may not be evident or may be limited to dark green streaks and minor distortion of the fingers.
- Commercial companies note a strong correlation between a high incidence of BBrMV and a high rejection rate for malformed bunches and low hand-class ratings.
- In the Philippines, yield losses have been estimated to be as high as 40% in the popular Cardaba and Saba (ABB) cultivars.
- In 1988, the disease reached epidemic proportions around the General Santos City, where 25,000 mats were destroyed.

In Australia, BBrMV would cause this spectrum of effects, including the possibility of a serious epidemic in some years.

Overall, the likely direct impact of BBrMV in terms of plant production losses was considered minor at the State or Territory level. This gave the disease a rating of C for this criterion.

**Human life or health**

There are no known direct impacts of BBrMV on human life or health and the rating assigned to this criterion was therefore A.

**Any other aspects of the environment not covered above**

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical and biological environment. There are no known direct impacts of BBrMV in these directions, and the rating assigned to this criterion was therefore A.
The indirect impact of BBrMV

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

On first detection, an eradication program could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. The cost is likely to be several million dollars per year over a number of years. For BBrMV disease in Queensland, the controls that may be applied in the event of an incursion are already prescribed under the Plant Protection Regulation 2002. These controls do not currently include restrictions on fruit movement.

Overseas experience with other potyvirus infections in perennial or continuously cultivated crops suggests that eradication may not be possible where the crop is widely grown. It is more likely that banana growers would be faced with an on-going control and containment program, using a combination of preventative and sanitation measures.

In addition to this, individual banana farmers would need to target the aphid vectors using pesticide applications. Pesticides are costly, and additional applications may alter the economic viability of some crops and affect existing integrated pest management programs. In addition, it is possible that with a ceiling on the number of pesticide applications tolerated by consumers, sprays targeting aphids would need to be used in the place of those previously targeting other pests. This might lead to an increase in other insect populations, a decrease in productivity and a further indirect loss associated with BBrMV.

Overall, the indirect impact of BBrMV on the cost of pest control programs was considered likely to be minor at the State or Territory level. Overall, this gave the pest a rating of C for this criterion.

Domestic trade or industry effects

The domestic trade effects associated with the introduction and spread of BBrMV are likely to result from intra- and interstate trading restrictions on planting materials and fruit. The effects on planting materials would be similar to those that already apply to other pests and diseases.

Restrictions on fruit could, however, disrupt national marketing arrangements for a short time after the initial discovery of disease and lead to longer-term changes in requirements for quarantine sensitive markets in production areas. For this reason, the indirect impact on domestic trade was considered minor at the district level, and a rating of B was assigned to this criterion.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market. The presence of BBrMV would not therefore disturb bilateral trade agreements, and the rating assigned to this criterion was A.

Indirect effects on the environment

Although additional pesticide applications may be required to control aphids on commercial banana plantations, this is unlikely to impact on the environment as it was not considered to be distinguishable from day to day variation of pesticides used by the banana industry. A rating of A was thus assigned to this criterion.
Conclusions — the overall impact of BBrMV

The direct and indirect impacts of BBrMV were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of BBrMV are likely to be low.

Unrestricted risk estimate — BBrMV

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the Method for Import Risk Analysis. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with BBrMV.

The results of these steps are summarised below.

- Probability of importation = Very low
- Partial probabilities of distribution
  - Commercial bananas = Extremely low
  - Household bananas or other susceptible household plants = Extremely low
  - Susceptible wild/commercial plants = Extremely low
- Partial probabilities of establishment
  - Commercial bananas = High
  - Household bananas or other susceptible household plants = High
  - Susceptible wild/commercial plants = High
- Partial probabilities of spread
  - Commercial bananas = High
  - Household bananas or other susceptible household plants = High
  - Susceptible wild/commercial plants = High
- Probability of entry, establishment or spread (1 tonne) = Extremely low
- Annual probability of entry, establishment or spread = Low
- Consequences = Low
- Unrestricted risk = Very low

Because the unrestricted risk meets Australia’s ALOP (very low) risk management would not be required for BBrMV.

Banana bunchy top virus

Banana bunchy top virus (BBTV) is a nanovirus of the genus Babuviridae that infects a range of Musa species and cultivars in the Eumusa and Australimusa series of edible banana, and also Ensete ventricosum (Thomas and Iskra-Caruana, 2000). In Australia, this includes native and feral bananas, as well as commercial bananas of all cooking and dessert varieties (while E. ventricosum
is a very rare garden plant in Australia, it was not considered further in this assessment). BBTV may be transmitted by the banana aphid (*Pentalonia nigronervosa*) or through infected planting material (Magee, 1927) and micro-propagation (Drew *et al.*, 1992).

The visible disease syndrome caused by BBTV depends on whether a plant is infected prior to being used for planting material, called primary infection by Magee (1927), or whether it is infected by aphid transmission later in growth (secondary infection).

- In a primary infection, suckers from infected planting material show severe symptoms in the first leaf to emerge, since the virus is already established in the growing point from which the leaves develop. The leaves are upright, small and with very chlorotic margins that tend to turn necrotic (Magee, 1927).
- In a secondary infection, symptoms appear on the first or up to the fifth leaf to emerge after inoculation, although usually on the second leaf (Magee, 1927; Allen, 1978a). The first symptoms consist of a few dark green streaks or dots on the minor veins on the lower portion of the lamina (Magee, 1927; Thomas and Iskra-Caruana, 2000). The streaks form ‘hooks’ as they enter the midrib and are best seen from the underside of the leaf in transmitted light. The ‘dot-dash’ symptoms can sometimes also be seen on the petiole. Successive leaves become smaller, both in length and in width of the lamina, and often have chlorotic, upturned margins. The leaves become harsh and brittle and stand more erect than normal giving the plant a rosette or ‘bunchy top’ appearance. Leaf emergence is influenced primarily by temperature (Allen, 1978a) so, under Philippines conditions, a leaf would emerge every 7 to 10 days and the incubation period would be expected to range from 1 to 6 weeks, with a modal value of about 3 weeks.

Plants that arise from primary infections, or are infected early in the growth cycle, rarely produce a bunch. At best, the bunch is distorted and unmarketable (Magee, 1927). However, plants that are infected late in the growth cycle may produce an apparently normal bunch with dark dot-dash symptoms only in the bracts of the male inflorescence (Magee, 1927). Some strains of BBTV produce only mild symptoms in host plants (Thomas and Iskra-Caruana, 2000).

The banana aphid is a common pest of bananas in Australia, as it is in other parts of the world (Thomas and Iskra-Caruana, 2000). Although the virus does not multiply in the aphid (Hafner *et al.*, 1995) and is not transferred to aphid offspring (Magee, 1940), it may remain viable in mouthparts for 13 – 20 days (Magee, 1940; Hu *et al.*, 1996) and be carried through nymphal moults (Magee, 1940). Transmission to healthy banana plants by individual aphids occurs at a rate of 46 – 67% (Magee, 1940). Nymphs are considered more efficient transmitters than adult aphids, but need to feed for 4 – 17 hours or more to acquire the virus and a further 15 minutes to 2 hours for transmission to occur (Magee, 1940; Hu *et al.*, 1996). Magee (1940) reported that aphids only acquired the virus when they fed on tissue with virus ‘channels’ — i.e. on histoid galls in infected phloem. This author also reported that detached banana leaves retained their infectivity for at least 12 days if maintained in a fresh condition.

After inoculation by banana aphids, the virus moves in the phloem tissue to physiologically active buds where it multiplies in the meristematic tissue (Magee, 1927; Hafner *et al.*, 1995; Hull, 2002). It may be found in the phloem of all plant tissues that subsequently develop, including leaf lamina and midrib, pseudostem, rhizome (corm), roots, fruit stalk and fruit peel. Although viral DNA component 1 of BBTV has been found at extremely low concentrations in previously developed tissues (Hafner *et al.*, 1995), an infective dose of virus particles can be found only in tissue that develops after inoculation (Magee, 1940; Hafner *et al.*, 1995).
In Australia, bunchy top occurs in some areas of southeast Queensland, south of Cooloolabin, and in the Brunswick and Tweed River Valleys of northern New South Wales. It does not occur in Western Australia, the Northern Territory, north Queensland, the Bundaberg area of Queensland, or the Coffs Harbour area of New South Wales. It is under official control in Queensland (Plant Protection Regulation 2002) and New South Wales with respect to the destruction of diseased plants and the movement of plant material but not, however, in relation to fruit movement. In the Philippines, a high incidence of bunchy top is observed in the major banana growing areas, that is, northern Luzon, southern Tagalog, western Visayas, northern Mindanao and central Mindanao.

There are significant differences between the isolates of BBTV that occur in Australia (the so-called South Pacific isolates), and those that occur in the Philippines, Vietnam and Taiwan, and Dale (2002) notes some important points arising from these differences.

- The two groups of isolates have greater than 10% sequence variation between them — variation within the Philippines group is even greater than between this group and the South Pacific isolates.
- There is no information regarding the relative pathogenicity of various strains within the two groups or of the possibility of synergism if strains from the two groups were to coexist in a country. Extrapolation from a similar situation in geminiviruses suggests that if heterogenous strains were to coexist in Australia, there would be potential for virus recombination and the generation of increasingly virulent isolates.
- Research in Australia has led to the development of transgenic bananas with resistance to the Australian strains of the South Pacific isolates. It is unlikely, however, that these transgenic bananas would have cross-protection against the Philippines strains.
- Satellite viruses have been found to be associated with the Philippines BBTV isolates, which may significantly enhance the virulence of Australian isolates of BBTV if they were introduced.

**Probability of importation**

The risk scenario of particular relevance to BBTV is that associated with symptomless infection of the vascular tissues of banana fruit. Symptomless infection means that infection occurs internally in the tissue but has not developed to the stage of visible symptom expression. This form of infection would not be detected by visual inspection; nor would it be affected by chlorine treatments or subject to desiccation.

Another pathway that was considered was the contamination of fruit surfaces with viruliferous aphids. However, whilst this pathway might be relevant to the transmission of virus in the field, it is expected that free aphids would be either removed from fruit in the packing station through the cleaning action of washing and brushing, or killed by the solution of chlorine and alum in the de-handing and flotation tanks (see: *Method for Import Risk Analysis* for a discussion of the efficacy of the chlorine and alum treatment).

**Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced**

BBTV occurs in Cavendish and local banana cultivars throughout the Mindanao Province from which export bananas are to be sourced. Survey data for the years 1998 to 2001 provided by BPI (Philippines Dept. of Agriculture, 2002a) indicated that BBTV is found throughout the year, with little seasonal variation. Overall, it was considered very likely that BBTV would be present on the plantation from which a tonne of fruit would be sourced, and Imp1 was therefore rated as **high**.
BBTV invades bananas systemically and may be found in all phloem tissues produced after infection has occurred (Magee, 1940; Hafner et al., 1995), including the phloem tissues in harvested banana fruit. All Cavendish banana plantations in Mindanao Province from which export bananas are sourced are subject to weekly inspections for bunchy top disease. Any diseased mats, as well as all mats within 5-6 metres of a diseased mat are sprayed with an insecticide and the diseased mat is destroyed (PCARRD, 1988). These measures have ensured that the prevalence of BBTV remains at a relatively constant level, with the implication that there are as many new infections occurring as there are diseased plants removed under the control program.

Survey data provided by BPI (Philippines Dept. Agriculture, 2002a) indicated that, in the years from 1998 to 2001, the incidence of BBTV varied from 0.08 to 0.471 cases (infected mats) per hectare per 4-week period. The average incidence was 0.185 new cases per hectare per 4-week period, and only 5% of the incidence values were greater than 0.350 cases per hectare per 4-week period. As these data were actually derived from weekly inspection records, it was assumed, that the incidence of BBTV disease in any one week is 0.35 cases per hectare divided by 4 weeks, or 0.09 case per hectare per week35.

Plant density in Philippine plantations varies between 1700 and 2400 mats per hectare, depending on the farming system (Philippines Dept. Agriculture, 2001). If it is assumed, that the density is 1700 mats per hectare, that each case of disease involves one whole mat of bananas, and that the prevalence of BBTV is 0.09 case per hectare per wk, then the probability of one plant (mat) being found with disease symptoms in the week of harvest is 0.09 in 1700, or 5.3 x 10^{-5}.

The likelihood that a bunch harvested from a diseased mat will bear symptoms and be in a potentially infectious state should be considered in relation to the developmental botany of the banana plant and the likelihood of the mat escaping detection in the period leading up to harvest.

- The latest time in the development of the phloem tissue in which symptoms could develop in the fruit coincides approximately with the time of bunch emergence (Simmonds, 1966).
- Symptoms will be displayed on the fruit as the bracts dehisce and the fruit expands.
- A period of approximately 7 weeks will elapse from the time all the fruit have developed to the point where symptoms can be seen and the time that the fruit are ready for harvest.
- Symptoms will also appear on other parts of the mat during this period and the mat will be inspected for BBTV symptoms at weekly intervals.

It will be very unlikely that diseased plants will escape detection over this 7-week period (Allen, 1978a; Allen, 1987). Based on estimates of detection efficiency under Australian conditions (Allen, 1978a; Allen, 1987), an estimate of the likelihood of a bunch harvested from an infected mat and also bearing disease symptoms would be no more than the top range of ‘very low’, and therefore was estimated at no more than 0.05. Under such circumstances the probability of a plant being both infected and bearing a bunch with disease symptoms is the product of 0.05 x 5.3 x 10^{-5} or 2.7 x 10^{-6}.

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35 This assumption is not necessarily the worst-case scenario, because the weekly incidence would be expected to show more extreme variation than the monthly summaries indicate, but weekly data were not available to assess this variation.
The likelihood that fruit in a tonne will contain at least one bunch with symptomless infection, or very mild symptom expression, will also depend on the number of bunches needed to constitute a tonne. Given that each bunch yields approximately 20kg of export quality fruit there are approximately 50 bunches needed for each tonne.

The likelihood that fruit in a tonne will carry BBTV in an infectious state can be estimated from the equation below.

\[ \text{Imp}_2 = 1 - (1 - P)^N \]

In this equation P is the likelihood that a harvested bunch will bear a symptomless infection \((2.7 \times 10^{-6})\) and N is the number of bunches required for a tonne of export quality fruit (50).

This calculation results in an estimate for \(\text{Imp}_2\) of \(1.3 \times 10^{-5}\), which falls within the category of extremely low.

\textbf{Imp}_3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete. Infection of harvested green bananas would require aphids to penetrate the ventilation holes or inspection windows of bunch covers, many of which are impregnated with the insecticide, chlorpyrifos, and then complete a transmission before arrival at the packing station. The likelihood of this scenario was considered negligible.

\textbf{Imp}_4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

BBTV is carried internally in the fruit and is transmitted during 15-30 minutes of feeding by viruliferous banana aphids. On arrival at the packing station, fruit are subjected to washing and immersion in a solution of chlorine and alum for at least 25 minutes. These conditions are not conducive to either the feeding activities of aphids or to their survival. Overall, the likelihood of transmission within the packing station was considered negligible.

\textbf{Imp}_5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Fruit are inspected within the packing station for adherence to basic quality parameters. Fruit are removed on the basis of blemishes, obvious distortion in shape, premature ripening and visible splits or other lesions. It was stated at the start of this risk assessment, however, that the pathway of concern relates to symptomless infection, and thus it is clear that the likelihood that affected fruit of this sort would be detected is negligible.

\textbf{Imp}_6 — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

While it is likely that any free aphids would be removed or destroyed as a result of washing, scrubbing, sponging and immersion in the chlorine and alum solution, virus within the fruit would not. Given that the risk pathway was considered the symptomless infection of fruit, the likelihood assigned to this step was rated as negligible.
Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Quarantine inspection would detect fruit blemishes, obvious distortion in shape, premature ripening and visible splits. By definition, however, symptomless infection would not be detected by visual inspection by BPI quarantine officers, so the likelihood of detection at this stage was considered negligible.

Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Although the persistence of BBTV in banana fruit and peel has not been studied, the accepted scientific position (Magee, 1940; Hull, 2002) is that BBTV would remain viable while ever the substrate is not completely necrotic. On this basis, it was considered virtually certain that BBTV would survive and remain viable during this step in the pathway.

Imp9 — the likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. However, because BBTV is considered tolerant of this temperature, and because other environmental factors are constant within the fruit, it was considered virtually certain that the virus would remain viable during this step in the pathway.

Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

BBTV produces visible lesions only when infection occurs early in the development of the fruit. In other words, symptoms would not express in fully developed fruit during the period of transport to Australia. By definition, symptomless infection of fruit would not be detected by visual inspection by AQIS officers regardless of the proportion of the consignment that was inspected. Imp 10 was thus rated as negligible.

Conclusions: probability of importation

When these likelihoods were inserted into the simulation model, the overall probability that BBTV would be present in a tonne of hard green bananas was found to be extremely low.

Probability of distribution

The initiating step for distribution of BBTV in Australia is the presence of virus particles in the peel or crown of banana fruit imported from the Philippines. The endpoint is the exposure of leaf tissue of a susceptible banana plant in Australia to virus via an aphid vector.

Dist1 — the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers

It was explained above that although the persistence of BBTV in banana fruit and peel has not been studied, the accepted scientific position (Magee, 1940; Hull, 2002) is that BBTV would remain viable while ever the substrate is not completely necrotic. On this basis, it was considered virtually certain that the virus would remain viable during the storage and ripening of fruit, and its distribution to wholesalers.
Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

The host range for BBTV in Australia is effectively restricted to native and commercial banana strains that are found in households in tropical and subtropical areas, and, to a lesser extent, the temperate areas of Australia. It was stated in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, approximately 32% of imported bananas would be consumed in an area in which household banana plants are found. Thus, for pests such as BBTV that are known to be specific to bananas, Prop2 is considered moderate.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was stated in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, approximately 11% of imported bananas would be consumed in an area in which wild (native or feral) bananas are found. Thus, for pests such as BBTV that are specific to bananas, Prop3 is considered low.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Although not documented, it is very likely that BBTV, if present in the flesh of a banana, would also be present in the skin and crown tissue. The skin and crown tissue are discarded in the normal course of the consumption of banana fruit. A percentage of discarded waste may also include discarded banana flesh. Spoiled fruit is likely to be discarded whole.

From these observations it was considered virtually certain that BBTV, if present in an imported banana, would be discarded with banana waste.

Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of BBTV to move from discarded banana waste to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of BBTV in or on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which BBTV can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

Persistence. BBTV will remain viable in fruit or in discarded waste while ever it is not completely necrotic. In tropical climates, this period may be in the order of a day. In cooler and drier climates,
decay may take 1-3 days. The virus persists in detached banana leaf for at least 12 days if kept fresh, and for up to 20 days in an aphid vector (Magee, 1940; Hu et al., 1996).

**Distance.** BBTV would enter the environment through the disposal of infected waste, whether this is peel and associated flesh or whole spoiled bananas, or by aphids feeding directly on fruit at the point of sale or after purchase. The implications of waste disposal patterns are discussed in the following bullet points. Aphid transmission is discussed under the heading of Dispersal mechanisms below.

- Individuals (rather than food service industries or food processors) consume the vast majority of bananas, and most of these individuals reside within the major population centres.
- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities. Bulk waste disposal will place virus associated with banana waste a substantial distance from commercial banana plants. Refuse disposal facilities bury waste frequently. Buried waste is likely to decay rapidly under Australian climatic conditions. This would lead to the rapid inactivation of BBTV.
- The balance of banana waste will be diverted to home composting, or discarded randomly in the form of peel and uneaten flesh, or whole spoiled fruit. Home composting will place the virus at some distance from commercial banana plants. In addition, the rapid decay of composted material will lead to rapid inactivation of BBTV. Random waste disposal is more likely to result in slow spoilage. There is some chance that random waste disposal would place infected peel or fruit at roadsides adjacent commercial banana plantations.

**Dispersal mechanisms.** The following points from Magee (1940) and Thomas and Iskra-Caruana (2000) are relevant to the dispersal of BBTV.

- The banana aphid is endemic and common in Australia; no other Australian aphids are vectors of BBTV.
- The banana aphid is considered a colonising species and not particularly itinerant.
- Although a single aphid could transmit the virus, the efficiency of virus transmission is probably very low given that relatively long acquisition and transmission times are required.

In other studies of dispersal, aphids are reported to move only short distances — specifically, non-winged forms walk between plants or are carried by ants (Ocfemia, 1930) whilst winged forms reluctantly fly. Studies of actual BBTV outbreaks in New South Wales show that the average distance of spread by aphids is 15.2 metres (Allen, 1987).

BBTV can also be spread in infected planting material (Magee, 1927; Allen, 1978a). BBTV does not kill plants so that an infected plant provides a continual source of inoculum for spread until it is removed (Magee, 1927).

**Exposure of a susceptible host.** The transmission requirements for bunchy top severely limit the possibility of spread from infected peel. Under the most favourable conditions, an aphid vector requires at least 4 hours to acquire the virus and a further 15 to 30 minutes of feeding on a new host plant to transmit it (Magee, 1940; Hu et al., 1996). The transfer must occur within 20 days. It is likely that only adult winged forms of banana aphid will be attracted to discarded banana peel and be capable of moving to another plant. Since there will be very few aphids involved, it is most unlikely that transmission will occur. This likelihood is further reduced by the fact that the waste from imported bananas will most likely be in a symptomless state of infection and therefore not a good source of virus (Magee, 1940; Hafner et al., 1995).

When these points were collated, the scenarios of highest concern were considered contact between an aphid vector and either: (a) infected banana waste discarded in close proximity to commercial
banana plantations; or (b) infected banana fruit on sale, or purchased and awaiting consumption, in close proximity to a commercial banana plantation.

The likelihood that either of these scenarios would occur was considered extremely low.

**Dist4** — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden plant.

The persistence of BBTV in banana peel and crown and the means by which it may be vectored from infected fruit to a susceptible plant were discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the distance likely to lie between fruit or discarded waste, and a susceptible household plant.

- The distance likely to lie between discarded waste and a susceptible garden plant will be determined largely by waste disposal patterns. It is known that most bananas will be consumed in the major population centres, and that most waste generated in these centres is managed through refuse disposal facilities. The balance is managed through garden compost, or discarded randomly into the environment. BBTV is unlikely to survive either managed refuse disposal sites or composting, and banana waste that is discarded randomly is more likely to lie in the general environment within a household or garden.

- The distance likely to lie between fruit at the point of sale or in households, and a susceptible garden plant, is extremely variable. Aphids that feed on fruit at the point of sale are less likely to contact a susceptible household plant than those that feed from purchased fruit in or near households. Bananas are not generally refrigerated, and opportunity would exist for aphids to subsequently move from the household to its immediate environment, which may include susceptible plants.

From these observations and discussions regarding BBTV persistence, the conditions needed for exposure of susceptible host plants, and dispersal mechanisms, the likelihood that susceptible household bananas would be exposed to BBTV (Dist4) was rated as extremely low.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) banana plants. In banana growing parts of Australia, feral banana plants occur as frequently as household banana plants, whereas native banana species are restricted largely to the tropical areas of north Queensland. As already noted, only *Musa* spp. are hosts of BBTV.

Technical issues associated with the persistence of BBTV, the conditions needed for infection of susceptible host plants, and its means of dispersal, need not be reiterated. Specific to Dist5 is the physical distance that may lie between discarded waste and a susceptible wild banana plant. Because the definition of a ‘wild’ plant includes native and feral bananas, amenity plants, and those that grow beside roadways and urban streets, the physical distance between discarded waste and a plant is likely to be less than considered for either Dist3 (the exposure of commercial plants) or Dist4 (the exposure of household plants). Offsetting this, however, is the observation that
susceptible native and feral banana plants are significantly less abundant. In Queensland, the cultivation of native and seeded bananas is prohibited except for registered botanical gardens and official controls are exercised to minimise the incidence of pests and diseases in feral bananas (*Plant Protection Regulation 2002*).

On balance, the likelihood that susceptible wild (native or feral) banana plants would be exposed to BBTV (Dist5) was considered **extremely low**.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to BBTV that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Extremely low
- Partial probability of distribution for susceptible household plants = Extremely low
- Partial probability of distribution for susceptible wild/commercial plants = Extremely low

**Probability of establishment**

The probability of establishment examines factors relevant to successful multiplication of the pest, and establishment of disease amongst the exposed plant, or group of plants. The initiation point for establishment of BBTV in Australia is its transmission to a banana plant following the feeding of a viruliferous aphid. The end-point is the development of a systemic infection within the banana plant in which infectious BBTV particles are present in sufficient concentration for aphid vectors to acquire them.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

**Commercially cultivated banana plants**

Given the successful establishment of this virus in the Philippines, and the presence of other strains of BBTV in restricted areas of Australia, it is clear that the availability, quantity and distribution of hosts in an Australian banana plantation, and the suitability of the tropical or subtropical environments, would favour its establishment in Australia. In this situation, adaptation would not be necessary, and the pest’s amplification within affected plants would only serve to enhance the likelihood of successful establishment. It is possible that a diseased plant will be removed by cultural methods already practiced for BBTV in subtropical banana areas but this is generally unlikely to occur before BBTV has spread to other plants. In regard to the final criterion, ‘cultural practices and control measures’, it is unlikely that differences between Australian and Philippines...
banana production practices (in particular, the management of aphid vectors) would reduce the ability of the virus to become established in commercial Australian banana plants.

Based on this evidence, it was considered very likely that BBTV would establish within exposed commercial banana plants, that is, the establishment potential was rated high.

**Susceptible household plants**

Whilst the availability, quantity and distribution of household bananas is less than would be the case in a commercial plantation, the aphid vector of BBTV is mobile and is likely to feed sufficiently on an exposed group of plants to ensure local establishment of the virus. A cultural practice of relevance in this context is the household control of aphids, but this is unlikely to be so effective as to hinder establishment. It is possible that a diseased plant will be removed by cultural methods already practiced for BBTV in subtropical banana areas but this is generally unlikely to occur before BBTV has spread to other plants.

Overall, it was considered very likely that BBTV would establish within exposed household banana plants. The potential for establishment amongst susceptible household plants was therefore considered high.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

While the availability, quantity and distribution of wild (native or feral) hosts is likely to be even lower than would be the case if susceptible household plants were exposed, viral multiplication in exposed plants and the ample opportunity for the reinfection of aphid vectors, result in a high likelihood of establishment within exposed wild plants.

**Probability of spread**

The probability of spread examines factors relevant to the movement of BBTV from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. Two mechanisms of spread are possible for BBTV; spread by banana aphid vectors and spread in infected planting material. The initiation point for spread by aphid vectors is acquisition of BBTV by an aphid species and the end point is the distribution of an infective dose of BBTV to other banana plants.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

Similarities between the natural and built environment in banana plantations in the Philippines and those in Australia, would suggest that conditions in Australia are suitable for spread of the Philippines strains of BBTV.
While the movement of the commodity (fruit) and its intended use are not directly relevant to this pest, the relative abundance of banana aphids and the practice of taking planting material from existing plantations would favour spread. Experience with BBTV in bananas cultivated commercially in sub-tropical areas of southern Queensland and northern New South Wales (Magee, 1927; Allen, 1978a) confirms this observation. While the official controls implemented in the 1930’s have contained BBTV to the areas of Australia that became infected before official controls were implemented, BBTV has persisted in these areas in spite of official controls (Allen, 1978a). Viruses do not have natural enemies as such, and it is clear that aphids are able to sustain stable populations in Australia despite predation.

Overall, it was considered very likely that BBTV would spread from a point of establishment within exposed commercial banana plants. The potential for spread from a point of establishment in commercially cultivated plants was therefore considered high.

**Susceptible household plants**

The spread of BBTV from a point of establishment in exposed household plants will be determined largely by the availability of aphid vectors, movement of infected planting material, and the proximity of other susceptible plants.

The following points are relevant:

- The aphid species known to vector BBTV is endemic in Australia, and common in the tropical and subtropical areas in which banana plants are kept as household plants.
- Household planting material is commonly taken from other household or commercial plants.
- An infected household banana that is not killed by BBTV may persist for many years.
- BBTV has persisted in Australian household banana plants in sub-tropical areas in spite of official controls for many decades. Further, evidence from these control operations is that household plants are an important source of BBTV for disease outbreaks in commercial banana plantations nearby (Allen, 2002).

Overall, it was considered very likely that BBTV would spread from a point of establishment among exposed household plants. Spread potential was therefore rated as high.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Although conditions for spread will vary substantially, spread from infected wild (native or feral) banana plants would be dependent on the factors discussed above. The distribution of native bananas is largely restricted to tropical north Queensland but feral banana plants may be found in all commercial banana production districts. The movement of planting material from wild and feral bananas is uncommon but opportunities exist over time for spread by the ubiquitous banana aphid, although the distance between these plants and other bananas would limit the rate of spread. Since BBTV does not kill plants, infected native and feral banana plants provide sources of infection for many years.

The likelihood of spread from a point of establishment in wild plants was therefore considered high.
Consequences

The consequences to the Australian community of the entry, establishment or spread of BBTV were assessed by considering its potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of BBTV was assessed on the basis of its potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of BBTV could be estimated by considering the scale of likely economic impact. For others, its effect could only be assessed in more subjective terms, such as the loss of social amenity.

The direct impact of BBTV

Animal or plant life, or health

This criterion describes the production losses associated with BBTV in commercial bananas. The direct effects of BBTV have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

At the start of this risk assessment it was noted that banana plants infected with BBTV rarely produce a bunch, and do not fruit in subsequent years. Plants infected late in the growing cycle may fruit once, but the bunch stalk and the fruit will often be small and distorted. On plants infected very late, the only symptoms present may be a few dark green streaks on the tips of the flower bracts. It was also noted that synergism between Australian and South Pacific isolates may occur, and that satellite viruses might also be introduced. Either scenario might result in a more virulent strain of BBTV.

Like the Philippines, Australia has a well-established program for BBTV that has contained the disease to relatively small areas and has kept the disease incidence very low (Magee, 1927; Allen, 1978a). This will assist to minimise the direct impacts of further incursions.

Overall, the likely direct impact of BBTV in terms of plant production losses was considered minor at the district level, which gave the disease a rating of B for this criterion.

Human life or health

There are no known direct impacts of BBTV on human life or health, and the rating assigned to this criterion was therefore A.

Any other aspects of the environment not covered above

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical or biological environment. There are no known direct impacts of BBTV in these areas, and the rating assigned to this criterion was therefore A.
The indirect impact of BBTV

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

If identified in Australia, the Philippines strains of BBTV would be managed by the same comprehensive control and eradication program as is currently in place for the Australian isolates. Administration of the current BBTV program requires approximately $0.5 million/year, which is funded jointly by State or Territory Governments and industry.

Overall, the indirect impact of BBTV on the cost of pest control programs was considered likely to be minor at the district level. This resulted in a rating of **B** for this criterion.

Domestic trade or industry effects

It is not likely that an incursion of the Philippines strains of BBTV would result in interstate trading restrictions on banana fruit. Neither would controls on planting materials be any more restrictive than those already in place for Australian strains of BBTV. A rating of **A** was given to this criterion.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market, and does not export significant quantities of other crops that would be of concern. Other countries are unlikely to introduce restriction on fruit as a result of a change in the existing pattern of infection. The presence of BBTV would not therefore disturb bilateral trade agreements, and the rating assigned to this criterion was **A**.

Indirect effects on the environment

It is not likely that BBTV would impact on the environment, and a rating of **A** was thus assigned to this criterion.

Conclusions — the overall impact of BBTV

The direct and indirect impacts of BBTV were combined using the decision rules discussed in the *Method for Import Risk Analysis*. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of BBTV are likely to be **very low**.

Unrestricted risk estimate — BBTV

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with BBTV.

The results of these steps are summarised below.
Probability of importation = Extremely low

Partial probabilities of distribution

- Commercial bananas = Extremely low
- Household bananas or other susceptible household plants = Extremely low
- Susceptible wild/commercial plants = Extremely low

Partial probabilities of establishment

- Commercial bananas = High
- Household bananas or other susceptible household plants = High
- Susceptible wild/commercial plants = High

Partial probabilities of spread

- Commercial bananas = High
- Household bananas or other susceptible household plants = High
- Susceptible wild/commercial plants = High

Probability of entry, establishment or spread (1 tonne) = Negligible

Annual probability of entry, establishment or spread = Very low

Consequences = Very low

Unrestricted risk = Negligible

Because the unrestricted risk meets Australia’s ALOP (very low) risk management would not be required for BBTV.

**Moko**

Moko is a vascular wilt disease of dessert bananas caused by the bacterium *Ralstonia solanacearum* (E.F. Smith) Yabuuchi *et al.* This bacterium, known previously as *Pseudomonas solanacearum*, is highly heterogeneous, and has been grouped into three Races based on its ability to cause disease on various hosts under field conditions (Buddenhagen *et al.*, 1962):

- Race 1 affects a range of solanaceous and other plants (known as the “tomato” Race);
- Race 2 affects *Musa* and *Heliconia* species (known as the “banana” Race); and
- Race 3 is specific to potatoes (known as the “potato” Race).

Race 2 is further divided into seven strains, designated ‘B’, ‘H’, ‘R’, ‘SFR’, ‘A’, ‘AFV’ and ‘T’, based on differences in host range and ecology (particularly frequency of insect transmission and persistence in soil), and on various characteristics in pure culture (Thwaites *et al.*, 2000). Other strains may be added to this list in future.

The Moko bacterium present in the Philippines is the B strain, as described in Central America (Raymundo *et al.*, 1997; Fegan, 2002). The B strain has been characterised genetically and designated ‘MLG 24’ (Cook *et al.*, 1989; Cook and Sequeira, 1994). Of those isolates of the Moko bacterium examined, ‘MLG 24’ represents a group that causes Moko disease of Cavendish (AAA) dessert bananas in both the Philippines and Central America, and also bugtok disease of Saba, Cardaba and Latundan (ABB/BBB) cooking bananas in the Philippines (Soguilon *et al.*, 1995; Raymundo and Ilagan, 1999).

The Moko bacterium infects wounds on any part of the plant, but particularly those made by cutting implements that expose the vascular tissues (Sequeira, 1958; Stover, 1972; Thwaites *et al.*, 2000; Takatsu, 2001). Wounding occurs throughout normal horticultural operations, such as de-
suckering, de-belling, de-leafing, propping and harvesting, which are carried out as regular plantation practice on the ‘mother’ (fruit bearing) pseudostem and its ‘followers’ (suckers). Infested sap can be transferred between plants on implements and may also be transferred by insects that may visit freshly wounded surfaces including floral bract scars (Stover, 1972). In addition, natural infection can occur through floral bract scars and, through wounded roots leading to infection of the ‘corm’ (Kelman and Sequeira, 1965; Stover, 1972; Wardlaw, 1972).

Regardless of the mode of transmission (cutting implements, hands, insects or soil), or the site of infection (wounds on the pseudostem, the corm or floral bract scars), bacteria may remain localised for some time before disseminating through the plant by way of mature xylem vessels (Stover, 1972). Studies of the dynamics of invasion through xylem of banana plants were not identified. The process is likely, however, to be similar to the invasion of tomato seedlings by \textit{R. solanacearum} Race 1, where multiplying bacteria move rapidly through a large proportion of the vascular bundles (Vasse \textit{et al}., 1995). In support of this, Stover (1972) reported that vascular browning becomes evident after the bacteria have invaded the tissues.

The first symptoms of Moko disease in dessert bananas, including Cavendish, are pallor and yellowing of the youngest leaves, and collapse near the junction of the lamina with the petiole (Stover, 1972). Suckers may also become blackened and twisted. In any case, vascular bundles in young tissue at the centre of the pseudostem usually become discoloured (Rorer, 1911; Ashby, 1926; Sequeira, 1958; Buddenhagen, 1961; Power, 1976; Kastelein and Gangadin, 1984; Soguilon \textit{et al}., 1994a; Jeger, \textit{et al}., 1995; Soguilon, 2003a) and ooze bacteria when wounded. Further, a few fruit in each bunch may become prematurely yellow and, as a result of occlusion of vascular tissue early in the development, may have a firm and dry internal rot (Buddenhagen, 1994).

Infection of fruit via bract scars is well known for bugtok disease in Saba bananas (Molina, 1996) and via bract scars by the SFR strain on Cavendish bananas in Central America (Stover, 1972). There are strong interactions between the strain of the Moko bacterium and the transmission and pathogenesis of disease in particular cultivars. Importantly, whilst insect transmission of the B strain, and subsequent fruit involvement, is common in Saba cooking bananas in the Philippines (Molina, 1996), it is reported as rare in Cavendish dessert bananas in the Philippines (Philippines Dept Agriculture, 2002a) and in Honduras (Stover, 1972). By contrast, insect transmission of the SFR strain to Cavendish bananas in Honduras may result in up to 15% of the bunches of infected plants expressing disease symptoms (Stover, 1972).

Other factors important to the epidemiology of the Moko bacterium are the environment and the ability of the pathogen to persist on susceptible asymptomatic hosts. The Moko bacterium is known to cause bacterial wilt symptoms on \textit{Musa} and \textit{Heliconia} species only in tropical countries–there are no confirmed reports of Moko disease on Cavendish bananas in sub-tropical areas (Buddenhagen, 1961; Thwaites \textit{et al}., 2000). In fact, Moko disease has only been found within 18° of the equator (see Moko Datasheet for more details). Whilst the Moko bacterium is not known to cause disease symptoms on plants other than \textit{Musa} and \textit{Heliconia} spp. (Buddenhagen, 1961; Buddenhagen, 1994), it may be harboursed on the root systems of other plants without causing disease symptoms (Berg, 1971; Granada, 2002). Of these species, \textit{Solanum nigrum} (black nightshade) and \textit{Bidens pilosa} (cobbler’s-pegs) are noted to be common and widely distributed weeds in rural and residential areas of Australia (Lazarides and Hince, 1993). Buddenhagen (1961; 1994) has argued that alternative weeds are not true hosts of the Moko bacterium in that they do not become diseased, whereas Jeger \textit{et al}. (1995) concluded that the Moko bacterium may survive in the rhizosphere and, thus, elimination of weed hosts is important in Moko control. Therefore, the IRA team has taken the view that alternative host plants such as \textit{S. nigrum} and \textit{B. pilosa} are a factor in the establishment or spread of the Moko bacterium.
Probability of importation

The risk scenario of particular relevance to Moko is that associated with symptomless infection of the vascular tissues of banana fruit. Symptomless infection means that infection occurs internally in the tissue but has not developed to the stage of visible symptom expression. This form of infection would not be detected by visual inspection; nor would it be affected by chlorine treatments or subject to desiccation.

Other pathways that were considered included the contamination of de-handing and flotation tanks with bacteria that may ooze from fruit cut during de-handing and the contamination of fruit or packaging surfaces with infested soil or with waterborne (rain-splash) inoculum, as occurs with some other bacterial pathogens. In these cases, however, it is clear that the Moko bacterium would be killed by a correctly maintained chlorine treatment in the packing station or when the fruit surfaces dried out.

In support of this:

- The chlorine treatment used in packing station de-handing and flotation tanks (20ppm available chlorine for 25 minutes) corresponds to a $CT_{\text{chlorine}}$ of 500ppm-minutes (using the approach described in the Method for Import Risk Analysis).
- In-vitro experiments undertaken by the BPI (Philippines Dept. Agriculture, 2002a) have shown that no bacterial growth was observed after exposure of cells of the Moko bacterium to a $CT_{\text{chlorine}}$ as low as 10ppm-minutes, i.e. at a chlorine treatment 1/50th of the strength of that used in the packing stations.
- It is well understood that the presence of organic impurities, including banana sap, will reduce the efficacy of chlorine treatment. However, in-vivo efficacy data involving various fruits and vegetables shows that effective disinfection for a range of bacteria can be achieved by washing in chlorine solutions corresponding to a $CT_{\text{chlorine}}$ of between 120 and 2000ppm-minutes (Dychdala, 1991; Holmes and Harrup, 2003; Zhuang et al., 1995; Bartz et al., 2001; Ritenour et al., 2002; Sanz et al., 2002).
- From these data it is clear that an appropriately maintained chlorine disinfection treatment in the de-handing and flotation tanks of $CT_{\text{chlorine}}$ 500ppm-minutes is within the $CT_{\text{chlorine}}$ range found to be effective against bacteria associated with fruit and vegetables and hence would be an effective and acceptable biocide against Moko bacteria.
- Additionally, the presence of alum in the wash water is likely to aid the biocidal capacity of the chlorine treatment. As noted previously in the Method for Import Risk Analysis the emphasis is on maintenance of the chlorine-alum treatment to maintain its biocidal effect.

**Imp1** — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

The results of weekly inspections in Philippines plantations show that Moko disease occurs year round in commercial Cavendish plantations throughout Mindanao, the province from which export bananas are to be sourced. As would be expected of an infectious disease, the prevalence of Moko-affected plantations within Mindanao varies with seasonal changes, with changes in the infection status of neighbouring plantations and with other variables relevant to the disease epidemiology and plantation management. Moko disease is also very prevalent in cooking banana cultivars (Soguilon et al., 1994b; Soguilon et al., 1994a) some of which are grown close to commercial banana plantations.
Given this, the disease is considered present in most commercial plantations and, at any point in time, is very likely to be present on the particular plantation from which a tonne of fruit harvested for export would be sourced. Imp1 was thus rated high.

**Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest**

As outlined above, banana plants may be infected with the Moko bacterium at any stage of plant growth. Infection is through wounds and invasion is through the vascular system. There is little available information on the dynamics of invasion of fruit by the Moko bacterium, so it is assumed that some infected plants will yield infected bunches unless the disease is otherwise controlled.

In commercial plantations in the Philippines, every banana plant is inspected at weekly intervals for symptoms of Moko. Diseased plants are immediately removed, along with adjacent plants (PCARRD, 1988; Philippines Dept. Agriculture, 2001; Philippines Dept Agriculture, 2002a). This equates to an eradication zone of approximately 5 to 6 metres from the infected plant (infected mat). This eradication practice (in conjunction with strict hygiene practices listed in Method for Import Risk Analysis) has kept the prevalence of Moko at a relatively constant level for a number of years.

Data provided by BPI (Philippines Dept. Agriculture, 2002a) indicate that the number of cases (infected mats) of Moko detected in routine control operations during 1998-2001 varied between 0.024 per hectare per 4 week period to 0.134 cases per hectare per 4 week period. The average incidence was 0.055 cases per hectare per 4 week period, and only 5% of the incidence values were greater than 0.1 cases per hectare per 4 week period. As these data were actually derived from weekly inspection data, it was assumed that the incidence of Moko in any single week is 0.1 cases per hectare divided by 4 weeks, or 0.025 cases per hectare per week.

The plant density in Philippine plantations is reported to vary from 1700 to 2400 mats per hectare depending on the farming system (Philippines Dept. Agriculture, 2001). If it is assumed that the density is 1700 mats per hectare, that each case of disease involves one whole mat of bananas, and that the prevalence of Moko is 0.025 cases per hectare per week, then the probability of one plant becoming infected in a week is 0.025 in 1700, or about 1.5 x 10^-5.

The proportion of plants that has been infected late in the development of the bunch, and has not yet displayed disease symptoms, is the sum of the likelihood of infection each week for successive weeks of the total incubation period. Authors report incubation periods ranging from approximately 1 week (Soguilon et al., 1994b) to 24 weeks or more (Woods, 1984), depending on the strain of pathogen, the host cultivar, the stage of growth, the method of experimental inoculation and the conditions for incubation (see Moko datasheet, Appendix 1 for more details). Buddenhagen (1961; 1994) stated that the disease is commonly found in young and actively growing suckers, and produces symptoms in 2 to 4 weeks. Stover (1972), however, reported that when suckers were pruned with a machete after cutting through a diseased pseudostem, 40% of mats showed symptoms after 70 days, and 60% after 90 days. This author concluded that symptoms could appear from 6 to 12 weeks or more. The Philippines BPI (Philippines Dept. Agriculture, 2002b) suggested that the incubation period in Cavendish banana plants in the Philippines might vary from 3-7 weeks, although in a recent Philippines field study of Moko, the

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36 This assumption is not necessarily the worst-case scenario, because the weekly incidence would be expected to show more extreme variation than the monthly summaries indicate, but weekly data were not available to assess this variation.
incubation period exceeded 13 weeks (Soguilon, 2003a). Given the level of variation around the length of the incubation period, it was assumed that symptoms would appear within 12 weeks and, thus, the proportion of plants infected and symptomless at the time of harvest was estimated to be $12 \times 1.5 \times 10^{-5}$, or $1.8 \times 10^{-4}$ plants.

It is recognised that only a proportion of banana plants infected with the Moko bacterium will develop (symptomless) infected bunches. Whilst this proportion has not been investigated for Philippines Cavendish bananas infected with the B strain of the Moko bacterium, it is expected to be no higher than the 15% reported for the insect-transmitted SFR strain in Central American Cavendish bananas (Stover, 1972). On this basis, the likelihood that an infected plant would bear a symptomless but infected bunch was calculated to be $0.15 \times 1.8 \times 10^{-4}$, or $2.7 \times 10^{-5}$.

It is also recognised that not all fruit are infected in every infected bunch regardless of whether Moko symptoms are externally visible or not (symptomless infection) (Rorer, 1911; Buddenhagen, 1961; Stover, 1972; Jeger et al., 1995; Soguilon, 2003a). This proportion has been described in terms such as many (Rorer (1911) reported that if disease is not severe, or a plant does not become infected until it has just formed a bunch it may remain perfectly healthy but many of the young fruits, or “fingers” do not properly mature; they remain small and eventually become black and rotten), few (Buddenhagen (1961) reported that an infected stem may show limited external symptoms consisting of a few split or prematurely yellow fingers), often (Stover (1972) reported that fruit symptoms of yellow fingers in an otherwise green stem will often indicate the presence of Moko disease) or some (Jeger et al. (1995) reported that the development of fruit bunches is arrested and some of the fingers may ripen prematurely or split). In a recent study, Soguilon (2003a) isolated the Moko bacterium from only a small proportion of fingers from symptomless but Moko infected bunches. The proportion of fruit that is infected on a symptomless infected bunch is likely to depend on various factors such as the number of vascular bundles affected at the point of infection, time period elapsed between infection and fruit harvest, and climatic conditions. It was assumed for this analysis, that the proportion of fruit that may be infected on a symptomless infected bunch is unlikely to exceed 50%. On this basis, the proportion of a symptomless infected bunch bearing symptomless but infected fruit was calculated to be $0.5 \times 2.7 \times 10^{-5}$, or $1.35 \times 10^{-5}$.

The likelihood that a tonne of harvested fruit will contain at least one bunch with some symptomless infected fruit will depend on the number of bunches that make up this weight. Given that each bunch yields approximately 20 kg of export quality fruit, there are approximately 50 bunches needed for each tonne.

The likelihood that fruit in a tonne will be infected with the Moko bacterium can be estimated from the equation below.

$$\text{Imp}^2 = 1 - (1-P)^N$$

In this equation:

- P is the likelihood that a harvested bunch will bear a symptomless infected fruit ($1.35 \times 10^{-5}$); and
- N is the number of bunches required for a tonne of export quality fruit (50).

This calculation results in an estimate for Imp2 of approximately $6.7 \times 10^{-4}$, which falls in the extremely low category, under the Biosecurity Australia’s classification system.
Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete. In this period, any infestation that may occur would not result in the bacterium entering the internal tissue of the fruit.

On this basis, the likelihood that fruit would be infected during transport to the packing station was considered negligible.

Imp4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

Whilst there is not any evidence to suggest that fruit might be contaminated within a packing station, the possibility that bacteria present within any infected fruit might move into the wash solution in the de-handing or flotation tanks (whether through skin ooze, or through lesions in the fruit) and thus contaminate the surface of other fruit, was considered. It is clear, however, that if the concentration of available chlorine and alum were maintained at 20ppm and 200ppm respectively, these bacteria would be killed.

Another avenue for possible infection is the use of a contaminated knife to remove the peduncle and to trim the crown. Fruit, however, are returned immediately to the chlorine and alum solution, leaving no residual opportunity for infection.

On the basis of this evidence, the likelihood that the tonne of fruit would become infected within the packing station was considered negligible.

Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Fruit are inspected within the packing station for adherence to basic quality parameters. Fruit are removed on the basis of blemishes, obvious distortion in shape, premature ripening and visible splits or other lesions.

Whether a result of rhizome or wound infection, the Moko bacterium leads to premature ripening (Stover, 1972), and it is at this point that any visibly affected fruit would be removed. It was stated at the start of this discussion, however, that the pathway of concern relates to symptomless infection, and thus it is clear that the likelihood that affected fruit of this sort would be detected is negligible.

Imp6 — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

While it is likely that any surface contamination with the Moko bacterium would be removed or destroyed as a result of washing, scrubbing, sponging and immersion in the chlorine and alum solution, bacteria within the fruit would not. Given that the risk pathway was considered the symptomless infection of fruit (rather than surface infestation), the likelihood assigned to this step was rated as negligible.

Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

The quarantine inspection would detect fruit blemishes, obvious distortion in shape, premature ripening and visible splits. By definition, however, symptomless infection would not be detected.
by visual inspection by BPI quarantine officers, so the likelihood of detection at this stage was considered negligible.

**Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export**

Given that the physiological state of the fruit during transport to the wharf is similar to that of freshly harvested fruit, it was considered very likely that the Moko bacterium would survive and remain viable during this step in the pathway. Imp8 was thus rated high.

**Imp9 — the likelihood that the pest will remain viable during transport to Australia**

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. Because the Moko bacterium is tolerant of this temperature, and because other environmental factors are constant within the fruit, it was considered very likely that the organism would remain viable during this step in the pathway. Imp9 was thus rated as high.

**Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia**

Transport conditions are not conducive to symptom development, so that there will be little change in the symptomless condition of fruit after its despatch from the Philippines. By definition, symptomless infection of fruit would not be detected by visual inspection by AQIS officers regardless of the proportion of the consignment that was inspected. Imp10 was thus rated as negligible.

**Conclusion — probability of importation**

When these likelihoods were inserted into the simulation model, the overall probability of importation for a tonne of bananas was found to be extremely low.

**Probability of distribution**

The initiation point for distribution of the Moko bacterium in Australia is the presence of bacterial cells in vascular tissue of imported fruit. The end-point is the exposure of a suitable site on a susceptible host to a number of bacteria sufficient to initiate infection. As discussed, a host plant in the case of the Moko bacterium is a species of *Musa* or *Heliconia*, both of which may develop disease symptoms, or one of a number of asymptomatic host species.

**Dist1 — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers**

Once the Moko bacterium has penetrated the fruit tissue, it would remain viable under the typical storage and ripening conditions. The likelihood that the bacterium would remain viable at this stage of the importation pathway was therefore rated high.

**Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially**

It was stated in the *Method for Import Risk Analysis* that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.
Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

If imported, bananas from the Philippines would be distributed for sale in all major Australian population centres. It was explained above that the host range for the Moko bacterium includes native and commercial strains of banana plants, as well as Heliconia spp., each of which can be found in households in tropical and subtropical parts, and, to a much lesser extent, the temperate parts of Australia. Importantly, it was also explained that weed species such as B. pilosa and S. nigrum, which are found throughout Australia, are also asymptomatic hosts.

It was shown in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest specific to bananas, Prop2 would be described as moderate. However, because the host range for Moko includes some common and widely occurring weed species, this proportion will be increased. Overall, it was considered very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown, and Prop2 was therefore rated high.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was explained in the Method for Import Risk Analysis, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood. The Moko bacterium, however, is also associated with some common and widely distributed weed species. The Moko bacterium can also infect commercially grown heliconias in tropical and subtropical parts of Australia, which, as ‘commercial plants other than bananas’ are included in Prop3.

Overall, it was considered very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts or susceptible commercial plants (other than bananas) can be found. Prop3 was therefore rated as high.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Although not documented, it is very likely that the Moko bacterium, if present in the flesh of a banana, would also be present in the skin and crown tissue. The skin and crown tissue are discarded in the normal course of the consumption of banana fruit. A percentage of discarded waste may also include discarded banana flesh. Spoiled fruit is likely to be discarded whole.

From these observations it was considered virtually certain that the Moko bacterium, if present in an imported banana, would be discarded with banana waste.

Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of the Moko bacterium to move from its point of entry into the environment, to a suitable site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of the bacterium in or on fruit, in discarded waste or in the soil including the
rhizosphere of asymptomatic hosts;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which the bacterium might move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant to a sufficient dose of a pathogen.

**Persistence.** Although there is little published information regarding the ability of the Moko bacterium to exude from discarded fruit waste and enter the soil environment, there is considerable evidence that it has an ability to persist while infected tissue is moist for several weeks and also to survive in a soil environment for 12-18 months or more (Stover, 1972; Sequeria, 1962).

The Moko bacterium does not produce desiccation-resistant resting cells and *in vitro* studies have shown that the bacterium survives poorly when subjected to air-drying (Kelman, 1953; Sequeira, 1958).

**Distance.** The Moko bacterium would enter the environment through the disposal of infected waste, whether this is peel and associated flesh or crown, or whole spoiled bananas. Some points are important:
- The majority of banana fruit is consumed by individuals, rather than by food service industries or food processors. Most of these individuals reside within the major population centres.
- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities. Bulk waste disposal will place organisms associated with banana waste a substantial distance from commercial banana plants. Refuse disposal facilities frequently bury waste. Buried waste is likely to rapidly decay under Australian climatic conditions, creating an environment with low pH and a high proportion of competitive saprophytes. This environment would not favour the Moko bacterium (Lehmann-Danzinger, 1987).
- The balance of banana waste will be diverted to home composting, or discarded randomly in the form of peel and uneaten flesh, or whole spoiled fruit.
- Home composting will place the organism at some distance from commercial banana plants. In addition, low pH and high number of saprophytes will lead to an unfavourable environment for the Moko bacterium (Lehmann-Danzinger, 1987).
- Random waste disposal is more likely to result in slow spoilage, and movement of the bacterium into the soil. Random waste disposal may result in peel or discarded fruit at roadsides adjacent commercial banana plantations.

**Dispersal mechanisms.** The following points are relevant to the dispersal of the Moko bacterium:
- The organism is transmitted between plantations through the movement of infected propagation material or contaminated equipment;
- The organism may persist in warm moist soil including the rhizosphere of asymptomatic hosts, and may move within contaminated soil water;
- Rain-splash may have some relevance to transmission of the organism over relatively short distances — the effect may be exacerbated in high wind;
- Floodwater and surface runoff may mobilise bacteria from decaying waste and carry them longer distances;
- Some insects may feed on discarded waste, and subsequently on sap from open pruning wounds on commercial bananas, or on their floral parts;
The organism does not produce desiccation-resistant resting cells and is sensitive to above ground desiccation; and

There is no evidence to suggest that aerosol transmission, or transmission through dust particles, occurs in those countries where it is endemic.

**Exposure of a susceptible host.** Given transfer to the vicinity of a susceptible host, the Moko bacterium can enter through wounds that sever the vascular tissue of plants either above or below ground (roots or rhizomes) or through floral bract scars on the plant (Kelman and Sequeira, 1965; Stover, 1972; Thwaites et al., 2000). Movement of the bacterium to these sites can be passive (as is the case for root infection), or be vectored by flood water, rain splash, insects or other animals attracted to disposed waste, or human activity involved with cultivation and pruning including vehicle movement.

Taking each of the above points into consideration, the scenario of highest concern was considered the movement of the Moko bacterium through a relatively short distance from banana waste discarded at a roadside, to an adjacent commercial banana plantation. In this situation, rain-splash or the movement of contaminated soil water with heavy rain would be the most likely means of dispersal. The likelihood that this might occur, given the distribution of symptomless infected bananas to an area where bananas are farmed commercially, and the discarding of the organism in banana waste, was considered **low**.

**Dist4** — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable site on a susceptible plant — in this case, a household or garden plant.

The persistence of the Moko bacterium, its means of dispersal and the conditions needed for exposure of a suitable site on the plant were discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the physical distance between discarded waste and a household banana or other susceptible garden plant. As discussed previously, these plants include *Musa* spp., *Heliconia* spp., *B. pilosa* and *S. nigrum*.

It was explained above that the bulk of consumer waste is managed through refuse disposal facilities, and that these present very limited opportunity for dispersal of the Moko bacterium. Residual household banana waste is either composted or discarded randomly. Household compost may place fruit peel containing the Moko bacterium in close proximity to a susceptible household plant. Most random disposal of peel is likely to take place outside the garden environment on roadsides, playgrounds etc, and at some distance from susceptible household plants.

From these observations, and from earlier discussions regarding the persistence of the Moko bacterium, its dispersal mechanisms, and the conditions needed for successful exposure of susceptible hosts (see Dist3), the scenario of greatest concern was the disposal of banana waste in the proximity of a susceptible household plant and the subsequent movement of the organism through contaminated soil or soil water. The likelihood that this, as well as the successful delivery of a sufficient dose of the organism to a suitable site on a susceptible host, would occur was considered **low**.
**Dist5** — the likelihood that susceptible wild (native or feral) plants or other susceptible cultivated plants would be exposed to the pest associated with banana waste (fruit and peel), or that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) plants or susceptible cultivated plants other than bananas. As noted, this would include *Musa* spp. and *Heliconia* spp., as well as some asymptomatic weed hosts such as *B. pilosa* and *S. nigrum*. There are, in addition, some commercially grown heliconias.

Technical issues associated with the persistence of the Moko bacterium, its infectivity and its means of dispersal need not be reiterated. Specific to Dist5 is the distance likely to lie between discarded waste and a susceptible wild plant or cultivated *Heliconia* spp. Here it is relevant that waste disposal patterns, and the unfavourable nature of compost as a substrate for the Moko bacterium (see Dist3), suggest that the scenario of concern for the exposure of wild plants would, again, be the random disposal of infected peel or crown tissue. Although relatively more banana waste would be discarded in the environment of wild plants than in gardens, wild (native or feral) bananas and susceptible weed species are relatively less common than susceptible garden plants and susceptible garden weeds. Additionally, whilst included in Dist5, commercially grown heliconias are extremely uncommon and generally placed at some distance from randomly discarded banana waste.

Overall, it was considered unlikely that susceptible wild (native or feral) plants would be exposed to the Moko bacterium, and Dist 5 was therefore rated as **low**.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to Moko bacteria that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Very low
- Partial probability of distribution for susceptible household plants = Low
- Partial probability of distribution for susceptible wild/commercial plants = Low

**Probability of establishment**

The initiation point for establishment of the Moko bacterium from imported fruit in Australia is the settling of bacterial cells on wounded host tissue and the end-point is the development of a sustained population of the Moko bacterium in that host. This may result in the development of symptoms in the case of banana plants under tropical conditions but may not be the case for alternative hosts or for bananas under sub-tropical conditions.

To establish on exposed host tissue, a bacterial cell would initially multiply at the point of entry, overcome host defences, and eventually invade the exposed vascular tissues (Stover, 1972). The bacteria would then move systemically in the plant through the xylem elements.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are discussed in detail in the Method for Import Risk Analysis but, in brief, will include:
• The availability, quantity and distribution of hosts;
• The suitability of the environment;
• The potential for adaptation of the pest;
• The reproductive strategy of the pest;
• The method of pest survival; and
• Cultural practices and control measures.

Commercially cultivated banana plants

It is clear that the availability of hosts within a commercial banana plantation would not be limiting. Given this, it is important that whilst bananas are grown commercially in tropical and sub-tropical parts of Australia, Moko has only been found in tropical conditions within 18° of the equator (Buddenhagen, 1994; Thwaites et al., 2000; Hayward, 2002). Although the bacterium’s reproductive strategy would enable multiplication in tropical parts of Australia, there is no evidence that it could adapt and establish in subtropical parts. In regard to the final criterion, ‘cultural practices and control measures’, it is unlikely that differences between Australian and Philippines banana production practices would reduce the ability of the Moko bacterium to colonise soil and infect banana plants.

On the balance of this evidence, the likelihood that the Moko bacterium would establish within exposed commercial banana plants was considered to be moderate.

Susceptible household plants

The Moko bacterium can infect a range of common and widely distributed household plants, including Heliconia and Musa spp., as well as common and widely distributed weed species such as B. pilosa and Solanum spp. While the availability, quantity and distribution of such hosts, as well as the availability of household bananas, would be less than in a commercial plantation, the organism is a successful soil contaminant and may remain viable in moist conditions for long periods. Cultural practices likely to be relevant to the establishment of Moko in exposed garden plants include pruning, which results in open wounds and may lead to the movement of the bacterium among plants, and the movement of infected clippings or transplanted plants from one point to another. In the absence of a diagnosis of Moko, control measures are unlikely to be used for household plants.

Given the above, the key determinant of the establishment of Moko amongst exposed household plants will be climate — i.e. Moko is a tropical disease, and establishment in subtropical, temperate or arid parts of Australia is extremely unlikely. Because a large proportion of Australia’s households reside in parts of Australia that are not considered tropical, the likelihood of establishment was (conservatively) considered moderate.

Susceptible wild plants, or susceptible cultivated plants other than bananas

The probability of establishment for the Moko bacterium on susceptible wild (native or feral) plants and those commercially grown heliconias would be governed by the same climatic factors as commercial bananas and susceptible household plants i.e. tropical warm moist conditions. The availability, quantity and distribution of susceptible wild plants and commercially grown heliconias are likely to be lower than susceptible household plants. Further, except for commercial heliconias, this class of hosts grows in areas not tendered or managed, hence the likelihood of above ground wounding would be less than for commercial bananas or susceptible household plants.
Once again it was considered, on balance, that the likelihood that establishment would follow from the exposure of susceptible wild plants or cultivated heliconias was moderate.

Probability of spread

The probability of spread examines factors relevant to the movement of the Moko bacterium from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are discussed in detail in the Method for Import Risk Analysis but, in brief, will include:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

Commercially cultivated banana plants

Of particular concern, is the role of mechanisation in Australian banana production may play in assisting spread of the bacterium. Because the B strain of the organism survives well in moist soil (Stover, 1972), and may be transmitted through the movement of contaminated soil or soil particles, it has been suggested that mechanised equipment moving within and between rows would lead to amplification of the number of observed cases. Furthermore, the cost of labour in Australia might preclude Australian growers from reducing their reliance on mechanisation by making increased use of manual labour.

Although there are no natural enemies, potential vectors may be important. The spread of Moko within and amongst most countries has resulted primarily from the dissemination of infected propagation material (Thwaites et al., 2000). In Australia, however, all States have official restrictions on the movement of banana planting material. These restrictions would slow the rate of spread, at least between major banana growing districts, but not entirely eliminate this means of spread over time. Other vectors that might be important include farm machinery, tools (e.g. cutting and piercing tools), personnel and, possibly insects. Finally, the frequency and severity of flooding in major production areas in north Queensland may be important, as floodwater has been implicated in the movement of the bacterium in the Philippines and other countries where the disease is endemic.

Overall, it was considered very likely that the Moko bacterium would spread from a point of establishment within exposed commercial banana plants. Thus, the probability of spread for commercial plants was rated as high.

Susceptible household plants

The suitability of the (natural or built) environment to the spread of the Moko bacterium is likely to vary with the species of susceptible household plant exposed to the bacterium, and with the geographic location of the household. In some cases (e.g. the State of Victoria), low ambient temperatures or humidity and relatively low numbers of household bananas, would mean that
spread would be unlikely to occur. In other cases (e.g. north Queensland), higher numbers of household hosts and favourable climatic conditions may lead to a higher likelihood of spread. Between these extremes is a range of possible permutations, each with implications regarding the likelihood of spread.

There is potential for the bacterium to be carried with infected planting material from vegetatively propagated plants (such as banana and Heliconia), on fruit, on gardening implements, on weeds removed from household gardens, with soil carried in storm or floodwater, or by insects. However, it is difficult to be precise in estimating the likelihood attributed to each of these pathways. In many cases, infections may remain localised for a considerable period before a suitable vectoring opportunity occurs. The bacterium is however, persistent in the host or contaminated soil.

Overall, variation in regard to each of the biological considerations led to an assumption that there is moderate potential for spread of Moko from a point of establishment in exposed household plants.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The potential for spread of the Moko bacterium from a point of establishment in susceptible wild and commercially grown plants will be dictated by the abundance and distribution of suitable hosts — i.e. other susceptible native and feral plants, commercial banana plants or susceptible household plants — and by the bacterium’s requirement for a tropical environment. Australia’s native banana species in particular, are isolated to tropical forests of north Queensland; they are not abundant and have limited distribution.

Once again, variability led to the assumption that there is a moderate likelihood that the bacterium might spread from a point of exposure and establishment in this group of host plants.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of Moko were assessed by considering its potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of Moko was assessed on the basis of its potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of Moko could be estimated by considering the scale of likely economic impact. For others, its effect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of Moko**

*Animal or plant life, or health*

This criterion describes the production losses associated with Moko in commercial banana plantations, as well as any loss in productivity of other susceptible species. The direct effects of Moko have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with additional control measures or trade restrictions as a result of introduction of the Moko bacterium are considered within the discussion of ‘indirect impacts’.
Moko is an aggressive disease, which, if permitted to progress leads to death of the plant. Stover (1972) reports that plant losses attributed to Moko disease were as low as 1% annually but this is only achieved as a result of the application of expensive control measures, without which losses could increase to 5% or more. Thwaites et al. (2000) state that:

“An improved understanding of the disease and the development of effective control measures resulted partly from research in the 1950’s and 1960’s and also from experience in controlling outbreaks of bacterial wilt in other crops, notably tomato, tobacco and potato (Kelman, 1953). Serious losses are now rare in commercial plantations because of the implementation of control measures. However, the disease still strikes susceptible plants grown on smallholdings and has continued to spread in Latin America and the southern Caribbean”.

In summarising the literature on the impact of Moko in smallholdings, Thwaites et al. (2000) refer to Lehmann-Danzinger (1987) in Nicaragua, where over 20% of Bluggoe plantings in some areas were found infected with Moko. They also refer to an outbreak in Trinidad in the early 1960s, which destroyed much of the island’s export banana trade, and to outbreaks in Guyana which reduced yields up to 74% (Phelps, 1987).

In Brazil, Moko is devastating to banana growers in the Amazonia area and is considered there the constraint most limiting to production (Coelho Netto and Nutter, 2002). In this area, disease incidence within plantations ranges from 0.62% to 63.8%. A similar situation applies to plantations in the Philippines, where Molina (1996) surveyed 14 barangays (villages) on Valencia and Negros Oriental for the presence of bugtok in the cooking bananas, Saba and Cardaba. In this survey, in which 163 farmers participated, the disease was found in every barangay surveyed, with incidences ranging from 60% to 92%. Additionally, between 80% and 100% of the fingers on infected bunches were considered unfit for consumption.

The direct impact of Moko on commercial banana production *per se* is not substantial in the Philippines, because control measures mean that the incidence of disease is about one mat per hectare per year. The high cost of the disease, and thus its importance in the Philippines, results largely from the instigation and management of control measures. The direct impact of the disease may be higher in the north Queensland banana production area of Australia by comparison with the Philippines, because mechanisation and topography may reduce the efficacy of available control strategies and hence lead to a substantially higher incidence of diseased plants. However, while commercial banana production in Australia may be based on smaller plantation size than the Philippines, the Australian banana industry has considerable experience in the management of diseases such as bunchy top (banana bunchy top nanovirus), Panama (*Fusarium oxysporum* f.sp. *cubense*) and the root burrowing nematode (*Radopholus similis*) with the result that the impacts of these diseases have been minimised. The direct effects of Moko on Australian banana production may not therefore be as great as its effects on small farms in other countries.

The direct impact of the disease on other susceptible cultivated plants (e.g. *Heliconia* spp.) is difficult to estimate, although unlikely to be discernible except for commercial growers who are directly affected. There are no obvious direct impacts of the disease on the environment, although there is some potential for the Moko Race of *R. solanacearum*, Race 2, to impact on native banana plants. The level of impact that could occur is unknown, however, native *Musa* species in Australia have already been exposed to Race 1 of *R. solanacearum* with no reported impact (Akiew, 1991). Further, as native bananas are not grown in monocultures, they are relatively much less likely to experience epidemics of pest and diseases that may occur in monocultures of commercial bananas. This is supported by the fact that no disease threats have been identified for the survival of native bananas. It appears that native bananas in Australia are generally disease free either due to their
low density and isolation from commercial plantations or some level of inherent tolerance to
disease.

In consideration of this evidence, the likely direct impact of Moko in terms of plant production
losses was considered minor at the district level. Overall, this gave the disease a rating of B for this
criterion.

*Human life or health*

There are no known direct impacts of Moko on human life or health, and the rating assigned to this
criterion was therefore A.

*Any other aspects of the environment not covered above*

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built
environment, such as the physical environment or micro-organisms. There are no known direct
impacts of Moko in these directions, and the rating assigned to this criterion was therefore A.

**The indirect impact of Moko**

*New or modified eradication, control, surveillance/monitoring and compensation
strategies/programs*

On first detection, an eradication program could be initiated under the national Generic Incursion
Management Plan approved by the Australian Primary Industries Standing Committee. The cost is
likely to be several $million per year over a number of years. For Moko in Queensland, the
controls that may be applied in the event of an incursion are already prescribed under the *Plant
Protection Regulation 2002*. These controls include restrictions on fruit movement.

If an eradication program failed, then the presence of the Moko bacterium in Australia could result
in significant modification of horticultural practices in the floodplain areas of tropical north
Queensland where the potential for disease establishment or spread is expected to be much higher
than in other banana growing areas of Australia. While measures are already in place for
controlling root burrowing nematode infestations, the advent of Moko in north Queensland would
increase costs and threaten the viability of some farms. The option of moving the enterprise to land
not affected by the disease may be available to some of the affected growers, although many would
be limited by a lack of availability of alternative land or the cost of moving.

Overall, it was considered likely that the indirect impact of new or modified control programs
would be minor at the State or Territory level. This gave the disease a rating of C for this criterion.

*Domestic trade or industry effects*

The presence of the Moko bacterium on a commercial banana plantation may result in additional
restrictions on the sale or movement of banana fruit. These restrictions are already prescribed for
Queensland under the *Plant Protection Regulation 2002*. The restrictions that already apply to
planting materials for banana diseases, including Panama and bunchy top, could apply equally to
Moko.

The banana industry is important to the economies of many localities and districts in New South
Wales, Queensland, Western Australia and the Northern Territory, and, most notably, in north
Queensland. Restrictions on the sale of bananas and, thus, on the viability of many producers,
would be damaging to rural communities. Restrictions on the movement of bananas and planting
materials might also result in destabilisation of existing marketing arrangements in areas susceptible to Moko. It is likely that such restrictions would lead to disruption of centralised packing stations, given the current need to move freely between properties and along roadways.

When these issues were collated, the indirect impacts of Moko on domestic trade and industry activity were considered minor at the State or Territory level. Overall this resulted in a rating of C for this criterion.

**International trade effects**

At present, Australia exports negligible quantities of bananas that go to a specialty market (see *Import Proposal for Philippines Bananas*). Banana producing countries are able to export their fruit to most markets around the world, regardless of the presence of the disease in the export production areas. For this reason, the rating assigned to this criterion was A.

**Indirect effects on the environment**

One of the considerations within this criterion was the possible indirect impact of a pest on rural economic viability. In assessing the indirect impact at each of the four levels, it was relevant to consider the resilience of rural communities, and the indirect impact of a threat to rural viability on all levels of the Australian community. The effects of Moko on changes to horticultural practices have already been considered under new or modified controls (see above).

One likely result of the establishment or spread of Moko in Australia would be a reduction in the degree of mechanisation, or, at least, a move towards systems that restrict movement of soil between farms. It is clear that if Moko became established in an area where the banana industry was highly significant to the local and district economy, aspects of these communities might also be threatened. For example, a reduction in banana shipments could affect the freight costs for goods imported into rural communities, as there may be limited opportunities for alternative exports.

Taking these issues into account, the indirect impact of Moko on rural communities was considered to be minor at the district level. Overall this resulted in a rating of B for this criterion.

**Conclusions — the overall impact of Moko**

The direct and indirect impacts of Moko were combined using the decision rules discussed in the *Method for Import Risk Analysis*. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of Moko are likely to be low.

**Unrestricted risk estimate**

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with Moko.
The results of these steps are summarised below.

Probability of importation = Extremely low

Partial probabilities of distribution
- Commercial bananas = Very low
- Household bananas or other susceptible household plants = Low
- Susceptible wild/commercial plants = Low

Partial probabilities of establishment
- Commercial bananas = Moderate
- Household bananas or other susceptible household plants = Moderate
- Susceptible wild/commercial plants = Moderate

Partial probabilities of spread
- Commercial bananas = High
- Household bananas or other susceptible household plants = Moderate
- Susceptible wild/commercial plants = Moderate

Probability of entry, establishment or spread (1 tonne) = Extremely low
Annual probability of entry, establishment or spread = Moderate
Consequences = Low

Unrestricted risk = Low

Because the unrestricted risk exceeds Australia’s ALOP (very low) risk management would be required for the Moko bacterium (Moko).

**Freckle**

Freckle is a leaf and fruit-spotting disease caused by the fungus Guignardia musae Racib. (anamorph, Phyllosticta musarum (Cooke) van der Aa). It affects a wide range of Musa spp. including dessert bananas, plantains and abacá (Meredith, 1968). The spots, commonly known as ‘freckles’, are reddish brown in colour and are the visual expression of the disease.

On Cavendish bananas, leaf spots are present mainly on the upper surface of old leaves but may occur also on midribs, transition leaves, peduncles and floral bracts (Meredith, 1968; Jones, 2000). Symptoms also occur on green fruit, numbers of lesions intensifying as the bunch matures and are particularly noticeable at the time of harvest (Meredith, 1968). Fruit symptoms are particularly severe when the young bunch is in contact with severely diseased leaves (Meredith, 1968; Jones, 2000) and little or no disease develops on fruit when the disease is not present on leaves of the same plant or if the fruit are covered with a paper bag (Meredith, 1968). The first freckles appear as minute dark areas surrounded by a green, water-soaked halo up to 2mm in diameter. Adjacent lesions may coalesce, resulting in large, irregular water-soaked areas with numerous brown flecks scattered throughout (Meredith, 1968). The result of infection is the premature death of older leaves and the disfigurement of fruit (Meredith, 1968; Jones, 2000).

The fungus reproduces both sexually and asexually in the dark brown to black centres of mature freckle lesions resulting in the formation of two types of infective structures commonly referred to as ‘spores’.
- **Sexual** spores are known as ascospores, and are produced in reproductive structures or ‘fruiting bodies’ called perithecia. Perithecia are globose in shape and are embedded within the surface layers of fruit peel or leaf. At maturity, a small pore opens at the top of the peritheciun at the
surface of the plant tissue, to release the ascospores into the air. The role of the sexual stage in the epidemiology of disease is unclear (Jones, 2000).

- *Asexual* spores are known as conidia, and are produced in fruiting structures known as pycnidia. Pycnidia are globose in shape and formed on the surface of the infected tissue, in many cases creating a sandpaper texture on the surface. At maturity and during wet conditions, mature pycnidia release tendrils of conidia in a gelatinous envelope. The gel dissolves in water, releasing the conidia for dispersal by water droplets that run across the fruit or leaf surface. Conidia germinate, form a germination tube (germ tube) and penetrate the surface layers of plant tissue in the presence of water. Under ideal conditions of warm temperature and free water, initial fleck symptoms may appear on green fruit 4 to 6 days after inoculation (Meredith, 1968). The lesions mature over the next few weeks at a rate determined by the age of tissue at infection, rainfall conditions, and the prevailing temperature (Meredith, 1968; Chuang, 1984). Pycnidia are found in mature fleckle lesions as early as 3 weeks after infection (Meredith, 1968). Pycnidia produce conidia continuously and erupt repeatedly when the diseased tissue is wet (Meredith, 1968). There may be from 5 to 70 pycnidia in each mature fleckle, depending on the size of lesion.

As mentioned above, under experimental conditions in Hawaii, the incubation period for fleckle may be as short as 4 to 6 days on 10 to 20 day old fruit (Meredith, 1968). However, in Taiwan, the incubation period for fleckle has been reported to vary from 17 days in the wet warmer months to 69 days in the dry cooler months (Chuang, 1984). The incubation period on fruit varied from 37 days when the tissue was 30 days old at inoculation to 23 days when the tissue was 120 days old at inoculation (Chuang, 1984). In the Philippines it is expected that most fruit would be harvested at 11 to 16 weeks after emergence and thus the age of the exposed fruit tissue would be less than 120 days and it follows that the incubation period in such fruit would be longer than 23 days and shorter than 37 days. However, it has not been clearly established how the studies by Meredith (1968) in Hawaii and Chuang (1984) in Taiwan relate to the time between infection and the time that fleckle can be recognised by field and packing station inspectors in the Philippines. Taking into account the variability in incubation period at different environmental conditions and maturity of the fruit tissues at the time of infection as previously described, it was assumed that the incubation period under Philippines conditions could be up to 4 weeks. On this basis, some hard green banana fruit could be harvested in the Philippines and be distributed in Australia before visible symptoms have developed.

### Probability of importation

Two risk pathways were considered of relevance to fleckle.

- **Firstly**, and of particular importance, is symptomless infection of the banana fruit. Symptomless infection means that the fungus has penetrated the fruit peel, but that the required period between penetration and the expression of visible fleckle symptoms has not yet elapsed. Lesions involving as few as five dead fruit peel cells may produce pycnidia (Jones, 2000). However, lesions so small would not be visually detectable and thus are included in the definition of symptomless infection.

- **Secondly**, the presence of small pieces of infected leaf trash trapped between the fingers of harvested fruit. Although the amount of leaf trash associated with marketed fruit is very small (see: *Method for Import Risk Analysis*), it may, if present, carry viable perithecia or pycnidia.

A third pathway that was considered was the contamination of fruit surfaces and packing materials with conidia still in their protective gelatinous envelope, or with free conidia that have been
released with exposure of the gel to water. Although their role in the epidemiology of freckle is unclear, it is also possible that fruit surfaces could be contaminated with free airborne ascospores. It is important, however, that free conidia or ascospores will germinate on exposure to water and high humidity (Meredith, 1968). Also, importantly, whilst this third pathway was likely to be relevant to fruit and leaf surfaces in the field, it is expected that both these spore types would be either removed from fruit through the cleaning action of washing and brushing, or be killed by a correctly maintained chlorine treatment in the de-handing and flotation tanks of \( CT_{\text{chlorine}} \) 500ppm-minutes.

In support of this:

- Conidia, under laboratory conditions, did not germinate when subjected to 1ppm available chlorine plus 200ppm alum for 10 minutes, which corresponds to a \( CT_{\text{chlorine}} \) of 10ppm-minutes (see Method for Import Risk Analysis) (Philippines Dept. Agriculture, 2001). This is 1/50th the strength of the chlorine treatment to which Philippines bananas are subjected in the de-handing and flotation tanks in packing stations.

- Similarly, while data were not provided for efficacy against \( G. \) musae ascospores, the Philippines Dept Agriculture data showed that the same \( CT_{\text{chlorine}} \)10ppm-minutes treatment was also lethal to ascospores of \( M. \) fijiensis, a species closely related to \( Guignardia \) spp.

- Even if fruit are processed in a mobile packing facility, where bunches are de-handed in the field and the exposure time is shortened, it is expected that free conidia on the surface of fruit would be exposed to a \( CT_{\text{chlorine}} \) many times the lethal dose.

- It is well understood that the presence of organic impurities including banana sap will reduce the efficacy of the packing station treatment hence, as noted in the discussion on chlorine in the Method for Import Risk Analysis, the emphasis is on maintenance of the chlorine treatment to maintain its biocidal effect. Additionally, the presence of alum in the wash water is likely to aid the biocidal capacity of the chlorine treatment.

**Imp1** — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

Freckle occurs on Cavendish and local banana cultivars throughout the Mindanao Province from where export bananas are to be sourced (Lee, 1922; Biosecurity Australia, 2002). As would be expected, the prevalence of freckle-affected plantations within Mindanao varies with seasonal changes, with changes in the infection status of neighbouring plantations and with other variables relevant to disease epidemiology.

Given this, the likelihood that the fungus would be present on the plantation from which a tonne will be sourced was considered high.

**Imp2** — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

Two pathways were considered relevant to freckle: (a) symptomless infection of banana fruit; and (b) particulate trash with pycnidia or perithecia trapped between banana fingers.

**Symptomless infection of banana fruit:** in the Philippines, bunches are bagged between 8-11 weeks prior to harvest (2-3 weeks after emergence of first hand of fruit). Given that the incubation period for freckle on the Philippines fruit is unlikely to be greater than 4 weeks fruit infected with conidia or ascospores prior to bagging would almost certainly show visual symptoms of freckle at the time of harvest. Visually affected fruit would be removed from the pathway. Although Meredith (1968) noted that infection was reduced if fruit were covered with paper bags, there is, however, some
possibility that fruit could become contaminated during bunch maturation by the movement of airborne ascospores or waterborne conidia through the top of the bag, through holes in the bags, or from below the bag. If contaminated late in the development of fruit (i.e. less than 4-weeks prior to harvest), then conidia or ascospores could have germinated and the fungus penetrated the fruit surface resulting in symptomless infected fruit at harvest. The likelihood of this pathway is greatly reduced by regular application of fungicide and weekly de-leafing of affected plants (Philippines Dept. Agriculture, 2001; 2002a; 2002b). In this situation disease spread on the same bunch would not occur because the fruit would be harvested before such infections have the opportunity to produce pycnidia or perithecia and spores for further fruit infections in the same bunch.

Given that Meredith (1968) reported that little or no disease develops on fruit when the disease is not present on leaves of the same plant, the likelihood of symptomless infection occurring on a bunch was considered to be very low in commercial plantations in the Philippines. The proportion of a bunch that may carry symptomless infected fruit is difficult to estimate but would be expected to be low given the protective bunch cover and absence of secondary disease spread within a bunch.

Contamination with infected leaf trash: leaf may be carried into bunches by rodents or may become entangled with fruit during the growth cycle. The extent to which this occurs under Philippines conditions has not been reported. However, in view of the level of field inspection carried out in the Philippines (Philippines Dept. Agriculture, 2001), and the results of the trash survey carried out by New South Wales quarantine inspectors (Lazar, 2003), the likelihood that a particular bunch contains trash particles was considered very low. As explained above, weekly de-leafing and the regular application of fungicides further reduce the likelihood that perithecia or pycnidia would be found within any particulate trash that might become lodged between banana fingers.

Overall, it was considered unlikely that *G. musae* would be present within a tonne of harvested fruit, and, thus, a rating of low was assigned to Imp2.

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**Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station**

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete. In this period, it is conceivable that fruit could be exposed to waterborne conidia, or airborne ascospores, via holes in the bags covering banana bunches. De-handing in the field, as is the practice when mobile packing stations are used, increases the likelihood of surface contamination of this sort. It is also possible that some trash particles containing viable pycnidia or perithecia could, by the same means, contaminate a bunch.

However, it was explained at the start of this assessment (see: Probability of Importation) that because conidia and ascospores would either be removed from fruit through the cleaning action of washing and brushing, or killed by the solution of chlorine and alum in the de-handing and flotation tanks, surface contamination was not considered a viable risk pathway. The same applies to free trash particles on the surface of fruit.

Since there is not sufficient time during transport to the packing station for spores to germinate and penetrate the fruit surface, a negligible likelihood was assigned to Imp3.

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37 Conidia require 24-72 hours to penetrate the surface of fruit assuming that sufficient moisture is present (Meredith, 1968). The infection period for ascospores of *G. musae* is unknown but as with similar fungi such as *Mycosphaerella fijiensis* (Carlier et al., 2000) the infection period for ascospores of *G. musae* is likely to be of a similar order to that for conidia.
**Imp4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station**

Whilst there is no evidence to suggest that banana fruit are contaminated within a packing station, they are immersed in water in the de-handing and flotation tanks. This would allow surface contamination in the form of waterborne conidia or particulate leaf trash with viable pycnidia or perithecia. Packing stations are open, allowing for ventilation as well as the possibility for fruit or packing material to be exposed to wind-driven rain, dust and pieces of infected particulate trash.

However, it is also important that steps taken on arrival of the fruit at the packing station effectively remove free leaf material, rodent nests and other litter prior to de-handing and the flotation of fruit. Subsequent de-handing, scrubbing and washing, then removes remaining surface particulate leaf trash. The wetting process including at least 25 minutes in the flotation tank also provides the stimulus for release of conidia and ascospores from mature pycnidia or perithecia, respectively. The flotation tank solution carries a concentration of chlorine and alum that is considered biocidal to free conidia and ascospores (Philippine Dept. Agriculture, 2001; see also Method of Import Risk Analysis), meaning that any free spores (and particularly the waterborne conidia) that might adhere to floating fruit will not be viable.\(^{38}\)

On balance, the likelihood that a tonne of fruit would become contaminated with viable *G. musae* during routine procedures undertaken within the packing station was considered negligible.

**Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine inspection procedures within the packing station**

Inspection procedures carried out in the packing station are concerned primarily with quality standards of fruit as regards damage, colour, shape and size. Fruit with visual symptoms of freckle are removed, as are visible pieces of leaf tissue.

However, because fruit are not inspected specifically for particulate leaf trash between fingers, and because symptomless infection is, by definition, not visible to the naked eye, the likelihood that infected fruit will be identified and removed from the pathway was considered negligible.

**Imp6 — the likelihood that the pest will be removed or destroyed as a result of routine procedures undertaken within the packing station**

It was explained above that whilst the cleaning action of washing and brushing will remove free leaf trash from fruit, some particulate leaf trash could still remain trapped between the individual fingers in fruit clusters and not be removed. It was also explained that mature pycnidia and perithecia in leaf trash would be stimulated by the wetting procedures to release their conidia and ascospores. It was further explained above that whilst the solution of chlorine and alum in the de-handing and flotation tanks will be biocidal to free conidia or ascospores, viable but immature pycnidia and perithecia in the skin of fruit or in leaf material would be protected.

Because the risk scenarios of concern in this assessment were symptomless infection of banana fruit and particulate leaf trash, a negligible likelihood was assigned to Imp6.

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\(^{38}\) Chlorine and alum solution is unlikely to penetrate and kill pycnidia or perithecia. Pycnidia and perithecia are protected by a thick wall of melanised fungal tissue — perithecia are, additionally, deeply embedded within the plant tissue (Meredith, 1968; Jones, 2000).
Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Because fruit are not inspected specifically for particulate leaf trash between fingers, and because symptomless infection is, by definition, not visible to the naked eye, the likelihood that infected fruit will be identified by BPI quarantine officers and removed from the pathway was considered negligible.

Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Fungus that has penetrated the fruit or leaf tissue will remain viable under transport conditions. Likewise, whilst cool storage employed in containers or at the wharf might slow internal penetration of skin tissues, or the development and maturation of pycnidia and perithecia, it would not threaten the viability of the organism.

On balance, the likelihood that *G. musae* would remain viable in a tonne of harvested fruit was considered high.

Imp9 — the likelihood that the pest will remain viable during transport to Australia

The arguments for Imp9 are the same as those for Imp8. A high likelihood was assigned to Imp9.

Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

Transport conditions (13°C for 10-14 days) are not conducive to symptom development (Chuang, 1984), so there will be little change in the symptomless condition of fruit after its despatch from the Philippines. By definition, symptomless infection of fruit would not be detected by visual inspection by AQIS officers, regardless of the proportion of the consignment that was inspected. Particulate leaf trash would also be difficult to find.

Overall, the likelihood that infection in a tonne of exported fruit would be detected at AQIS on-arrival inspection was considered negligible.

Conclusion — probability of importation

When these likelihoods were inserted into the simulation model (see Method for Import Risk Analysis), the overall probability of importation for a tonne of bananas was found to be low.

Probability of distribution

The initiating step for distribution of *G. musae* in Australia is the presence of viable pycnidia or perithecia embedded in particulate leaf trash, or symptomless infected imported fruit. The end point is the exposure of leaf tissue of a host plant to conidia or ascospores following their release from pycnidia or perithecia. As discussed, hosts of *G. musae* are restricted to *Musa* spp. (Meredith, 1968).

Dist1 — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers

Once the fungus has penetrated the fruit or leaf tissue, it would remain viable under storage and ripening conditions. The reduced temperatures of storage, ripening of fruit and distribution
(compared to ambient) would slow the internal penetration of fruit peel tissue during the incubation period of this fungus (Chuang, 1984) but not its survival.

The likelihood that the fungus would remain viable at this stage of the importation pathway is therefore **high**.

**Prop1** — *the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially*

It was stated in the *Method for Import Risk Analysis* that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered **low**.

**Prop2** — *the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found*

It was stated in the *Method for Import Risk Analysis* that, if distributed according to the distribution of the Australian population, approximately 32% of imported bananas would be consumed in an area in which household banana plants are found. Thus, for pests such as *G. musae* that are known to be specific to bananas, Prop2 is considered **moderate**.

**Prop3** — *the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found*

It was stated in the *Method for Import Risk Analysis* that, if distributed according to the distribution of the Australian population, approximately 11% of imported bananas would be consumed in an area in which wild (native or feral) bananas are found. Thus, for pests such as *G. musae* that are specific to bananas, Prop3 is considered **low**.

**Dist2** — *the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment*

The peel is discarded in the normal course of the consumption of banana fruit. Spoiled fruit is likely to be discarded whole. Associated leaf trash may become separated from the peel during the retail or home consumption steps in the pathway, but would still enter the environment as waste.

On balance, it was considered **virtually certain** that *G. musae*, if present on the fruit, would be discarded with banana waste.

**Dist3** — *the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment*

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of *G. musae* to move from discarded banana waste to a suitable entry point on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of *G. musae* in or on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which *G. musae* can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.
Persistence. Although studies of the persistence and infectivity of *G. musae* under field conditions are limited (Meredith, 1968; Chuang, 1984), these are likely to be linked to environmental conditions at the site of waste disposal — in particular, to temperature and humidity, and the time taken for the fungal nutrient source (the fruit peel or leaf trash) to decay. For example, it is known that when the supporting plant material becomes wet, conidia are released from pycnidia over an extended period (Meredith, 1968). Ascospores, on the other hand, are likely to be released only over a comparatively short period (based on studies with *Mycosphaerella fijiensis*, a species closely related to *Guignardia* spp.). Nevertheless, once both spore types are exposed to water, they would likely commence germination within a few hours.

Distance. The following points are relevant to the distance between discarded fruit waste and a susceptible commercially grown banana plant:

- Much of the leaf trash associated with imported fruit would be discarded with packaging materials after the carton is opened at the retail outlet. This waste material is largely disposed through municipal systems although some cartons may be re-used prior to disposal. Other leaf trash will be carried to consumer households, where it will become separated from the fruit cluster as the individual fingers are broken off prior to consumption and discarded with garbage or into household compost areas not in close proximity to commercial banana plants.

- The vast majority of bananas are consumed by individuals (cf. food service industries or food processors). Consumption by individuals is likely to be concentrated: (a) beyond areas of Australia in which bananas are commercially grown; and (b) in the major population centres. There are approximately 2000 commercial banana farms, generally at some distance from major centres of population. Where bananas are brought onto commercial farms, most banana waste will be disposed near farm houses or near worker facilities near packing sheds where bananas are consumed, rather than in the plantation.

- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities. Bulk waste disposal will place organisms associated with banana waste a substantial distance from commercial banana plants. Refuse disposal facilities frequently bury waste. Hence, neither water-dispersal of conidia nor windborne dispersal of ascospores is likely to occur at these facilities.

- The balance of banana waste will be diverted to home composting or discarded randomly in the form of peel and uneaten flesh, or whole spoiled fruit. Home composting will place the organism at some distance from commercial banana plants. In addition, composting will lead to rapid decay of the peel, which lessens the time available for conidia or ascospores to find commercial banana plant tissue.

- Banana waste is considered ‘organic’ hence random waste disposal (peel or whole fruit) is common along roadsides. Banana plantations are often close to roadways and are generally unfenced.

Dispersal mechanisms. Conidia are waterborne and, whilst there are no data on distance of dispersal, waterborne inoculum generally moves over very short distances. In support of this, Meredith (1968), reports that the most severe infection occurs when infected host material is touching another leaf or fruit surface. Ascospores are released directly into the air, and like ascospores of *M. fijiensis*, are expected to be carried one to several kilometres before being killed by ultraviolet light or desiccation (Stover, 1980; Parnell et al., 1998). Because commercial banana plantations are in areas of high rainfall, and are subject to seasonal cyclonic conditions where rain is driven by high winds, there is considerable opportunity for dispersal of conidia and ascospores.

Exposure of a susceptible host. The threshold number of conidia or ascospores of *G. musae* required to infect bananas and cause disease symptoms is unknown, however, like most fungi, it is
expected to be more than one and likely to be very many.

After considering these issues, it was concluded that the likelihood that commercially cultivated bananas would be exposed to *G. musae* discarded with banana waste from a tonne of fruit would be very low.

**Dist4** — *the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment*

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a *G. musae* to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household banana plant. The persistence of the *G. musae* inoculum, the conditions needed for infection of susceptible host plants and its means of dispersal have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the physical distance between discarded waste and a susceptible household banana plant, and the percentage of households that grow banana plants.

It was explained above that the bulk of consumer waste is managed through refuse disposal facilities, and that these present very limited opportunity for dispersal of conidia or ascospores. Residual household banana waste is either composted or discarded randomly. Household compost may place fruit peel with pycnidia or perithecia in close proximity to a susceptible household banana plant. Most random disposal of peel is likely to take place outside the garden environment on roadsides, playgrounds etc, and at some distance from susceptible household plants.

A survey of Australian households (see: Appendix 2) found that banana plants are grown in households from Sydney to north of Cairns. However the incidence of banana plants in households varies considerably. For instance, no bananas are grown in Hobart and very few in Melbourne or Adelaide and less than 1% in Perth. It is estimated that the incidence is about 1-5% in the Sydney metropolitan area, 10-25% in northern New South Wales, up to 25% in southeast Queensland, about 10% around Cairns, and about 20% around Mosman and Innisfail. The incidence of household bananas around Tully has been limited to scheduled black Sigatoka resistant varieties as a result of the recent black Sigatoka eradication campaign. The lowest incidence of household banana plants is in the areas of highest population.

From these observations, and from earlier discussions regarding the persistence of *G. musae*, its dispersal mechanisms, and the conditions needed for successful exposure of a susceptible host (see Dist3), the likelihood that a non-commercial (household) banana plant would be exposed to *G. musae* was rated as very low.

**Dist5** — *the likelihood that susceptible wild (native or feral) plants or other susceptible cultivated plants (other than bananas) would be exposed to the pest associated with banana waste (fruit and peel), or that had otherwise entered the environment*

**Dist5** is again a complex variable, similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) *Musa* species. In banana growing parts of Australia, feral banana plants occur as frequently as household banana plants, whereas Australia’s three native species of bananas, *M. acuminata* subsp. *banksii*, *M. jackeyi* and *M. fitzalanii*, are all restricted to wet tropical areas of north Queensland. In Queensland the cultivation of native and seeded bananas is prohibited except for registered botanical gardens and official controls are exercised to minimise the incidence of pests and diseases in feral bananas (*Plant Protection Regulation 2002*).
Technical issues associated with the persistence of *G. musae* inoculum, the conditions needed for infection of susceptible host plants, and its means of dispersal, need not be reiterated. Specific to Dist5 is the physical distance that may lie between discarded waste and a susceptible wild plant. Exposure of native banana species would most likely result from random disposal of fruit peel along roadsides, walking tracks, picnic or camping grounds in the tropics. However, because the definition of a ‘wild’ plant includes amenity plants, and those that grow beside roadways and urban streets, the physical distance between discarded waste and a plant is likely to approximate Dist4 (see above).

From these observations, and from earlier discussions regarding the persistence of *G. musae*, its dispersal mechanisms, and the conditions needed for successful exposure of a susceptible host (see Dist3), the likelihood that a susceptible wild (native or feral) plant would be exposed to *G. musae* was rated as very low.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) household banana plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to *G. musae* that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Very low
- Partial probability of distribution for susceptible household plants = Very low
- Partial probability of distribution for susceptible wild/commercial plants = Very low

**Probability of establishment**

The initiation point for establishment of *G. musae* from imported fruit in Australia is the settling of conidia or ascospores on susceptible host material and the end-point is the development of freckle disease symptoms on the exposed plant.

To establish on exposed host tissue, conidia or ascospores require a wet environment to germinate, produce a germ tube and appressorium, and then breach the host epidermis (Meredith, 1968). The fungus must then develop sufficiently for a secondary crop of spores to be produced before the host tissue decays.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

**Commercially cultivated banana plants**

Freckle is a disease of tropical and subtropical areas. Given the successful establishment of freckle in most other banana producing countries, it is clear that the availability, quantity and distribution
of banana hosts, and the suitability of the environment, would favour its establishment in Australia. In this situation, adaptation would not be necessary. In order to successfully infect an exposed plant, however, suitable moisture conditions would need to occur for the 72 hours while the fungus germinates and produces an appressorium (Meredith, 1968).

In regard to the final factor, ‘cultural practices and control measures’, it is likely that commercial fungicide spray programs would restrict the development of germ tubes on banana plant surfaces and therefore restrict the establishment potential. In tropical areas of Australia, banana plantations are sprayed on a year-round basis so it is less likely that freckle would establish in these areas. In sub-tropical areas however, fungicidal sprays are only applied in the December to May period and not in the June to November period. The likelihood of establishment is therefore greater in these areas.

On this basis, it was considered unlikely that *G. musae* would establish within exposed commercial banana plants. The establishment potential is therefore considered low.

**Susceptible household plants**

Of particular importance to the establishment of freckle amongst exposed household plants is the availability, quantity and distribution of susceptible hosts. Here it is clear that in contrast to the situation on a commercial plantation, susceptible plants would be relatively few and relatively sparsely distributed. This might be offset by the observation that, unlike commercial banana growers, households are relatively unlikely to spray plants with fungicides.

Overall the likelihood that *G. musae* would establish within exposed household banana plants was considered to be moderate.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The establishment potential for freckle on wild (native or feral) plants would be governed by the same factors as for household plants, and is again considered moderate.

**Probability of spread**

The probability of spread examines factors relevant to the movement of *G. musae* from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. The initiation point for spread of freckle is the production of the first crop of conidia or ascospores of *G. musae* in an infected host plant in Australia and the end-point is the distribution of that inoculum to other host plants. Host plants are perennial herbs and freckle does not kill infected plants, so spread may occur at an indefinite time after establishment has occurred.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.
Commercially cultivated banana plants

The occurrence of freckle in most banana-producing countries worldwide, and similarities between the natural and built environment in banana plantations in the Philippines and those in Australia, would suggest that conditions in Australia are suitable for spread. Other than water or wind, the pest does not require particular vectors for spread and does not have any natural enemies in Australia that would retard spread. As discussed above (see: Probability of distribution) it is possible that the consumption of banana fruit and the disposal of waste would lead to the dissemination of infected tissue and the spread of the organism.

On balance, it was considered very likely that *G. musae* would spread from a point of establishment within exposed commercial banana plants. Spread potential for commercial bananas was therefore rated *high*.

Susceptible household plants

Biological and environment factors relevant to the spread of freckle from a point of establishment were outlined briefly above. The principal difference between spread from household plants and spread from commercial plants is the immediate availability of susceptible hosts — the maximum incidence of household growing bananas in areas where bananas are found is 25%. This is particularly the case for freckle for which the main means of dispersal is conidia, which are released on exposure to water from their protective gel and desiccate unless placed on a susceptible fruit surface. Additionally, waterborne conidia do not disperse as readily over long distances as, for example, airborne ascospores. It might, however, be the case that the disease would be spread through the movement of infected planting materials, or, because Australian households would not be vigilant to minor blemishes such as small freckles, through the movement of fruit.

On balance, the likelihood that *G. musae* would spread from a point of establishment within household banana plants was considered *moderate*.

Susceptible wild plants, or susceptible cultivated plants other than bananas

The potential for spread of freckle from a point of establishment in wild plants will be dictated by similar considerations as discussed above for household plants. In some cases, there may be a higher density of wild plants but, to offset this, planting materials or fruit from wild plants will not be moved in the way that household planting materials and fruit might be.

On balance, the likelihood that the *G. musae* would spread from a point of establishment in susceptible wild plants was again considered *moderate*.

Consequences

The consequences to the Australian community of the entry, establishment or spread of freckle were assessed by considering its potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of freckle was assessed on the basis of its potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of freckle could be estimated by considering the scale of likely economic impact. For others, its effect could only be assessed in more subjective terms, such as the loss of social amenity.
The direct impact of freckle

Animal or plant life, or health

This criterion describes the production losses associated with freckle in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of freckle were considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

Freckle is a disease of *Musa* species only, and thus there is no direct impact on other plant or animal species. On Cavendish bananas, freckle is not considered a disease that leads to the death of plants. Rather, freckle symptoms reduce the photosynthetic tissues of the banana leaves and disfigure fruit. Freckle is generally restricted to the older leaves and becomes severe on fruit when young fruit are in close contact with severely diseased leaves (Meredith, 1968).

In some tropical areas overseas, freckle is listed as a minor disease while in others it is reported as following black Sigatoka in importance. Freckle is a major problem in subtropical Taiwan (Chuang, 1984). It is expected that in Australia, the severity of freckle will be reduced by existing control programs for the control of yellow Sigatoka disease caused by *Mycosphaerella musicola*, which are known to also assist in the control of miscellaneous fruit diseases such as that caused by *Deightoniella torulosa* (Jones et al., 2000).

The severity of freckle infection on native Australian *Musa* spp. is unknown. *Musa acuminata* subsp. *banksii* is reported to be susceptible to freckle (Jones, 2000) but the susceptibilities of the other two native bananas in Australia (*M. jackeyi* and *M. fitzalani*) have not been assessed. In any event, freckle does not kill infected plants. Rather, as explained above, *G. musae* reduces the photosynthetic area of the plant generally on the older leaves.

The main impact of freckle is on the quality (and quantity) of the fruit produced in terms of surface blemishing that is not tolerated by many consumers. This will result in downgrading of fruit for discerning markets and the impact for producers is that a considerable quantity of fruit will be discarded at the packing station.

On this basis the likely impact of freckle in terms of *plant production losses* was considered to be minor at the district level. Overall, this gave a rating of B for this criterion.

Human life or health

There are no known impacts of freckle on human life or health, and the rating assigned to this criterion was therefore A.

Any other aspects of the environment not covered above

This criterion addresses the possible impact of pests on other aspects of the natural or built environment, such as the physical or biological environment. There are no known impacts of freckle in these directions, and the rating assigned to this criterion was therefore A.
The indirect impact of freckle

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

An eradication program would be considered in Australia if freckle was identified on Cavendish bananas. Such a program was conducted in 2001 following an outbreak of freckle in a remote settlement in Western Australia. Eradication programs can be very expensive if an outbreak is not detected early, and involve cooperation from all levels of government and industry but the cost could amount to several million dollars over 2-3 years. This cost could be shared between the Commonwealth Government, the Governments of banana-producing States or Territories, and the banana industry.

Additional requirements for the control of freckle in Australia are unknown due to conflicting reports from overseas and the likelihood, as discussed under direct impacts above, that existing disease control programs for yellow Sigatoka disease will also control freckle. In the Philippines, fungicide control programs for black Sigatoka also control freckle. The Philippines presently applies up to 45 sprays per year for black Sigatoka, compared to the 20-22 sprays per year presently used in north Queensland for yellow Sigatoka (caused by a similar fungus *M. musicola*). In subtropical areas of Australia, only 4-6 sprays per year are presently applied for yellow Sigatoka. It is expected however that freckle could be controlled by fungicide sprays and de-leafing programs similar to those already used for yellow Sigatoka in Australia, although some fungicides may have to be applied more frequently.

Overall, it was considered that the impact of new or modified control programs, including any eradication program, would be minor at the district level. The adverse impacts of an eradication program would be short term. This resulted in a rating of B for this criterion.

Domestic trade or industry effects

As previously noted, freckle is primarily a disease affecting the presentation quality of fruit. Australian consumers have a very low tolerance for blemished fruit, and, hence, fruit expressing freckle symptoms would be downgraded or rejected in the Australian marketplace. It is possible that embargoes could be installed on fruit, as occurred after the discovery of black Sigatoka in the Tully district in 2001, although *G. musae* is not currently under any government regulatory control. This embargo disrupted for a short period the orderly marketing system across Australian markets, until the disease was brought under control.

Overall, the impact of freckle on domestic trade and industry was considered likely to be minor at the State or Territory level. This resulted in a rating of C for this criterion.

International trade effects

At present, Australia exports negligible quantities of bananas that go to a specialty market (see: Import Proposal for Philippines Bananas). It is unlikely that a future trading partner would regard freckle as a quarantine issue. For this reason, the rating assigned to this criterion was A.

Indirect effects on the environment

One of the considerations within this criterion was the possible indirect impact of freckle on rural and regional economic viability. In assessing the indirect impact at each of the four levels, it was relevant to consider the viability of rural communities, and the indirect impact of a threat to rural
viability, and to biodiversity, endangered species, the integrity of ecosystems, reduced tourism and such on all levels of the Australian community.

It is expected that fungicide sprays could control freckle and de-leafing programs similar to that already used for yellow Sigatoka in Australia. If this is the case, there are unlikely to be any additional indirect effects on the environment.

After consideration of these issues, the indirect impact of freckle on the environment was considered likely to be minor at the local level. The indirect impact on the environment was therefore rated as A.

Conclusions - the overall impact of freckle

The direct and indirect impacts of freckle were combined using the decision rules discussed in the *Method for Import Risk Analysis*. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of freckle are likely to be low.

Unrestricted risk estimate

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with freckle.

The results of these steps are summarised below.

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial probabilities of distribution</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= Very low</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= Very low</td>
</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= Very low</td>
</tr>
<tr>
<td>Partial probabilities of establishment</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= Low</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Partial probabilities of spread</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= High</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Probability of entry, establishment or spread (1 tonne)</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>Annual probability of entry, establishment or spread</td>
<td>= High</td>
</tr>
<tr>
<td>Consequences</td>
<td>= Low</td>
</tr>
</tbody>
</table>
Unrestricted risk = Low

Because the unrestricted risk exceeds Australia’s ALOP (very low) risk management would be required for freckle.

Black Sigatoka

Black Sigatoka is a leaf spot disease that is caused by the fungus \textit{Mycosphaerella fijiensis} Morelet. It affects a wide range of \textit{Musa} spp. including dessert bananas and plantains but not abacá or enset (Carlier \textit{et al.}, 2000). The spots or lesions are expressed as black flecks and streaks on the leaves and are the visual expression of the disease. The first symptoms are yellow spots (Stage 1), which progress rapidly to brown flecks and streaks (Stage 2) and through four more stages until the leaf is necrotic at Stage 6 (Carlier \textit{et al.}, 2000). The destruction of banana leaves depresses yield and leads to premature ripening of fruit.

The fungus reproduces both asexually and sexually in diseased tissue from Stage 2 onwards, resulting in the production of two types of infective structures commonly referred to as ‘spores’.

\textit{Asexual} spores are known as conidia. They are produced on special fruiting structures known as conidiophores, which appear at Stage 2 of symptom development. Conidiophores arise singly from a lesion on the lower surface of leaves; few arise from upper leaf surfaces. Conidia are formed singly at the apex of the conidiophore with up to four mature conidia being attached to a single conidiophore at a given time. Conidia are dislodged from conidiophores by water and wind (Stover, 1980; Burt \textit{et al.}, 1997). They survive for 60 days or more on dried leaf surfaces, for up to 30 days on cardboard and plastic surfaces and for up to 18 days on fruit surfaces (Hanada \textit{et al.}, 2002). Conidia germinate in free water and under conditions of high humidity, and at a rate determined by temperature within the range of 11-38°C (optimally at 27°C) (Jacome \textit{et al.}, 1991; Jacome and Schuh, 1993; Carlier \textit{et al.}, 2000). It is thought that germinated conidia and their germ tubes become bound to the substrate, as is the case for some other fungi (Nicholson and Epstein, 1991), and therefore become ineffective agents of spreading black Sigatoka when attached to non-host substrates.

\textit{Sexual} spores are known as ascospores, and are produced in reproductive structures, or ‘fruiting bodies’, called perithecia. Each perithecium has numerous (four or more) asci and each of these contains eight ascospores. Perithecia are globose in shape and are embedded within leaf tissue. In Cavendish bananas, perithecia are abundant in the necrotic areas of black Sigatoka lesions (at Stages 5 and 6 of symptom development, as described in Carlier \textit{et al.}, 2000) between five to seven weeks after initial infection, depending on the severity of infection, intensity of rainfall and prevailing temperature. The numbers of perithecia in leaves not sprayed with fungicides range from 1 to 8 per square millimetre of necrotic tissue (Blanco, 1987; Burt \textit{et al.}, 1999), depending on the overall degree of leaf necrosis and seasonal conditions.

At maturity, a small pore opens at the top of the perithecium at the surface of the plant tissue to release the ascospores into the air. Perithecia release ascospores after the necrotic leaf tissue is thoroughly wetted (Meredith, 1970; Fouré and Moreau, 1992; Gauhl, 1994). Each perithecium produces only one crop of ascospores (Stover, 1965) although the release of spores from a population of perithecia in necrotic tissue may continue with repeated wetting and drying as individual perithecia reach maturity (Gauhl, 1994; Burt \textit{et al.}, 1999, Carlier \textit{et al.}, 2000). Ascospores can be retained in dry perithecia for 20 weeks or more but for only a few (3-6) weeks in tissue that is repeatedly wetted and dried (Sebasigari, 1990; Gauhl, 1994; Carlier \textit{et al.}, 2000).
Not all perithecia release ascospores into the air; possibly because some are infertile or because many ascospores simply do not escape the boundary layer on the leaf surface (Burt et al., 1999). Once released, ascospores germinate in free water and, under high humidity conditions, at a rate determined by temperature within the range of 11-38°C (optimally at 27°C) (Carlier et al., 2000). As with conidia, it is thought that germinated ascospores and their germ tubes become bound to the substrate, as is the case for some other fungi (Nicholson and Epstein, 1991), and therefore become ineffective agents of spreading black Sigatoka on non-host substrates.

On Cavendish bananas, *M. fijiensis* attacks tissues on the laminae and, to a minor extent, the mid-rib. It is not known to infect flowers, stems (corm or stalk), mature leaf bases (pseudostem) or, very importantly, fruit (Carlier et al., 2000; Kumar et al., 2002). On plantains, however, *M. fijiensis* has been shown to infect fruit to a limited extent causing fleck lesions that bear conidia (Cedeno et al., 2000).

### Probability of importation

The risk pathway of particular relevance to black Sigatoka for Cavendish banana fruit is that associated with viable perithecia present in leaf tissue trapped between the individual fingers in fruit clusters. The amount of leaf trash associated with marketed fruit is very small (see Method for Import Risk Analysis), and, in addition, it is only that with Stage 5 or 6 black Sigatoka lesions that will bear perithecia (Burt et al., 1999; Carlier et al., 2000). When lesions are present, however, there may be in the order of 1 to 8 perithecia in each (Blanco, 1987; Burt et al., 1999).

A second pathway that was considered was the direct contamination of fruit or packaging surfaces with ascospores or conidia. It is important, however, that free spores will germinate on exposure to water and high humidity (Carlier et al., 2000), and that germinated spores cannot invade fruit surfaces. It is also important that free spores will either be removed from fruit through the cleaning action of washing and brushing, or be killed by the solution of chlorine and alum in the de-handing and flotation tanks.

In support of this:

- Ascospores, under laboratory conditions, did not germinate when subjected to 1ppm available chlorine plus 200ppm alum for 10 minutes, which corresponds to a CT_{chlorine} of 10 ppm-minutes (Philippines Dept. Agriculture, 2001). This is 1/50th of the 500ppm-minutes CT_{chlorine} to which Philippines bananas are subjected under field conditions in permanent packing stations.

- Similarly, while data were not provided for efficacy against *M. fijiensis* conidia, the Philippines Department of Agriculture data showed that the same CT_{chlorine}10ppm-minutes treatment was also lethal to conidia of *G. musae*, a species closely related to *Mycosphaerella* spp.

- Although another study reported that about 13% of *M. fijiensis* conidia remained viable after 30 hours exposure to 100ppm chlorine product (Gasparotto et al., 2000), this report does not indicate the concentration of available chlorine, nor how the chlorine concentration was maintained for such a long time, nor provide any details of the pH of the solution, so the significance of this study must be questioned.

- Even if fruit are processed in a mobile packing facility, where bunches are de-handed in the field and the exposure time is shortened, it is expected that free conidia on the surface of fruit would be exposed to a CT_{chlorine} many times the lethal dose.

- It is well understood that the presence of organic impurities including banana sap will reduce
the efficacy of the packing station treatment hence, as noted in the discussion on chlorine in the Method for Import Risk Analysis, the emphasis is on maintenance of the chlorine treatment to maintain its biocidal effect. Additionally, the presence of alum in the wash water is likely to aid the biocidal capacity of the chlorine treatment.

On the basis of these observations, free spores (ascospores or conidia) were not considered a risk pathway for black Sigatoka.

**Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced**

Black Sigatoka occurs on Cavendish and local banana cultivars throughout the province of Mindanao from which export bananas are to be sourced (Anonymous 1994a; Jones and Daniells, 1988; Peasley, 2001a). As would be expected, the prevalence of black Sigatoka-affected plantations within Mindanao varies with seasonal changes, with changes in the infection status of neighbouring plantations and with other variables relevant to the disease epidemiology.

Given this, the likelihood that the fungus would be present on the plantation from which a tonne will be sourced was considered high.

**Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest**

Because the pathway of concern is particulate leaf trash carrying viable perithecia, the likelihood of infestation will be a combination of: (a) the likelihood of trash being present in a tonne of harvested fruit; and (b) of the likelihood of that trash being infested with viable perithecia.

**Contamination with leaf trash:** leaf may be carried into bunches by rodents or may become entangled with fruit during the growth cycle. The extent to which this occurs under Philippine conditions has not been reported. However, in view of the level of field inspection carried out in the Philippines (Philippines Dept. Agriculture, 2001), and the results of the trash survey carried out by New South Wales quarantine inspectors (Lazar, 2003), it was considered very unlikely that any particular bunch would contain trash particles.

**The presence of perithecia:** perithecia may survive in leaf trash for more than 20 weeks if kept in a dry condition, so that particulate leaf trash could carry perithecia that have not released ascospores (Stover, 1980; Gauhl, 1994; Peterson et al., 1998). However, if associated with harvested banana fruit, leaf trash is unlikely to be fresh or to be dry. Because of this, perithecia that might be present are likely to have released their ascospores. Ascospores might subsequently have germinated on the surface of the fruit, but because M. fijensis does not infect fruit, these ascospores would have died. It is known that very few viable ascospores can be recovered from leaf trash that is repeatedly wetted and dried for a few weeks (Sebasigari, 1990; Gauhl, 1994). Given the hot and wet tropical conditions in the export areas of Mindanao, the likelihood that leaf trash will bear perithecia that have not released ascospores at the time of harvest was considered extremely low. Perithecia that had not released ascospores would either be immature or dead.

It is additionally important that banana plantations in Mindanao are subject to weekly inspections to estimate the incidence of black Sigatoka, and to carry out de-leafing operations. Leaves with early lesions (Stage 3 or less) are identified and removed, and placed on the plantation floor (Philippines Dept. Agriculture, 2002a; Philippines Scientific Delegation, 2002), so relatively few leaves with Stage 5 or 6 lesions are seen. Spraying with fungicide, on the basis of weekly surveys, further reduces the number of Stage 5 or 6 lesions. Overall, the prevalence of leaves with Stage 5 or 6 lesions in which perithecia are abundant was considered extremely low.
In view of: (a) the very low likelihood that leaf trash would be present in a tonne of harvested fruit; and (b) the extremely low likelihood that leaf trash would be derived from leaf tissue bearing Stage 5 or 6 lesions with viable perithecia, Imp2 was considered extremely low.

**Imp3** — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete.

During this period, it is possible for fruit to be exposed via holes in bunch covers to either windborne or waterborne spores. Where mobile packing stations are used, it is also possible that fruit may become exposed through the process of in field de-handing. The likelihood that particulate trash with viable perithecia being blown into the bagged fruit through holes is more remote although de-handing in the field would increase the likelihood of harvested fruit being infested with particulate trash containing viable perithecia. However, any level of infestation by inoculum would remain as surface contamination because germination of ascospores and conidia requires at least 2-3 hours (Carlier et al., 2000). As previously discussed surface contamination of spores is not considered a viable pathway.

Overall, the likelihood that fruit would be infested during transport to the packing station was considered negligible.

**Imp4** — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

Whilst there is no evidence to suggest that banana fruit are contaminated within a packing station, they are immersed in water in the de-handing and flotation tanks. This would allow surface contamination in the form of particulate leaf trash, which might carry viable perithecia, or conidia or ascospores. Packing stations are also open, allowing for the possibility for fruit or packing material to be exposed to wind driven rain, dust and pieces of particulate trash containing perithecia.

Accepting this, steps taken on arrival of the fruit at the packing station effectively remove leaf material, rodent nests and other litter. The subsequent de-handing, scrubbing and washing by immersion in the de-handing and flotation tanks then removes most of the remaining particulate leaf trash. The wetting process, which includes at least 25 minutes in the flotation tank, provides the stimulus for release of ascospores from mature perithecia on leaf trash that may still be floating in the tanks or caught between the banana fingers (Meredith, 1970; Fouré and Moreau, 1992; Gauhl, 1994). Once ascospores have been released, the perithecia die. Finally, chlorine in the water provides a CT_{chlorine} of 500 ppm-minutes, which is regarded as an effective biocidal treatment for both ascospores and conidia (Philippines Dept. Agriculture, 2001)^{39}. 

In view of these considerations, the likelihood that the tonne of fruit would become infested with particulate trash embedded with viable perithecia within the packing station was considered negligible.

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^{39} Chlorine and alum solution is unlikely to penetrate and kill perithecia, which are protected by a thick wall of melanised fungal tissue, and deeply embedded within the plant tissue (Meredith, 1968; Jones, 2000).
Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine inspection procedures within the packing station

Although inspection procedures are concerned primarily with fruit not meeting quality standards for damage, colour, shape and size, large visible pieces of leaf trash would be identified and removed. Similarly, large visible pieces of trash in packing materials would be removed. However, because the risk pathway for black Sigatoka was considered particulate trash in spaces between fingers, the likelihood of detection and removal was rated as negligible.

Imp6 — the likelihood that the pest will be removed or destroyed as a result of routine procedures undertaken within the packing station

It was explained above that whilst the cleaning action of washing and brushing will remove free leaf trash from fruit, some particulate leaf trash could still remain trapped between the individual fingers in fruit clusters and not be removed. It was also explained that mature perithecia that are embedded in leaf trash would be stimulated by the wetting procedures to release their ascospores. It was further explained above that whilst the solution of chlorine and alum in the de-handing and flotation tanks will be biocidal to free ascospores, viable but immature perithecia in leaf material would be protected.

Taking all these issues into account, the likelihood that *M. fijiensis* embedded in particulate trash associated with a tonne of fruit would be removed or destroyed as a result of routine procedures undertaken within the packing station was considered moderate.

Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Unless specifically charged to inspect for particulate trash trapped between fruit fingers, the likelihood that inspection by BPI quarantine officers would detect infested fruit was considered negligible.

Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Black Sigatoka perithecia are known to remain viable for 20 weeks in dried leaf trash but for much shorter periods under wet and humid conditions (Gauhl, 1994; Kumar *et al.*, 2002). As export fruit are packed wet, any mature perithecia embedded in particulate leaf trash that did not release ascospores as a result of the water stimulus in the packing station operations may be expected to release ascospores during transport and storage prior to export as a result of continuing wetness and humidity. However, immature perithecia would not develop further because of the cool storage temperatures.

On balance, the likelihood that *M. fijiensis* would remain viable in a tonne of harvested fruit under the given transport conditions was considered high.

Imp9 — the likelihood that the pest will remain viable during transport to Australia

Black Sigatoka perithecia are known to remain viable for 20 weeks in dried leaf trash (Gauhl, 1994; Kumar *et al.*, 2002). However, the high prevailing humidity and possibly free water surrounding banana fruit in polythene lined cartons would reduce the viability time of perithecia during the 7-10 day transport period to Australia. Some mature perithecia will also release
ascospores as a result of the wetness (Meredith, 1970; Fouré and Moreau, 1992; Gauhl, 1994). Immature perithecia would develop only slowly because of the cool storage temperatures.

On balance, the likelihood that the fungus would remain viable at this stage under the given transport conditions was considered moderate.

**Imp10** — *the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia*

Trash particles between banana fruit fingers will not become more visible during transport to Australia and, thus, the likelihood of detection was, as stated for Imp7 above, considered negligible.

**Conclusion — probability of importation**

When these likelihoods were inserted into the simulation model (see *Method for Import Risk Analysis*), the overall probability of importation for a tonne of bananas was found to be extremely low.

**Probability of distribution**

The initiating step for distribution of *M. fijiensis* in Australia is the presence of viable perithecia embedded in particulate leaf trash associated with imported banana fruit. The end point is the exposure of leaf tissue of host plants to ascospores. As discussed, hosts of *M. fijiensis* are restricted to *Musa* spp. but not abacá or enset (Carlier et al., 2000).

**Dist1** — *the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers*

Perithecia embedded in leaf trash will not be adversely affected by the storage and ripening conditions. However, many will slowly mature, and, as a result of continuing high humidity within cartons, will release ascospores and subsequently die. Released ascospores will also germinate and die.

Overall, the likelihood that *M. fijiensis* would survive storage and ripening and distribution conditions was considered moderate.

**Prop1** — *the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially*

It was stated in the *Method for Import Risk Analysis* that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.

**Prop2** — *the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found*

It was stated in the *Method for Import Risk Analysis* that, if distributed according to the distribution of the Australian population, approximately 32% of imported bananas would be consumed in an area in which household banana plants are found. Thus, for pests such as *M. fijiensis* that are known to be specific to bananas, Prop2 is considered moderate.
**Prop3** — *the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found*

It was stated in the *Method for Import Risk Analysis* that, if distributed according to the distribution of the Australian population, approximately 11% of imported bananas would be consumed in an area in which wild (native or feral) bananas are found. Thus, for pests such as *M. fijiensis* that are specific to bananas, Prop3 is considered **low**.

**Dist2** — *the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment*

The peel is discarded in the normal course of the consumption of banana fruit. Spoiled fruit is likely to be discarded whole. Associated leaf trash would become separated from the peel during the retail or home consumption steps in the pathway, but would still enter the environment as waste.

On balance, it was considered **virtually certain** that *M. fijiensis*, if present on the fruit, would be discarded with banana waste.

**Dist3** — *the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment*

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of *M. fijiensis* to move from discarded banana waste to a suitable entry point on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of *M. fijiensis* in or on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which *M. fijiensis* can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

**Persistence.** While *M. fijiensis* may be grown on specialised culture media (Carlier *et al.*, 2000), it only infects banana leaves. It would not develop saprophytically or multiply on discarded leaf trash or peel. Survival of *M. fijiensis* inoculum therefore depends on the environmental conditions found at the site where the particulate leaf trash was disposed and the rate of decay of the particulate leaf trash.

Although perithecia are known to survive 20 weeks or more under dry conditions, hot wet conditions as found in compost would lead to rapid decay of particulate leaf trash and to rapid dispersal of ascospores from maturing perithecia. A large proportion of these ascospores would land on non-host surfaces and germinate ineffectively. A small proportion might land on banana leaves where infection could occur.

**Physical distance.** The following points are relevant to the distance between discarded fruit waste and a susceptible commercially grown banana plant:

- Much of the leaf trash in which perithecia are embedded would be discarded with packaging materials after the carton is opened at the retail outlet and the fruit clusters are handled for the first time since packing. This waste material is largely disposed through municipal systems although some cartons may be re-used prior to disposal. Other leaf trash will be carried to consumer households, where it will become separated from the fruit cluster as the individual fingers are broken off prior to consumption and be discarded with garbage or into household...
compost areas not in close proximity to commercial banana plants.

- The vast majority of bananas are consumed by individuals (cf. food service industries or food processors). Consumption by individuals is likely to be concentrated: (a) beyond localities of Australia in which bananas are commercially grown; and (b) in the major population centres. There are approximately 2000 commercial banana farms, generally at some distance from major centres of population. Where bananas are brought onto commercial farms, most banana waste will be disposed near farm houses or near worker facilities near packing sheds where bananas are consumed, rather than in the plantation.

- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities. Bulk waste disposal will place organisms associated with banana waste a substantial distance from commercial banana plants. Refuse disposal facilities frequently bury waste. Hence, wind-borne dispersal of ascospores is unlikely to occur at these facilities.

- The balance of banana waste will be diverted to home composting, or discarded randomly. Home composting will place the organism at some distance from commercial banana plants. In addition, composting will lead to rapid decay of the leaf trash, which lessens the time available for conidia or ascospores to be spread to commercial banana plant tissue.

- Banana waste is considered ‘organic’ hence random waste disposal (peel or whole fruit) is common along roadsides. Banana plantations are often close to roadways, and are generally unfenced.

**Dispersal mechanisms.** To move from discarded leaf trash to commercially cultivated bananas, ascospores must be released from perithecia, transcend boundary layers and other obstacles near the source (Burt et al., 1999), and be carried in the air to a banana leaf within one to several kilometres before they are killed by ultraviolet light or desiccation (Stover, 1980; Parnell et al., 1998).

**Exposure of a susceptible host.** The threshold number of ascospores of *M. fijiensis* required to infect bananas and cause disease symptoms is unknown, however, like most fungi, it is expected to be more than one and likely to be very many. Ascospores must settle directly on susceptible host tissue, as there is no opportunity for secondary spore production by ascospores if they land on non-host material. If ascospores are not on suitable banana leaf tissue at the time of germination they will fail to develop.

After considering these issues, it was concluded that the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste derived from a tonne of fruit, is extremely low.

**Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment**

As was the case for Dist3 (see above), Dist4 is a complex variable that encompasses biological and epidemiological factors that may contribute to the ability of *M. fijiensis* to move from discarded banana waste to a suitable point of entry on a susceptible — in this case, a household or garden plant. The persistence of the *M. fijiensis* inoculum, the conditions needed for infection of a susceptible host, and its means of dispersal, have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the physical distance between discarded waste and a susceptible household banana plant, and the percentage of households that grow banana plants.
It was explained above that the bulk of consumer waste is managed through refuse disposal facilities, and that these present very limited opportunity for the dispersal of *M. fijiensis*. Much of the leaf trash would be discarded with packaging material at the retail outlets, and thence through municipal refuse disposal systems. A proportion would, however, be discarded randomly in close proximity to the residence. Household compost may place leaf trash with embedded viable perithecia in close proximity to a susceptible household banana plant. Most random disposal of peel is likely to take place outside the garden environment on roadsides, playgrounds etc, and at some distance from susceptible household plants.

A survey of Australian households (see: Appendix 2) found that banana plants are grown in households from Sydney to north of Cairns. However the incidence of banana plants in households varies considerably. For instance, no bananas are grown in Hobart and very few in Melbourne or Adelaide and less than 1% in Perth. It is estimated that the incidence is about 1-5% in the Sydney metropolitan area, 10-25% in northern New South Wales, up to 25% in southeast Queensland, about 10% around Cairns, and about 20% around Mosman and Innisfail. The incidence of household bananas around Tully has been limited to scheduled black Sigatoka resistant varieties as a result of the recent black Sigatoka eradication campaign. The lowest incidence of household banana plants is in the areas of highest population.

From these observations, and from earlier discussions regarding the persistence of *M. fijiensis*, its dispersal mechanisms, and the conditions needed for successful exposure of a susceptible host (see Dist3), the likelihood that a non-commercial (household) banana plant would be exposed to *M. fijiensis* was rated as extremely low.

**Dist5** — *the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment*

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) plants and other susceptible commercial plants. In banana growing parts of Australia, feral banana plants occur as frequently as household banana plants, whereas Australia’s three native species of bananas, *M. acuminata* subsp. *banksii*, *M. jackeyi* and *M. fitzalanii*, are all restricted to wet tropical areas of north Queensland. In Queensland the cultivation of native and seeded bananas is prohibited except for registered botanical gardens and official controls are exercised to minimise the incidence of pests and diseases in feral bananas (*Plant Protection Regulation 2002*).

Technical issues associated with the persistence of *M. fijiensis* inoculum, the conditions needed for infection of susceptible host plants, and its means of dispersal, need not be reiterated. Specific to Dist5 are issues relevant to the physical distance that may lie between discarded waste and a susceptible wild plant. Exposure of native banana species would most likely result from random disposal of fruit peel along roadsides, walking tracks, picnic or camping grounds in the tropics. However, because the definition of a ‘wild’ plant includes amenity plants, and those that grow beside roadways and urban streets, the physical distance between discarded waste and a plant is likely to approximate Dist4 (see above).

From these observations, and from earlier discussions regarding the persistence of *M. fijiensis*, its dispersal mechanisms, and the conditions needed for successful exposure of a susceptible host (see Dist3), the likelihood that a susceptible wild (native or feral) plant would be exposed to *M. fijiensis* was rated as extremely low.
Conclusions — probability of distribution

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to *M. fijiensis* that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Extremely low
- Partial probability of distribution for susceptible household plants = Extremely low
- Partial probability of distribution for susceptible wild/commercial plants = Extremely low

Probability of establishment

The initiation point for establishment of *M. fijiensis* from imported fruit in Australia is the settling of ascospores on host leaf material and the end-point is the development of secondary black Sigatoka spores on the diseased plant.

To establish on the surface of a banana leaf, an ascospore must germinate and penetrate through an open stomate (Carlier *et al.*, 2000). Temperature and moisture must be suitable for germination and mycelial growth — importantly, the fungus must develop sufficiently for a secondary crop of spores to develop before the leaf tissue decays. Ascospores exposed to water germinate at temperatures between 11-38°C although optimum temperature for germination and growth is above 20°C (Jacome *et al.*, 1991; Carlier *et al.*, 2000). These conditions are more likely to occur in tropical parts of Australia, than in subtropical or temperate parts (Carlier *et al.*, 2000; Kumar *et al.*, 2002).

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:
- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

Commercially cultivated banana plants

Black Sigatoka is primarily a disease of tropical areas, although it has shown a tendency in recent years to spread into subtropical parts of some affected countries (Carlier *et al.*, 2000). Given this, it is clear that the availability, quantity and distribution of susceptible banana hosts, and the suitability of the environment, would favour its establishment in most banana growing areas of Australia except the most arid areas of Western Australia, and the more southern banana producing areas of New South Wales (Kumar *et al.*, 2002).

Offsetting environmental suitability is the consideration of fungicide spraying programs currently used in Australia for the control of yellow Sigatoka (*M. musicola*) and leaf speckle (*M. musae*).Whilst not entirely preventing establishment, as evidenced through the incursion of black Sigatoka in commercial plantations in the Tully district of north Queensland prior to the commencement of a
zero disease control program in June 2001, these programs would substantially reduce establishment potential.

Overall, the likelihood of establishment of black Sigatoka on exposed commercial bananas in Australia was considered low.

**Susceptible household plants**

As with commercial banana plants, the fungus will need to encounter warm wet conditions to infect exposed plants in household situations. Secondly and of particular importance to the establishment of black Sigatoka amongst exposed household plants is the availability, quantity and distribution of susceptible hosts, which would be substantially lower than in a commercial plantation. Importantly, in Queensland the cultivars grown in household situations are controlled to some extent by government regulations (*Plant Protection Regulation 2002*), and include Lady Finger (AAB), which is susceptible to black Sigatoka, and Ducasse (ABB) and Goldfinger (AAAB), which are somewhat resistant. This might be offset by the observation that, unlike commercial banana growers, households are relatively unlikely to spray plants with fungicides.

Overall, the likelihood that *M. fijiensis* would establish within exposed household banana plants was considered moderate.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The establishment potential for black Sigatoka on wild (native or feral) plants would be governed by the same factors as for household plants, and is again considered moderate.

**Probability of spread**

The probability of spread examines factors relevant to the movement of *M. fijiensis* from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. The initiation point for spread of black Sigatoka is the production of the first crop of conidia or ascospores of *M. fijiensis* in an infected host plant in Australia and the end-point is the distribution of that inoculum to other host plants. Host plants are perennial herbs and black Sigatoka does not kill infected plants, so spread may occur at an indefinite time after establishment has occurred.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

The occurrence of black Sigatoka in most banana-producing countries worldwide, and similarities between the natural and built environment in banana plantations in the Philippines and those in tropical and subtropical parts of Australia, would suggest that conditions in Australia are suitable
for spread. The outbreak of black Sigatoka in the Tully area of north Queensland is evidence to support this contention. Comparisons between the climate in Tully and Cardwell districts, and that of other parts of Australia where bananas are grown (Kumar et al., 2002), confirm the potential for natural spread amongst commercial bananas in all but the most arid or temperate parts of Western Australia and New South Wales. Once established, *M. fijiensis* would produce ascospores and conidia and spread as an airborne and waterborne pathogen, or be carried on infected leaf material.

Other than wind, the pest does not require particular vectors for spread and does not have any natural enemies in Australia that would retard spread. It is also possible that *M. fijiensis* might be spread within Australia on infected planting materials.

Overall, the likelihood that *M. fijiensis* would spread from a point of establishment within exposed commercial banana plants was considered high.

**Susceptible household plants**

Whilst banana plants are grown in households along northern coastal areas from Sydney in the east, to Perth in the West, the maximum incidence is about 25%, and, hence, establishment of *M. fijiensis* in one household plant does not easily lead to airborne spread to a plant in another household or to a commercial plantation. This depends on distance between susceptible banana plants. The likelihood of airborne spread is greater in tropical parts of Australia where the production of perithecia is higher (Carlier et al., 2000; Burt et al., 1997). It might also be important that black Sigatoka can be spread via leaves and planting materials, which are sold through weekend markets in tropical and subtropical parts of Australia.

Overall, the likelihood that *M. fijiensis* would spread from a point of establishment within household banana plants to other susceptible banana plants was considered moderate.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The potential for spread of black Sigatoka from a point of establishment in susceptible wild plants will be dictated by the abundance and distribution of suitable hosts — i.e. other susceptible native and feral plants, commercial banana plants or susceptible household plants.

Native bananas are restricted to the forests of tropical parts of north Queensland, although *M. acuminata* subsp. *banksii*, which is regarded as susceptible to black Sigatoka, grows in close proximity to commercial plantations in those areas. The cultivation of native and seeded bananas is prohibited except for registered botanical gardens. However, feral bananas are common in all banana-growing areas, in spite of official controls to minimise the incidence of pests and diseases.

On balance, the likelihood that *M. fijiensis* would spread from a point of establishment in susceptible wild plants was considered moderate.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of black Sigatoka were assessed by considering its impact on a range of direct and indirect criteria at the local, district, State or Territory and national level. Impact was described using four qualitative terms - unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of black Sigatoka was assessed on the basis of its potential effect on the entire local, district, State or Territory or national community. For
some criteria, the effect of black Sigatoka could be estimated by considering the scale of likely economic impact. For others, its effect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of black Sigatoka**

*Animal or plant life, or health*

This criterion describes the production losses associated with black Sigatoka in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of black Sigatoka have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

In summarising the literature on direct impacts of black Sigatoka, Carlier et al. (2000) note that black Sigatoka

“…. does not kill plants immediately, but crop losses increase gradually with the age of the plantings. The decrease in functional leaf area caused by the disease results in a reduction in the quality and quantity of fruit. Fruit from affected plants ripens prematurely and does not fill properly. Bananas for export are sometimes harvested at a lower grade (younger age) in order to reduce the risks of premature ripening in transit to overseas markets”.

Carlier et al. (2000) also note that black Sigatoka is a major constraint to banana production and that, after the first occurrence in an area, the disease builds up and often reaches epidemic proportions. The speed of build-up depends on environmental conditions, the degree to which other leaf diseases are established in the area, the degree to which fungicides are already used, and the virulence of the introduced *M. fijiensis* to the local banana cultivars. In Australia, black Sigatoka is expected to be most significant in the tropical parts of north Queensland, and less significant in subtropical, temperate or arid areas. Its effects will be minimised by fungicide sprays and leaf sanitation measures already used against established diseases such as yellow Sigatoka (*M. musicola*) and leaf speckle (*M. musae*). However, the disease is likely to spread within a short time to all banana farms in a production district, and to affect these farms to various degrees, depending on the management systems in place. In household situations, fruit production and fruit quality would be reduced and the growing of the susceptible lines would be impractical in most tropical areas for most householders.

The severity of black Sigatoka on native Australian *Musa* species (*M. acuminata* subsp. *banksii*, *M. jackeyi*, *M. fitzalanii*) is unknown. However, given their limited distribution in Australia and their isolation from other native and commercial bananas, it is very unlikely that they would be infected.

On this basis, the likely impact of black Sigatoka in terms of *plant production losses* was found to be minor at the State or Territory level. Overall, this resulted in a rating of *C* for this criterion.

*Human life or health*

The black Sigatoka fungus is not known to affect human life or health hence this criterion was rated as *A*. 
Any other aspects of the environment not covered above

*M. fijiensis* is specific to banana species and is not known to impact on other aspects of the natural or built environment, such as the physical environment or micro-organisms. A rating of A was assigned to this criterion.

The indirect impact of black Sigatoka

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

Initially an eradication program would be considered. Host plants would be removed and controls on the movement of plant material and fruit would be enhanced. This was the case when black Sigatoka was found in the Tully district in April 2001. This eradication program cost the Australian Commonwealth and State Governments in the order of $8 million, and cost the banana industry more than $7 million.

If eradication fails, black Sigatoka would require on-going fungicide spraying and leaf sanitation measures additional to those required for control of endemic leaf diseases such as yellow Sigatoka. Currently, 20 to 24 fungicide sprays are applied to control yellow Sigatoka in tropical north Queensland and 4 to 8 in the subtropical parts. The number of spray and de-leafing cycles would probably double, leading to an increase in the cost of production in the order of $1650 per hectare, which represents approximately $2 per carton or $36 million across the industry per year (Allen, 2000).

Given the possibility of an initial eradication program and on-going control programs, it was considered that the impact of new or modified control programs would be minor at the State or Territory level. Overall, this resulted in a rating of C for this criterion.

Domestic trade or industry effects

Domestic trade effects associated with the introduction and spread of black Sigatoka are likely to result from intra- and inter-state trading restrictions on planting materials, leaf material and fruit. The effects on planting materials would be no greater than already apply to other pests and diseases. The restrictions on leaf and bell materials would be minor to the few producers affected by the restrictions but hardly discernible at the district, State or Territory, or national levels.

However, restrictions on fruit could disrupt national marketing arrangements for a short time after the initial detection of disease in an area but would be no more than currently exist for outbreaks of black Sigatoka that have occurred previously in Australia. For this reason, the likely indirect impacts were considered to be minor at the district level. The rating assigned to this criterion was, therefore, B.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market, and it is unlikely that any future trading partners would regard black Sigatoka as a quarantine issue. For this reason, a rating of A was assigned to this criterion.

Indirect effects on the environment

One of the considerations within this criterion was the possible indirect impact of black Sigatoka on rural and regional economic viability. Black Sigatoka would be more difficult and more costly
to control than yellow Sigatoka. The potential increases in production costs could reduce farm viability and many growers could be forced from the industry, particularly in the tropical areas of Queensland, resulting in possible loss of jobs and downturns in local economies.

Additionally, local government and health authorities often raise concerns over the application of chemical sprays near urban areas. While the chemical residues would be the same as those currently contaminating the environment, a potential increase would not be tolerated in high profile protected areas. Local restrictions on additional chemical sprays may be imposed that would further impact on farm viability.

After consideration of these issues, the indirect impact of black Sigatoka on the environment was considered likely to be minor at the district level. Overall, this resulted in a rating of B for this criterion.

**Conclusions - the overall impact of black Sigatoka**

The direct and indirect impacts of black Sigatoka were combined using the decision rules discussed in the *Method for Import Risk Analysis*. This led to the conclusion that the overall likely consequences to the Australian community of the entry, establishment or spread of black Sigatoka are low.

**Unrestricted risk estimate**

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with black Sigatoka.

The results of these steps are summarised below.

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Extremely low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial probabilities of distribution</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= Extremely low</td>
</tr>
</tbody>
</table>

| Partial probabilities of establishment | = Low          |
| Commercial bananas                    |                 |
| Household bananas or other susceptible household plants | = Moderate     |
| Susceptible wild/commercial plants    | = Moderate     |

| Partial probabilities of spread      | = High         |
| Commercial bananas                   |                 |
| Household bananas or other susceptible household plants | = Moderate     |
| Susceptible wild/commercial plants   | = Moderate     |
Probability of entry, establishment or spread (1 tonne) = Negligible
Annual probability of entry, establishment or spread = Extremely low
Consequences = Low
Unrestricted risk = Negligible

Because the unrestricted risk does not exceed Australia’s ALOP (very low) risk management would not be required for black Sigatoka.

**Panama disease**

Panama disease is a vascular wilt of banana caused by the fungus *Fusarium oxysporum* Schlecht f. sp. *cubense* (E.F. Smith) Snyder & Hansen.

The disease primarily affects *Musa* spp. and has three pathogenic Races with differential virulence to banana cultivars (Ploetz and Pegg, 2000):

- Race 1 typically affects Gros Michel (AAA) and Silk (AAB) bananas, but not Cavendish (AAA) or Bluggoe (AAB);
- Race 2 affects Bluggoe but not Cavendish; and
- Race 4, which is the focus of this assessment, affects all banana clones affected by Races 1 and 2, as well as Cavendish.

An early report by Waite (1963) indicated a fourth Race, designated as ‘Race 3’, affecting *Heliconia* spp. and seedlings of *Musa balbisiana*. Race 3 was reported as mildly pathogenic to *Musa* spp. but, Race 3 has not been found on any host in recent field surveys (Ploetz and Pegg, 2000).

The fungus is perpetuated as asexual clones in the form of mycelia, chlamydomyces, macroconidia and microconidia. The clones can be distinguished by somatic compatibility, virulence, genetic fingerprinting, clonal lineages, aldehyde formation and on whether or not the clone affects bananas in subtropical or tropical areas (Ploetz and Pegg, 2000). Of the *F. oxysporum* f. sp. *cubense* Race 4 vegetative compatibility groups (VCG) that affect Cavendish bananas, only VCG 0122 has been recorded in the Philippines, whereas VCG 0120-01215, 0124, 0129 and 01213-01216, but not VCG 0122, have been recorded in Australia (Ploetz and Pegg, 2000).

The Panama fungus is a root-inhabiting organism that propagates principally in the roots of susceptible *Musa* spp. (Garrett, 1960; Ploetz and Pegg, 2000). Waite and Dunlap (1953) reported that *F. oxysporum* f. sp. *cubense* could also be isolated from the roots of disease-resistant hosts such as *Paspalum fasciculatum* (bull grass), *Panicum purpurascens* [Brachiara mutica] (para grass), *Ixophorus unisetus* and *Commelina diffusa* (spreading dayflower) following artificial inoculation. While this work did not clearly establish that the fungus isolated from roots was *F. oxysporum* f. sp. *cubense*, and not a saprophytic strain of *F. oxysporum*, it does suggest that *F. oxysporum* f. sp. *cubense* may propagate in the roots of plants that are not susceptible to vascular wilt (‘asymptomatic infection’). Given this possibility, the IRA team has taken the view that alternative host plants do exist, and has made the following assessments accordingly.

The Panama fungus is only pathogenic on *Musa* spp., which it enters through young secondary roots or through freshly exposed stele tissue (Stover, 1972). The fungus invades the host from infected roots through the xylem tissues to the corm, pseudostem and bunch stalk, but does not invade the edible part of the fruit tissue (pulp). Most infections are restricted to the corm and lower parts of the pseudostem (Stover, 1972; Ploetz and Pegg, 2000). *F. oxysporum* f. sp. *cubense* is
unable to invade the host directly through the corm, pseudostem or bunch stalk, even if massive quantities of inoculum are used (Stover, 1972).

The first external symptoms of Panama are a yellowing of the oldest leaves or a longitudinal splitting of the lower portion of the outer leaf sheaths (Ploetz and Pegg, 2000). These symptoms are followed by a wilting and collapse of the leaves at the petiole base, leading to death of the entire leaf canopy. Internally, the vascular strands are characteristically reddish-brown in colour.

F. oxysporum f. sp. cubense survives almost indefinitely in colonised soils, as small populations of chlamydospores associated with plant material (Stover, 1972; Ploetz and Pegg, 2000). These spores germinate in the presence of host root exudates, and thus initiate a new infection cycle. The spores are readily transferred with soil on farm machinery or in flood and irrigation waters (Stover, 1972). However, infected planting material is the principal means of spread.

All VCG clones of F. oxysporum f. sp. cubense Race 4 present in Australia are of limited distribution and under official control (Queensland Plant Protection Regulation 2002), although no controls exist on the movement of fruit from infected plants.

Probability of importation

Two risk pathways were considered of relevance to Panama:

- Firstly, symptomless infection of the vascular strands in the peduncle tissue supporting each hand of banana fruit. This tissue, otherwise known as the ‘crown’, forms part of the peel that is discarded at the point of consumption. F. oxysporum f. sp. cubense does not infect the pulp or edible parts of the fruit per se (Stover, 1972). Symptomless infection means that infection occurs internally in the tissue but has not developed to the stage of visible symptom expression. This form of infection would not be detected by visual inspection; nor would it be affected by chlorine treatments or subject to desiccation.

- Secondly, the presence of small pieces of infected leaf trash trapped between the fingers of harvested fruit. Although the amount of leaf trash associated with marketed fruit is likely to be extremely small (see: Method for Import Risk Analysis), it may, if present, carry viable fungal bodies.

A third pathway that was considered was the contamination of fruit and packaging surfaces with soil containing Panama spores. However, it is expected that free spores would be either removed from fruit in the packing station through the cleaning action of washing and brushing, or killed by the solution of chlorine and alum in the de-handing and flotation tank (see: Method for Import Risk Analysis for a discussion of the efficacy of the chlorine and alum treatment). Moreover, packing materials, polystyrene pads, bags and cartons are all new and are assembled on a needs basis leading to the conclusion that contamination of packaging is not a viable risk pathway.

**Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced**

F. oxysporum f. sp. cubense Race 4 (VCG 0122) occurs sporadically in Cavendish cultivars in localised areas of the province of Mindanao from which export bananas are to be sourced (Stover, 1990; Ploetz and Pegg, 2000). Given this, data on the incidence of new cases, or on changes in prevalence of the disease in different years and seasons, were not available, and a likelihood of **low** was assigned to Imp1.
Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

Two pathways were relevant to Panama: (a) symptomless infection of crown tissue; and (b) infected particulate trash.

Symptomless infection of banana fruit: banana plantations in Mindanao are subject to weekly inspections and all plants found with Panama disease symptoms are destroyed (Philippines Dept. Agriculture, 2002a). No data have been supplied on the incidence of Panama in plantations from which export fruit are harvested. It is known, however, that *F. oxysporum* f. sp. *cubense* only invades the peduncular tissue in the most advanced stages of the disease (Stover, 1972).

Contamination with infected leaf trash: leaf may be carried into bunches by nesting rodents or may become entangled with fruit during windstorms during the growth cycle. The extent to which this occurs under Philippine conditions has not been reported. However, in view of the level of field inspection carried out in the Philippines (Philippines Dept. Agriculture, 2001), and the results of the trash survey carried out by New South Wales quarantine inspectors (Lazar, 2003), the likelihood that a particular bunch contains trash particles was considered very low. The likelihood that those trash particles would be infected with Panama was considered negligible.

Overall, the likelihood that *F. oxysporum* f. sp. *cubense* would be present within a tonne of harvested fruit was considered negligible.

Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The movement of fruit from the point of harvest to the packing station involves a series of steps that takes no more than 1 to 2 hours to complete. In this period, it is conceivable that fruit could be exposed to soil-borne spores in dust via holes in the bags covering banana bunches. De-handing in the field, as is the practice when mobile packing stations are used, increases the likelihood of surface contamination of this sort. It is also possible that some trash particles containing viable fungus could, by the same means, contaminate a bunch.

However, these means of contamination were viewed as remote possibilities. Moreover, it was explained at the start of this assessment (see: Probability of Importation) that because free spores would either be removed from fruit through the cleaning action of washing and brushing, or killed by the solution of chlorine and alum in the de-handing and flotation tanks, surface contamination was not considered a viable risk pathway. The same applies to free trash particles on the surface of fruit.

In consideration of this, a negligible likelihood was assigned to Imp3.

Imp4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

Whilst there is no evidence to suggest that banana fruit are contaminated within a packing station, they are immersed in water in the de-handing and flotation tanks. This would allow surface contamination in the form of free spores, or particulate leaf trash containing viable fungus. It is also true that packing stations are open, allowing for ventilation as well as the possibility for fruit or packing material being exposed to wind-driven rain, dust and pieces of infected particulate trash.

However, it is also important that steps taken on arrival of the fruit at the packing station effectively remove most free leaf material, rodent nests and other litter prior to the de-handing and flotation of fruit. Subsequent de-handing, scrubbing and washing, then removes remaining surface...
particulate leaf trash. As previously mentioned, the solution in the de-handing and flotation tanks carries a concentration of chlorine and alum that is expected to be biocidal to *F. oxysporum* f.sp. *cubense* (Bartz et al., 2001; Dychdala, 1991; Holmes and Harrup, 2003; Ritenour et al., 2002; Robbs et al., 1995; Sanz et al., 2002; Zhuang et al., 1995), meaning that any free spores that might adhere to floating fruit will not be viable.

On balance, the likelihood that a tonne of fruit would become contaminated with viable *F. oxysporum* f. sp. *cubense* during routine procedures undertaken within the packing station was considered **negligible**.

**Imp5** — *the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine inspection procedures within the packing station*

Inspection procedures carried out in the packing station are concerned primarily with quality standards of fruit as regards damage, colour, shape and size. Visible pieces of leaf tissue would be removed.

However, because fruit are not inspected specifically for particulate leaf trash between fingers, and because symptomless infection of the crown tissue is, by definition, not visible to the naked eye, the likelihood that infected fruit will be identified and removed from the pathway was considered **negligible**.

**Imp6** — *the likelihood that the pest will be removed or destroyed as a result of routine procedures undertaken within the packing station*

As previously mentioned in Imp 4, whilst the solution of chlorine and alum in the de-handing and flotation tanks will be biocidal to free Panama spores, *F. oxysporum* f.sp. *cubense* present internally in leaf tissue or crown tissue would not be susceptible to this treatment.

On this basis, the likelihood that *F. oxysporum* f. sp. *cubense* associated with fruit would be removed was considered **negligible**.

**Imp7** — *the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf*

Because fruit are not inspected specifically for particulate leaf trash between fingers, and because symptomless infection of the crown tissue is, by definition, not visible to the naked eye, the likelihood that infected fruit will be identified by BPI quarantine officers and removed from the pathway was considered **negligible**.

**Imp8** — *the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export*

*F. oxysporum* f. sp. *cubense* is known to survive for long periods as chlamydomspores associated with plant material (Stover, 1972; Ploetz and Pegg, 2000). Given this, there is no reason to suspect that conditions under which bananas are transported to the wharf and stored prior to export would alter its viability. A **high** likelihood was assigned to Imp8.

**Imp9** — *the likelihood that the pest will remain viable during transport to Australia*

The argument for Imp9 is the same as those for Imp8. A **high** likelihood was assigned to Imp9.
Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

By definition, symptomless infection of crown tissue would not be detected by visual inspection by AQIS officers, regardless of the proportion of the consignment that was inspected. Particulate leaf trash would also be difficult to find.

Overall, the likelihood that infection in a tonne of exported fruit would be detected at AQIS on-arrival inspection was considered negligible.

Conclusion — probability of importation

When these likelihoods were inserted into the simulation model (see: Method for Import Risk Analysis), the overall probability of importation for a tonne of bananas was found to be negligible.

Probability of distribution

The initiating step for distribution of *F. oxysporum* f.sp. *cubense* Race 4 (VCG 0122) in Australia is the presence of fungal spores and mycelia in the vascular crown tissue of imported banana fruit, or particulate leaf trash associated with fruit. The end point is the exposure of young secondary roots or wounded mature roots of susceptible *Musa* spp. and alternative hosts to spores released from discarded crown or leaf material.

Dist1 — the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers

The Panama fungus is known to survive for long periods within plant material and there is no reason to suggest that storage, ripening and distribution conditions would affect viability. Therefore, the likelihood that the fungus would remain viable at this stage was considered high.

Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

If imported, bananas from the Philippines would be distributed for sale in all major Australian population centres. It was explained above that, in the absence of data to the contrary, the host range for *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) is assumed to include most cultivars grown in residential gardens in Australia. This includes Cavendish (AAA), Lady Finger (AAB), Ducasse (AAB), Red Dacca (AAA) and Gold Finger (AAAA). *F. oxysporum* f. sp. *cubense* has also been associated with asymptomatic infection of hosts such as *P. fasciculatum*, *P. purpurascens* [*Brachiara mutica*], *I. unisetus* and *C. diffusa*, which can be found as weeds in households in tropical and subtropical parts, and, to a much lesser extent, the temperate parts of Australia. Of these, *B. mutica* is known as a serious weed of waterways and sugarcane in Australia (Lazarides and Hince, 1993).
It was shown in the *Method for Import Risk Analysis* that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest *specific to bananas*, Prop2 would be described as moderate. However, because the host range for *F. oxysporum f. sp. cubense* Race 4 includes some common and widely occurring weed species, this proportion will be increased. Overall, it was considered very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown, and Prop2 was therefore rated high.

**Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found**

It was explained in the *Method for Import Risk Analysis* that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood. *F. oxysporum f. sp. cubense* Race 4, however, can also infect some common weed or pasture species (see above) — notably, *B. mutica* is a widespread grass in tropical areas of northern Australia.

Overall, it was considered very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts can be found. Prop3 was therefore rated as high.

**Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment**

The crown is discarded in the normal course of the consumption of banana fruit. Spoiled fruit is likely to be discarded whole. Associated leaf trash would become separated from the peel during the retail or home consumption steps in the pathway, but would still enter the environment as waste.

On balance, it was considered virtually certain that Panama, if present on the fruit, would be discarded with banana waste.

**Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment**

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of *F. oxysporum f. sp. cubense* Race 4 (VCG 0122) to move from discarded banana waste to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of *F. oxysporum f. sp. cubense* in or on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which *F. oxysporum f. sp. cubense* can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

**Persistence.** *F. oxysporum f.sp. cubense* is a root-inhabiting fungal organism characterised by a filamentous mycelium from which macroconidia, microconidia and chlamydospores are produced by vegetative processes. No sexually produced spore stages are known for this species. Mycelium is typically associated with a suitable substrate such as a plant root or decomposing organic matter. However, the three spore types can be spread and survive independently of the fungal mycelium.
Chlamydospores are produced typically in or on dead host plant tissue in the final stages of wilt development and have potential for long-term survival for years in the absence of host or substrate (Ploetz and Pegg, 2000). Conidial forms are produced in or on host tissue but have potential for only local spread in the soil because they do not survive for more than a few weeks except when stored in the laboratory under specialised conditions. As discussed above, the fungus is also able to colonise and persist in the roots of alternative hosts, including close relatives of the banana and other tropical plants such as *P. fasciculatum*, *B. mutica*, *I. unisetus* and *C. diffusa*.

Hot wet conditions would lead to rapid decay of leaf trash and discarded fruit peel. Chlamydospores within the tissue would be available to be released into the soil as the tissue decayed.

**Distance.** *F. oxysporum f. sp. cubense* would enter the environment through the disposal of infected waste, whether this is peel and associated flesh or whole spoiled bananas.

- The vast majority of bananas are consumed by individuals (rather than food service industries or food processors). Consumption by individuals is likely to be concentrated: (a) beyond areas of Australia in which bananas are commercially grown, and (b) in the major population centres. There are approximately 2000 commercial banana farms, generally at some distance from major centres of population. Where bananas are brought onto commercial farms, most banana waste will be disposed near farm houses or near worker facilities near packing sheds where bananas are consumed, rather than in the plantation.

- The bulk of waste generated by individuals in the major production centres is managed through refuse disposal facilities although some cartons may be re-used prior to disposal. Refuse disposal facilities frequently bury waste and will place organisms associated with banana waste a substantial distance from commercial banana plants.

- The balance of banana waste will be diverted to home composting, or discarded randomly in the form of peel or whole spoiled fruit. Home composting will place the organism at some distance from commercial banana plants. Random waste disposal is more likely to result in slow spoilage, and movement of the fungus into the soil. Random waste disposal may result in peel or discarded fruit at roadsides adjacent commercial banana plantations.

**Dispersal mechanisms.** Chlamydospores within discarded banana tissue would be released into the soil as the tissue decayed. The fungus will spread slowly from plant to plant, from an isolated point of introduction in a disease-free plantation. Chlamydospores can also be carried in surface run-off water, or may contaminate irrigation reservoirs, leading to rapid and extensive spread of the disease. Given that commercial banana plantations are in areas of high rainfall and are subject to seasonal cyclonic conditions, surface run-off water should not be a limiting factor for dispersal. Spread of spores in air, aerosols and dust clouds may be possible, but has not been demonstrated under natural conditions. Contaminated soil can also be moved by machinery, cultivation, tools, vehicles, animals, and on footwear, and through the movement of infected planting materials.

**Exposure of a susceptible host.** Spores must be in direct contact with young secondary root or freshly exposed stele tissue (Stover, 1972). The threshold number of spores required to infect bananas and cause disease symptoms is unknown, however, like most fungi, it is expected to be more than one and likely to be very many.

After considering all these issues, particularly the persistence of chlamydospores, it was concluded that the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste, would be low.
**Dist4** — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from discarded banana waste to a suitable point of entry on a susceptible plant — in this case, a household or garden plant. The persistence of *F. oxysporum f. sp. cubense*, the conditions needed for the exposure of a susceptible host plant, and its means of dispersal, have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the distance between discarded waste and a susceptible household banana plant.

It was explained above that the bulk of consumer waste is managed through refuse disposal facilities, and that these present a poor environment for the fungus. Alternative host species may be growing at the refuse disposal sites, which improves the opportunity for the fungus to survive among the roots of these plants and be eventually spread to roots of a susceptible banana plant. Residual household banana waste is either composted or discarded randomly. Household compost may place it in close proximity to a susceptible household banana plant or close enough to colonise the roots of alternative hosts and subsequently spread to the roots of a susceptible household plant. Most random disposal of peel or spoiled fruit is likely to take place outside the garden environment and at some distance from susceptible household plants.

From these observations, discussions regarding the persistence of *F. oxysporum f. sp. cubense*, the conditions needed for exposure of susceptible host plants, and dispersal mechanisms, the likelihood that a susceptible non-commercial (household) banana plant or other susceptible garden plant would be exposed to the *F. oxysporum f. sp. cubense* Race 4 (VCG 0122) was considered **low**.

**Dist5** — the likelihood that susceptible wild (native or feral) or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) plants. There are no commercially grown hosts of *F. oxysporum f. sp. cubense* other than bananas. Given this, technical issues associated with the persistence of Panama inoculum, the conditions needed for the exposure of a susceptible host plant, and its means of dispersal, need not be reiterated. Specific **Dist 5** is the distance between discarded waste and an individual plant in this group of susceptible hosts.

Because the definition of a ‘wild’ plant includes native and feral plants, amenity plants, and those that grow beside roadways and urban streets, the physical distance between discarded waste and a plant is likely to be less than considered for either Dist3 (the exposure of commercial plants) or Dist4 (the exposure of household plants). Offsetting this, however, is the observation that susceptible native and feral banana plants are significantly less abundant. Native species are largely restricted to the wet tropical areas of north Queensland. Feral bananas may be found in all areas where bananas are or have been grown, although under official control in the production areas currently of major significance. Random disposal of fruit peel could also be in close enough proximity to the alternative hosts (including some common weed species) to colonise their roots, survive and at a later time spread through the soil or movement of the soil to come in contact with susceptible wild or native banana plants.
Overall, the likelihood that susceptible wild (native or feral) plants would be exposed to *F. oxysporum f. sp. cubense* Race 4 (VCG 0122) that had entered the environment with discarded fruit waste was considered low.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to *F. oxysporum f. sp. cubense* that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Very low
- Partial probability of distribution for susceptible household plants = Very low
- Partial probability of distribution for susceptible wild/commercial plants = Very low

**Probability of establishment**

The initiation point for establishment of *F. oxysporum f. sp. cubense* Race 4 (VCG 0122) from imported fruit in Australia is the settling of conidia or chlamydospores on host material and the end-point is the development of Panama disease symptoms on the exposed plant.

To establish on exposed host tissue, a *F. oxysporum f. sp. cubense* spore must: (a) germinate and produce mycelium on the surface of young secondary roots or wounded mature roots of susceptible *Musa* spp. or alternative hosts; (b) overcome host defences; and (c) invade the exposed vascular tissues (Stover, 1972). The mycelia then produce microconidia, and spread systemically in the plant through the xylem elements.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

**Commercially cultivated banana plants**

Panama disease occurs in tropical and subtropical areas. Given the successful establishment of *F. oxysporum f. sp. cubense* in most other banana producing countries, it is clear that the availability, quantity and distribution of banana hosts and alternative hosts in Australia, and the suitability of the environment, would favour its establishment. In this situation, adaptation would not be necessary.

On this basis, it was considered very likely that *F. oxysporum f. sp. cubense* Race 4 (VCG 0122) would establish within exposed commercial banana plants. Establishment potential on commercially cultivated bananas was therefore rated as high.
Susceptible household plants

As for commercial bananas, environmental conditions are likely to be suitable for *F. oxysporum* f. sp. *cubense* to establish amongst exposed household banana plants. Of particular importance to this likelihood, however, are the availability, quantity and distribution of susceptible hosts. Here it is clear that in contrast to the situation on a commercial plantation, susceptible plants would be relatively few and relatively sparsely distributed.

This may be offset by the observation that host range for *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) is assumed to include most cultivars grown in residential gardens in Australia. This includes Cavendish (AAA), Lady Finger (AAB), Ducasse (AAB), Red Dacca (AAA) and Gold Finger (AAAA). The fungus has also been associated with asymptomatic infection of hosts such as *P. fasciculatum*, *P. purpureascens* [*Brachiara mutica*], *I. unisetus* and *C. diffusa*, which can be found as weeds in households in tropical and subtropical parts, and, to a much lesser extent, the temperate parts of Australia.

Also relevant to the establishment of *F. oxysporum* f. sp. *cubense* amongst exposed plants is the longevity of the organism in spore form. Specifically, chlamydospores, which may be produced in or on dead host plant tissue in the final stages of wilt development, and have potential to survive for years in the absence of host or substrate (Ploetz and Pegg, 2000). Chlamydospores are stimulated to germinate by the presence of root exudate of a susceptible host plant. This mechanism will increase the likelihood of transfer of the organism to other susceptible household host plants.

On balance, the likelihood that *F. oxysporum* f sp. *cubense* Race 4 (VCG 0122) would establish within exposed household banana plants was considered high.

Susceptible wild plants, or susceptible cultivated plants other than bananas

The establishment potential for *F. oxysporum* f. sp. *cubense* on wild (native or feral) plants (there are no commercially grown plants other than bananas) would be governed by the same factors as for household plants, and is again considered high.

Probability of spread

The probability of spread examines factors relevant to the movement of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. The initiation point for spread of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) is the presence of the fungus in plant material or in decaying banana tissue present in the soil, and the end point is the movement of that inoculum in propagation material to new sites or in soil to other host plants.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.
Commercially cultivated banana plants

The occurrence of Panama in most banana-producing countries worldwide, and similarities between the natural and built environment in banana plantations in the Philippines and those in Australia, would suggest that conditions in Australia are suitable for spread.

The Panama fungus is a soil organism that can be carried in spore form in surface run-off water, or may contaminate irrigation reservoirs, leading to rapid and extensive spread of the disease. Spread of spores in air, aerosols and dust clouds may be possible, but has not been demonstrated under natural conditions. Given that commercial banana plantations are in areas of high rainfall and are subject to seasonal cyclonic conditions, surface run-off water should not be a limiting factor for dispersal. Contaminated soil can also be moved by machinery, cultivation, tools, vehicles, animals, and on footwear, and through the movement of infected planting materials. There are, however, controls on the movement of plant material under regulations such as Queensland Plant Protection Regulation 2002. The extensive use of machinery on some Australian plantations would enhance spread. Chlamydospores can persist for extensive periods, if associated with plant material, and the organism has no natural enemies.

Overall, the likelihood that *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) would spread from a point of establishment within exposed commercial banana plants was considered high.

Susceptible household plants

Biological and environment factors relevant to the spread of the fungus from a point of establishment were outlined briefly above. The principal difference between spread from household plants and spread from commercial plants is the immediate availability of susceptible hosts. Although the host range extends beyond bananas to include some weed and pasture species, it is unlikely that in any part of Australia, the proportion of households with susceptible plants would exceed 25% (based on a survey of households in Australia, March 2002 see: Appendix 2). Offsetting this is the longevity of the organism, and, although not documented, its ability to be transferred mechanically in soil associated with garden implements, footwear, etc. Households might also inadvertently distribute the fungus between households through transplanted rhizomes and suckers with infected roots via local fetes, weekend markets etc.

On balance, the likelihood that *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) would spread from a point of establishment within household banana plants to other susceptible banana plants was considered moderate.

Susceptible wild plants, or susceptible cultivated plants other than bananas

The potential for spread of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) from a point of establishment in wild plants will be dictated by similar considerations as discussed above for household plants, particularly, proximity to other hosts. In some cases, there may be a higher density of wild plants (including susceptible weed species) but, to offset this, planting materials or fruit from wild plants will tend not to be moved in the way that household planting materials and fruit might be.

Native bananas are largely restricted to the wet tropical areas of north Queensland, although *M. acuminata* subsp. *banksii* grows in close proximity to commercial plantations in those areas. The cultivation of native and seeded bananas is prohibited except for registered botanical gardens. However, feral bananas are common in all banana-growing areas, although official controls are
exercised in Queensland to minimise the incidence of pests and diseases (Plant Protection Regulation 2002).

On balance, the likelihood that *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) would spread from a point of establishment in susceptible wild and commercial plants was again considered moderate.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) were assessed by considering its potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of Panama was assessed on the basis of its potential effect on the entire local, district, State or Territorial and national community. For some criteria, the effect of the disease could be estimated by considering the scale of likely economic impact. For others, its effect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of Panama disease**

*Animal or plant life, or health*

This criterion describes production losses associated with Panama in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of Panama have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

Panama is one of the most destructive and notorious diseases of banana, and has caused extensive damage in export plantations in Panama and elsewhere (Stover, 1972). By 1960, for example, *F. oxysporum* f. sp. *cubense* had destroyed an estimated 40,000 hectares of Gros Michel (AAA) in Panama. Alternatively, *F. oxysporum* f. sp. *cubense* Race 1 was responsible for the progressive decline of plantations in the Latin America and the Caribbean, and for the need for the banana export industry to convert to disease resistant cultivars of the Cavendish subgroup (AAA). When this occurred, *F. oxysporum* f. sp. *cubense* Race 1 ceased to be a concern to the export trade. These banana cultivars continue to perform well in the western hemisphere, although in other areas they are susceptible to some clones of *F. oxysporum* f. sp. *cubense* Race 4.

Panama causes direct losses on banana productivity because susceptible cultivars succumb to wilting and die. The level of destruction depends on the degree of host susceptibility, drainage, environmental conditions and soil type. Suppressive soils (i.e. soils with a high microbial loading) reduce the population of *F. oxysporum* f. sp. *cubense* and have been recorded in Central America, Canary Islands, South Africa and Australia (Moore *et al.*, 1995). Further, the presence of the fungus in the soil interferes with long-term land use because of the long survival time of chlamydospores.

While it is known that the native *M. acuminata* subsp. *banksii* is susceptible to the organism, the susceptibility of the other two native bananas in Australia, *M. jackeyi* and *M. fitzalanii*, is
unknown. However, given the limited distribution of native bananas in Australia and their isolation from other native and commercial bananas, it is extremely unlikely that they would be infected.

On balance, the impact of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) in terms of plant production losses was considered likely to be minor at the State or Territory level. This resulted in a rating of C for this criterion.

**Human life or health**

*F. oxysporum* f. sp. *cubense* is not known to affect human life or health hence this criterion was rated as A.

**Any other aspects of the environment not covered above**

*F. oxysporum* f. sp. *cubense* is pathogenic only to banana species. It is not known to impact on other aspects of the natural or built environment, such as the physical environment or micro-organisms, hence the rating assigned to this criterion was A.

**The indirect impact of Panama disease**

**New or modified eradication, control, surveillance/monitoring and compensation strategies/programs**

Should *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) appear in Australia, an eradication program could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. The cost of such a program could amount to $1 million or more, as evidenced by the response to an incursion of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 01213-01216) in the Northern Territory. Government costs were in the order of $200,000 with substantially greater costs to the farmers affected.

In Queensland, plants and soil in the immediate area of a confirmed outbreak would be treated as follows:

- An infected plant and surrounding plants would be injected with Roundup® to quickly kill them;
- A heavy application of urea would be distributed on the surrounding soil;
- Grass seed would be spread over the soil (to stabilise the soil and improve its quality); and
- Mulch would be spread over the area and the area would be fenced off indefinitely.

These treatments are prescribed under legislation in Queensland (*Plant Protection Regulation 2002*).

To maintain banana production in an area with Panama disease, enhanced regulatory enforcement would be required, with its associated costs. Further, modification of on-farm management practices would be needed. These would include reduced access to, or use of, machinery and other means of moving soil, and a prohibition on the movement of banana planting material. Movement of *Musa* spp. germplasm by tissue culture is considered essential to prevent spread of Panama disease. Many of these control strategies are already practiced in Australia.

Given the cost of an initial eradication program and on-going control programs, it was considered that the impact of new or modified control programs would be minor at the State or Territory level. Overall, this resulted in a rating of C for this criterion.
Domestic trade or industry effects

An outbreak of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) would become a factor in the movement of banana planting material, but these restrictions would be no more than those that already apply to other forms of *F. oxysporum* f. sp. *cubense* in Australia. No interstate trading restrictions and embargoes on fruit are expected.

Considering these issues, the impact of Panama on domestic trade and industry was considered likely to be minor at the local level, which resulted in a rating of A for this criterion.

International trade effects

At present, Australia exports only negligible quantities of bananas that go to a specialty market (see Import Proposal for Philippines Bananas). For this reason, the rating assigned to this criterion was A.

Indirect effects on the environment

One of the considerations within this criterion was the possible indirect impact of Panama on rural and regional economic viability. In assessing the indirect impact at each of the four levels, it was relevant to consider the viability of rural communities, and the indirect impact of a threat to rural viability, and to biodiversity, endangered species, the integrity of ecosystems, reduced tourism and such on all levels of the Australian community.

If there were no other viable alternative agricultural or silvicultural uses for land contaminated with Panama, the economic viability of those landholders and farm workers would be threatened. If the number of land holdings affected was considerable, consequent local and maybe district industry changes would affect dependent town economies through lost service industries and local employment.

After consideration of these issues, the indirect impact of Panama disease on the environment was considered likely to be minor at the State or Territory level. Overall, this resulted in a rating of C for this criterion.

Conclusions — the overall impact of Panama disease

The direct and indirect impacts of Panama disease were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of *F. oxysporum* f. sp. *cubense* Race 4 (VCG 0122) are likely to be low.

Unrestricted risk estimate

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the Method for Import Risk Analysis. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with Panama.
The results of these steps are summarised below.

Probability of importation = Negligible

Partial probabilities of distribution

- Commercial bananas = Very low
- Household bananas or other susceptible household plants = Low
- Susceptible wild/commercial plants = Low

Partial probabilities of establishment

- Commercial bananas = High
- Household bananas or other susceptible household plants = High
- Susceptible wild/commercial plants = High

Partial probabilities of spread

- Commercial bananas = High
- Household bananas or other susceptible household plants = Moderate
- Susceptible wild/commercial plants = Moderate

Probability of entry, establishment or spread (1 tonne) = Negligible

Annual probability of entry, establishment or spread = Very low

Consequences = Low

Unrestricted risk = Negligible

Because the unrestricted risk meets Australia’s ALOP (very low) risk management would not be required for Panama disease.

ARTHROPODS

Fruit flies

Fruit flies oviposit (lay eggs) under the surface of immature fruit of susceptible host plants and the larvae develop as the fruit mature. Fruit flies are regarded as important quarantine pests.

Fruit flies have not been reported as pests of bananas in the Philippines (Philippines Dept. Agriculture, 2001). This is probably because:

- A comprehensive host plant survey for fruit fly in the Philippines has not been undertaken (CABI, 2002; Drew, 2002), either in Cavendish or in local banana and plantain cultivars.
- Cavendish fruit are harvested for export at the hard green stage before oviposition has occurred.
- Insecticide sprays and insecticide-impregnated bunch covers offer considerable security against fruit infestation.

Notwithstanding these points, flies of the Oriental fruit fly (B. dorsalis) complex present in South-East Asia are known to attack a wide range of commercial and native host plants, including banana (Fletcher, 1989).

Two species of the fruit flies were examined in this import risk analysis; Bactrocera occipitalis (Bezzi) and Bactrocera philippinensis Drew and Hancock. Both of these species occur in the Philippines but are not known to occur in Australia (Drew and Hancock, 1994).
Bactrocera occipitalis has been reported on various host plants, including carambola, mandarin, mango, sapodilla, and guava (Drew and Hancock, 1994; CABI, 2002). This species is generally regarded in the Philippines as a pest of mangoes. However, according to CABI (2002), it is primarily a forest species that occurs in much lower numbers in mango than does *B. philippinensis*. There are no published records of this species on commercial bananas, although, as mentioned above, a survey of fruit fly host plants in the Philippines has not been undertaken (Drew, 2002).

*Bactrocera philippinensis* has also been reported on a range of host plants, including breadfruit, carambola, papaw, mandarin, mango, sapodilla, guava, and malay-apple (Drew and Hancock, 1994; CABI, 2002). It is considered an important pest of mango in the Philippines (CABI, 2002). There are no published records of this species on commercial bananas. However, the Philippines has not been the focus of a major fruit fly survey in the same manner as Malaysia and Thailand, and so the extent to which other fruit crops are attacked is uncertain (CABI, 2002). *B. philippinensis* is closely related to *B. papayae* Drew and Hancock which is a serious pest of banana in Malaysia (Drew, 2002).

**Probability of importation**

The risk scenario of concern for fruit flies is oviposition within fine cracks in fruit. Although unlikely to occur, eggs placed within cracks in fruit would be relatively protected from inspection, chlorine treatment and other hazards on the importation pathway, and would be likely to survive artificial ripening and the distribution of bananas in Australia.

A second pathway that was considered, but not included in the analysis, was the potential for adult flies in the proximity of processed fruit to be incorporated into packed cartons and thus shipped to Australia. Adult fruit flies, however, would not be expected to survive cool storage in an environment with little free air nor survive the process of ethylene ripening within Australia.

Finally, it is important that fruit flies have not been reported as pests of bananas in the Philippines. This is probably for two reasons. First, there has been no comprehensive host plant survey for fruit fly in the Philippines (CABI, 2002; Drew, 2002). Second, this is more likely to result from the removal of fruit from the plantation at the hard green stage, and the security offered by insecticide sprays and insecticide-impregnated bunch covers, than a species incompatibility, as fruit flies are known to utilise an extremely wide range of commercial and native host plants (Fletcher, 1989).

**Imp1** — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

Although there are no records of either species of fruit fly as pests of bananas, both fruit fly species are found on other fruit crops throughout the province of Mindanao (Drew and Hancock, 1994) and both are capable of flying the distances between these crops and banana plantations. Their populations would be restricted by horticultural practices that remove prematurely ripened fruit (Philippines Dept. Agriculture, 2001) but the presence of non-commercial bananas and alternative host plants in the vicinity of export plantations would provide a reservoir of fruit flies for continual infestation.

On this basis, it was assumed to be very likely that fruit flies would be present on the plantation from which any single tonne of fruit would be sourced, and a **high** likelihood was assigned to Imp1.
Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

Although fruit flies are very likely to be present on most plantations in the Philippines, they are not attracted to or oviposit on hard green bananas. Given this, it is possible that fruit flies would be attracted to cracked fruit, and that the combination of horticultural management, insecticide sprays and insecticide-impregnated bunch covers would not completely prevent oviposition. This is, however, a very remote scenario, and the overall likelihood that fruit fly eggs would be included with a tonne of fruit harvested for export was considered negligible.

Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

Because fruit harvested for export is in the hard green stage of development and is both unattractive and impervious to fruit flies, and because bunch covers will be left in place until fruit reach the receiver patio, there is a negligible likelihood that oviposition would occur during transport to the packing station.

Imp4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

Fruit harvested for export is in the hard green stage of development and is both unattractive and impervious to fruit flies. In addition, the presence of chlorine and alum within the de-handing and flotation tanks would act as a deterrent to adult fruit flies. Moreover, the movement of fruit within the tanks and at other steps in the processing chain, and the movement and activities of packing station staff around fruit at each step in the chain, would discourage oviposition.

In view of this, the likelihood that eggs would be laid in fruit within the packing station was considered negligible.

Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Packing station workers remove fruit that are prematurely ripened, and those with visible cracks. Fruit with fine cracks, however, may not be detected and removed. Fruit with fine cracks represent the scenario of concern in this assessment as such cracks may contain fruit fly eggs. Overall, likelihood that such cracked fruit that may be infested with fruit fly eggs would be detected and removed as a result of quality inspection procedures carried out in the packing station was considered to be moderate.

Imp6 — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

Fruit fly eggs deposited in fine cracks are likely to be protected by closure of those cracks, or by plugging with skin wax, and therefore resistant to the effects of washing or the chlorine and alum solution. Because the risk scenario of concern in this assessment related to eggs deposited in fine cracks in green fruit, a negligible likelihood was assigned to Imp6.

Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Because this step in the importation scenario occurs after rigorous quality inspection within the packing station, any cracks in packed fruit are likely to be extremely fine and difficult to detect. It was considered extremely unlikely that fruit with fine cracks that contained fruit fly eggs, and that
had remained undetected to this point, would be removed by quarantine inspectors. An extremely low likelihood was therefore assigned to Imp7.

**Imp8** — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Whilst adult fruit flies would not be expected to survive the reduced free air environment in a packed carton, eggs within cracked fruit will be protected within an environment entirely conducive to their development. Imp8 was therefore rated as high.

**Imp9** — the likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. Given this, there is a high likelihood that, if deposited in cracks in hard green bananas, fruit fly eggs would remain viable during transit.

**Imp10** — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

The difference between quarantine inspection in Australia and quarantine inspection in the Philippines (Imp7), is that a proportion of eggs may have developed during the period of transport and some associated surface blemishes may be visible on the fruit. In consideration of this, Imp10 was rated as very low.

**Conclusions — probability of importation**

When these likelihoods were inserted into the simulation model, the overall probability of importation for a tonne of hard green bananas was found to be negligible.

**Probability of distribution**

The initiating step for distribution of fruit flies in Australia is the presence of eggs or immature fruit flies associated with imported fruit. The end-point is the exposure of fruit on a suitable host plant to an adult female.

**Dist1** — the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers

Whilst adult fruit flies would not survive cool storage and ethylene ripening, these conditions would be unlikely to threaten the viability of eggs protected in cracks in imported fruit. Indeed, it is likely that eggs deposited in fruit that is cool-stored at 13°C are likely to experience delayed development, and that larvae may not be present for as long as 20 days after oviposition.

In view of this, there is a high likelihood that fruit fly eggs would remain viable through this step in the distribution pathway.

**Prop1** — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.
Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

If imported, bananas from the Philippines would be distributed for sale in all major Australian population centres. It was explained in the introductory text that these two fruit flies infest a range of horticultural and ornamental fruiting plants. Whilst there are some differences in host range between the two species, hosts generally include tropical and temperate fruits. These hosts can be found in households in most parts of Australia.

It was shown in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest specific to bananas, Prop2 would be described as moderate. However, because the host range of these fruit flies is expected to be relatively broad, this proportion will be increased.

Overall, it was considered very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown, and Prop2 was therefore rated high.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was explained in the Method for Import Risk Analysis, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood. The known and likely host ranges of these two fruit flies includes most of the fruiting plant species grown commercially, ornamentally or as a household source of edible fruit. It follows that similar species grown as amenity plants (e.g. in public gardens, or on urban streets), or growing in the wild as feral plants, would also produce fruit that would be attractive to these fruit fly as potential oviposition sites. Although not reported, it is also possible that native fruiting species such as native bananas would be susceptible.

Overall, it was considered very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts can be found. Prop3 was therefore rated as high.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Fruit flies might enter the environment through two scenarios.

• Firstly, eggs may become larvae within stored fruit, fruit at the point of sale or fruit that has been purchased. Larvae may then pupate and develop into adult flies, which are competent fliers and able to move directly into the environment.

• The second scenario would be that wholesalers, retailers or consumers discard fruit with pockets of spoiled flesh containing eggs or visible larvae. Larvae could then complete their development within discarded fruit, and move from that point into the environment.

In either case, it was considered virtually certain that any eggs or larvae present in imported fruit, and that had survived storage ripening and distribution in Australia, would enter the environment.
Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of fruit flies to move from a point of entry into the environment, to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of fruit flies in or on fruit, or in the environment;
- The distance likely to lie between the point at which fruit flies enter the environment, and commercial banana plants;
- The means by which fruit flies can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of commercial banana plants.

Persistence. Temperature, rainfall and soil types within the tropical and sub-tropical commercial banana growing parts of Australia would favour the reproduction and persistence of adult flies.

Distance. As mentioned, fruit flies may enter the environment directly from purchased fruit, or from fruit at the point of sale, or through larvae and pupae that have undergone development in discarded fruit or fruit waste. The scenario that would place fruit flies closest to commercial banana plants would be infested waste discarded on rural roadides adjacent to, or in the proximity of, banana plantations. For reasons associated with the proportional distribution of waste, this is considered a low probability scenario. However, because fruit flies are mobile, and may persist successfully in a tropical or sub-tropical environment, distance is not the critical issue that it may be for some non-motile or fragile pathogens.

Dispersal. Fruit flies are competent fliers, and capable of moving the distances likely to lie between their point of entry into the environment (whether this is fruit or discarded waste) and a commercial banana plantation.

Exposure of a susceptible host. Hard green bananas may not be attractive to adult fruit flies. As plantation practice in Australia is generally to harvest fruit at the hard green stage, it is unlikely that fruit flies would immediately find a suitable host on a commercial plantation. However, there are times when fruit ripens naturally in the field and these fruit would be highly attractive to the fruit flies.

When these points were collated, it was considered very likely that, having entered the environment within an area where bananas are grown commercially, fruit flies would locate and infest susceptible fruit. Dist3 was therefore rated as high.

Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), Dist4 is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden plant.

The persistence of fruit flies, the conditions needed for infestation of susceptible host plants and their means of dispersal have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the distance likely to lie between fruit or discarded waste and a susceptible household plant. However, it is clear that because fruit flies are
competent fliers and capable of moving substantial distances, and because susceptible garden plants are abundant and likely to be found within the proximity of infested fruit or discarded waste, there is a high likelihood of exposure.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) plants, including amenity plants and susceptible plants growing on urban or rural roadways. Dist5 also encompasses the exposure of commercially grown plants other than bananas. Again, the host range of the two fruit flies, and their ability to move substantial distances in search of mates or suitable oviposition sites, gives a high likelihood of exposure of wild plants. Dist5 was rated as high.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild/commercial plants (other than bananas) would be exposed to fruit flies that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Low
- Partial probability of distribution for susceptible household plants = Moderate
- Partial probability of distribution for susceptible wild/commercial plants = Moderate

**Probability of establishment**

The probability of establishment examines factors relevant to successful multiplication of the pest, and establishment of disease amongst the exposed plant, or group of plants. The initiation point for establishment of the fruit flies from imported fruit in Australia is the exposure of the host plants to the larvae and adults and the end-point is the successful establishment of these fruit flies on any of the exposed plants. To establish on an exposed host plant, larvae would need to develop into adults and mate before producing eggs of the next generation.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

**Commercially cultivated banana plants**

The likelihood that fruit flies would find suitable oviposition sites in commercial bananas has been discussed above. If this has occurred, the availability, quantity and distribution of hosts will be
determined largely by plantation practices — in particular, the harvesting of hard green fruit and the removal of damaged or ripening fruit. Whilst these practices are considered routine in Australia, fruit flies are persistent, and are able to travel within plantations to locate the exceptions. The remaining factors, although relevant to fruit flies as to all other pests, need little discussion since it is clear that the environment in tropical and sub-tropical parts of Australia is suitable. It is also clear that the reproductive strategy of fruit flies is effective, that they will survive at a rate equivalent to that observed in the Philippines, and that cultural practices are unlikely to hinder this.

Overall, the likelihood of establishment, given the exposure of commercial banana plants, was considered high.

**Susceptible household plants**

The ability of fruit flies to establish within exposed household or garden plants will be governed by similar factors to those relevant to commercial plantations. The differences between the two scenarios are that: (a) most Australian households are placed in a temperate climate; (b) fruit borne from susceptible plants are generally permitted to ripen; and (c) damaged or ripened fruit are less likely to be removed from the environment. It can be seen that while the first factor may detract from the likelihood of establishment, the management of household fruiting plants will favour it.

Overall, there is a high likelihood that fruit flies would establish among susceptible household plants.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The establishment of fruit flies in exposed wild (native or feral) plants, or susceptible cultivated plants other than bananas would again be dictated by the balance between climatic suitability, and the availability of ripe or decaying fruit. Although fruit flies may favour tropical and sub-tropical environments, evidence suggests that there is a high likelihood that they would establish in most parts of Australia where suitable oviposition sites can be found in ripe and decaying fruit.

**Probability of spread**

The probability of spread examines factors relevant to the movement of fruit flies from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

It is clear that the tropical or sub-tropical environment in which bananas are grown commercially would favour the spread of fruit flies. While movement with commercial bananas may be limited
by the harvesting of hard green fruit, it is likely that fruit flies would move to other fruit crops, or into garden plants, and subsequently with the transport of these alternative fruit hosts. As they are competent fliers, adult fruit flies do not require vectors as such. Eggs, larvae and pupae may however, be vectored mechanically in the decaying remains of the organic material into which eggs were deposited. All insects are subject to a range of natural enemies and the two fruit fly species considered here may be impacted by wasp parasites of native Australian fruit flies.

Overall, there is a **high** likelihood that fruit flies would spread within Australia if they became established among commercial banana plants.

**Susceptible household plants**

Aside from the limits posed by a cool, temperate environment, factors determining the spread of fruit flies from a point of establishment among household or garden plants will be very similar to those discussed above. Given the persistence of these pests, the mobility of adults, and the fact that eggs, larvae and pupae may be vectored mechanically in fruit or decaying organic material, there is a **high** likelihood that spread in Australia would occur following establishment among exposed household plants.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Spread from susceptible wild plants, or susceptible cultivated plants other than bananas will again be governed by the biological factors outlined by IPPC. In this situation, it is possible that the environment in which establishment has occurred may not favour fruit flies. However, given the mobility of adults, and the fact that eggs, larvae and pupae may be vectored mechanically in fruit or decaying organic material, there is a **high** likelihood that spread in Australia would occur following establishment among exposed native or feral plants.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of fruit flies were assessed by considering their potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of fruit flies was assessed on the basis of their potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of fruit flies could be estimated by considering the scale of likely economic impact. For others, their effect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of fruit flies**

*Animal or plant life or health*

This criterion describes production losses associated with the presence of fruit flies in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of fruit flies have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.
Fruit flies are not considered a damaging pest of bananas, since banana fruit is harvested and removed from the plantation at the hard green stage. Fruit flies are, however, polyphagous and responsible for fruit damage and production losses in other horticulture industries. Overall, it was assumed that the direct impact of fruit flies would be minor at the local level. This gave the pest a rating of A for this criterion.

*Human life or health*

There are no known direct impacts of fruit flies on human life or health, and the rating assigned to this criterion was therefore A.

*Any other aspects of the environment not covered above*

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical environment or micro-organisms. There are no known direct impacts of fruit flies in these directions, and the rating assigned to this criterion was therefore A.

**The indirect impact of fruit flies**

*New or modified eradication, control, surveillance/monitoring and compensation strategies/programs*

On first detection, an eradication program could be initiated under the national Generic Incursion Management Plan approved by the Australian Primary Industries Standing Committee. Given past success with the eradication of exotic fruit fly, this program would be likely to succeed. If the fruit fly could not be eradicated, control could be absorbed into existing management programs for species of fruit fly that are present in Australia.

On balance, the cost of control is likely to be minor at the district level. This would result in a rating of B for this criterion.

*Domestic trade or industry effects*

The presence of either of these fruit flies on a commercial fruit crop would result in restrictions on the sale or movement of fruit. The horticulture industries are important to the economies of many localities and districts throughout Australia. Restriction on the sale of fruit and, thus, on the viability of many producers, would be damaging to each of these communities.

On this basis, the indirect impact of fruit flies on domestic trade and industry was considered likely to be minor at the State or Territory level, which resulted in a rating of C for this criterion.

*International trade effects*

Fruit flies are responsible worldwide for considerable restrictions on the international movement of fruit. The presence of either of the Philippines species would result in the need for Australia to renegotiate international bilateral agreements for many horticulture crops. Market competition for horticulture crops is intense, and renegotiation of market access may lead to losses to Australian producers of a magnitude that would be recognised by the Australian community. On this basis, a rating of D was assigned to this criterion.
Indirect effects on the environment

Fruit flies are unlikely to lead to any indirect impacts on the environment, and a rating of A was thus assigned to this criterion.

Conclusions — the overall impact of fruit flies

The direct and indirect impacts of fruit flies were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of fruit flies are likely to be moderate.

Unrestricted risk estimate

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the Method for Import Risk Analysis. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with fruit flies.

The results of these steps are summarised below.

Probability of importation = Negligible

Partial probabilities of distribution
- Commercial bananas = Low
- Household bananas or other susceptible household plants = Moderate
- Susceptible wild/commercial plants = Moderate

Partial probabilities of establishment
- Commercial bananas = High
- Household bananas or other susceptible household plants = High
- Susceptible wild/commercial plants = High

Partial probabilities of spread
- Commercial bananas = High
- Household bananas or other susceptible household plants = High
- Susceptible wild/commercial plants = High

Probability of entry, establishment or spread (1 tonne) = Negligible
Annual probability of entry, establishment or spread = Very low
Consequences = Moderate

Unrestricted risk = Very low

Because the unrestricted risk falls within Australia’s ALOP (very low) risk management would not be required for fruit flies.
**Hard scales**

Hard scales are insect species that feed by sucking plant sap through their tubular stylets. Heavy infestations may damage plants and are more likely to occur when a species is introduced into a new area without its natural enemies. Many hard scale species are important agricultural pests (Williams and Watson, 1988).

Three species of hard scale were considered in this analysis:

- *Aspidiotus coryphae* Cockerell and Robinson;
- *Aspidiotus excisus* Green; and
- *Pinnaspis musae* Takagi.

In the Philippines, *A. coryphae* has only been reported on *Corypha elata* and *Cocos nucifera* (Munting, 1971) while *A. excisus* has been reported on *Carica papaya*, *Citrus aurantifolia*, other *Citrus* sp., and *Euphorbia* sp. (Williams and Watson, 1988). *Pinnapsis musae*, on the other hand, has been reported only from banana (Takagi, 1963) and only from the Philippines (Miller and Gimpel, 2002). All three species have been identified on Philippines bananas exported to Japan (Sugimoto, 1994), whilst *A. excisus*, and other unidentified Diaspid scales, are frequently intercepted on Philippines bananas exported to New Zealand (Spence, 2002).

Because no published information on the biology of these three species could be identified, the biology of a cogeneric species of *A. coryphae* and *A. excisus*, *A. destructor*, served as a guide for this assessment. A précis of biological information can be found in the datasheet (see Appendix 1: Pest Data Sheet). It is notable that *A. destructor* is able to reproduce without fertilisation (parthenogenesis) to the extent that females produce both male and female progeny.

**Probability of importation**

The risk scenario of concern in this analysis is the infestation of banana skins by adult female hard scales or nymphs — in particular, infestation of skin between the fingers of bananas, or at the crown end of the hand.

Adult female hard scales are sedentary. They attach to vegetative plant surfaces as nymphs, insert their mouthparts into the vascular plant tissue and begin secreting protective armour. The scale cover of the adult female is oval to circular, 1.5-2.0 mm across; fairly flat, very thin and translucent (Williams and Watson, 1988). Eggs are laid beneath the female scale, and remain there until hatched. Mobile first-instar nymphs (called ‘crawlers’) move from under the female and search the plant surface for a suitable point of attachment. Although crawlers may wander for a period of days, they usually settle and become attached to a vegetative surface within hours of leaving the female. Crawlers may be distributed by wind, or by a range of mechanical or biological vectors including propagation material, plantation equipment and personnel.

- Short-range transfer of hard scales is generally attributed to the movement of crawlers, either through their own efforts or by vectors.
- Long-range movement of scales occurs when gravid females are transferred *in situ* with the vegetative material upon which they are feeding.

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40 Of 82 consignments of Philippines bananas inspected in New Zealand between 11 January 2001 and 23 March 2002, 47 were infested with hard scales (Spence, 2002).
It is this second scenario that is of concern in the context of hard green bananas from the Philippines.

**Imp1** — *the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced*

Each of the three species of hard scale has been reported on commercial bananas sourced from the Philippines (Takagi, 1963; Sugimoto, 1994; Spence, 2002). Whilst there is little information regarding the prevalence of affected plantations, scales are considered ubiquitous, and the likelihood that they would be found on the particular plantation from which a tonne of bananas would be sourced was considered **high**.

**Imp2** — *the likelihood that a tonne of harvested fruit will be infected or infested with the pest*

Although there is little data specific to this step, it was known that scales are common in banana plantations in the Philippines, and that they are found frequently on exported bananas (Takagi, 1963; Sugimoto, 1994; Spence, 2002). On this basis, it was considered very likely that scales would be present on a tonne of harvested fruit, and Imp2 was rated as **moderate**.

**Imp3** — *the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station*

The scenario of concern with regard to hard scales was the attachment of hard scales to inaccessible (or less accessible) parts of a hand or cluster. While it is conceivable that newly hatched crawlers might slip through holes in bunch covers and come into contact with banana fruit during the short transport time to the packing station, these crawlers are vulnerable and would not persist through washing and other routine procedures carried out in the packing station, and, thus, were not regarded a risk scenario.

On balance, the likelihood that fruit would become infested during transport was considered **negligible**.

**Imp4** — *the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station*

By the same logic as Imp3, the likelihood that hard scales would successfully attach to banana fruit as they are processed within the packing station was considered **negligible**.

**Imp5** — *the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station*

Inspection procedures carried out in the packing station are concerned primarily with quality standards of fruit as regards blemishes, obvious distortion in shape, premature ripening and visible splits or other lesions. Given this, neither the adult hard scale nor the lesion it produces on the surface of the fruit is easily detected if the scale is attached between banana fingers. The detection of hard scales on arrival of Philippines bananas in New Zealand (Spence, 2002) demonstrates that quality assurance inspectors within the packing station must miss some infested fruit. On this basis, Imp5 was rated as **very low**.
**Imp6** — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

Bananas are sponged or brushed on removal from the de-handing tank in addition to exposure to the chlorine and alum solution in the de-handing and flotation tanks. Scrubbing or brushing will remove most scales from fruit — in particular those nymphs that are less firmly attached, or adults that are attached to the more accessible surfaces of the banana. Attached adults that evade sponging or brushing are likely to be protected from the chlorine and alum solution by their non-living waxy armour. This is borne out by the frequent detection of hard scales on Philippines bananas exported to New Zealand (Spence, 2002).

Because the risk scenario of concern in this assessment was the infestation of banana peel by adult female hard scales or nymphs, it was considered unlikely that the pest would be removed by washing or decontamination procedures undertaken in the packing station. Imp6 was therefore rated as **low**.

**Imp7** — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Of all the bananas presented to quarantine inspectors at the point of loading, the proportion that contains female adult hard scales or nymphs attached between banana fingers was considered to be very low. When this estimate was combined algebraically with the number of fruit that would be inspected in each lot, the likelihood that infestation would be detected at this step was found to be very low. The detection of hard scales on arrival of Philippines bananas in New Zealand (Spence, 2002) demonstrates that quarantine inspectors must miss some infested fruit.

Imp7 was therefore rated as **very low**.

**Imp8** — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Although there are no published data on the survival of hard scales during transport to the wharf and storage prior to export, it is unlikely that the modified atmosphere and high humidity in the partially vacuum packed cartons would affect their viability. It is also unlikely that the storage at 13°C on arrival at the wharf would affect viability. The interception of live scales on arrival of Philippines bananas in New Zealand would suggest that at least a proportion of these scales must survive.

On this basis, it was considered very likely that if present at the point of packing, at least some live adult scales within a tonne of bananas would remain alive after storage and transport to the wharf. Imp8 was therefore rated as **high**.

**Imp9** — the likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. Attached adults and nymphs are likely to survive the transport and the storage, as borne out by the interception of live scales at the New Zealand border.

Overall, there is a **high** likelihood that, if present and viable at the point of departure from the Philippines, at least some live scales within a tonne of bananas would remain alive after transport to Australia.
Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

The difference between this likelihood and that assigned to Imp7 (quarantine inspection prior to transport) would be that despite the slowing of development as a result of cool storage, a proportion of eggs beneath a gravid female might have developed during the period of transport into more visible crawlers (first-instar nymphs).

In consideration of this, Imp10 was rated as low.

Conclusions — probability of importation

When these likelihoods were inserted into the simulation model, the overall probability that a tonne of hard green bananas would be infested with hard scales was found to be low.

Probability of distribution

The initiating step for distribution of hard scales in Australia is the presence of attached adults on imported fruit. The end-point is the exposure of host plants in Australia to mobile crawlers.

Dist1 — the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers

Although published literature is lacking in this area, extrapolation from similar pests suggests that development of nymphs and other pre-adult stages would be slowed or halted by cool storage and ethylene ripening, but that attached adults and nymphs would remain viable within their protective armour. Thus there is a high likelihood that any hard scales that had passed undetected through quarantine at the Australian border would remain viable during storage and ripening and the redistribution of fruit to wholesalers. Dist1 was rated as high.

Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are raised commercially was considered low.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

If imported, bananas from the Philippines would be distributed for sale in all major Australian population centres. It was explained above that the host range for hard scales includes several hosts in addition to bananas. In particular:

- *A. coryphae* has been reported on banana, *Cocos nucifera* and *Corypha elata* (Munting, 1971; Sugimoto, 1994);
- *A. excisus* has been reported on *Carica papaya*, *Citrus aurantifolia*, *Citrus* sp. and *Euphorbia* sp. (Williams and Watson, 1988) as well as bananas; and
- *P. musae* has been reported from *Musa sapiens* and *Musa* sp. (Miller and Gimpel, 2002).

These plants can be found in households or gardens in tropical or subtropical parts of Australia. Additionally, citrus (see *A. excisus*) can be found in temperate parts.
It was shown in the *Method for Import Risk Analysis* that, if distributed according to the
distribution of the Australian population, then approximately 32% of imported bananas would be
distributed to an area in which household banana plants are found. Thus, for a pest *specific to bananas*, Prop2 would be described as moderate. However, because the host range for hard scales includes other household or garden plants, and because some of these can also be found in temperate parts of Australia, this proportion will be increased.

Although Prop2 will differ to some extent amongst the three species examined, it was considered, on balance, very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown. Prop2 was therefore rated **high**.

*Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found*

It was explained in the *Method for Import Risk Analysis*, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood. The hard scales, however, infest several wild and commercially grown hosts in addition to bananas (see above). While the distribution of these hosts is mainly tropical, citrus, in particular, can be found in temperate parts of Australia.

Although Prop3 will differ to some extent amongst the three species examined, it was considered, on balance, very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts can be found. Prop3 was therefore rated as **high**.

*Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment*

Hard scales may enter the environment through two scenarios:

- First, when conditions of temperature and humidity are favourable, crawlers move away from the adult female and search for attachment points on a vegetative surface. This may take minutes to days, but is generally achieved within a few hours. Crawlers are light, and, being dorso-ventrally flattened, may be carried from the plant surface and the immediate environment of the adult female by wind. If suitable hosts in the immediate proximity of the female are abundant, wind may provide an effective means of dispersal. If hosts are not abundant, most crawlers will die.

- Second, the movement of the attached nymph or adult with the plant or plant part to which it is attached. This mechanism is a more effective means of long-distance dispersal, because the adult scales remain protected within their armour.

In the context of *imported bananas*, hard scales may enter the environment through the passive movement of hatched crawlers from the surface of unpacked fruit at the point of sale, or after purchase by the consumer. Alternatively, the attached nymph or adult may enter the environment with discarded banana peel or whole fruit. The nymph or adult would not be motile, and would die with the decay of the banana waste. If gravid, however, the adult could produce eggs that would give rise to crawlers that subsequently would move off the banana waste and onto a suitable plant surface, or be dispersed further by wind.

These processes will form the basis for the remaining likelihoods. Overall, it was considered **virtually certain** that, by one means or the other, hard scales present on imported bananas would enter the environment.
Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of hard scales to move from discarded banana waste, to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of hard scales on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which hard scales can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

Persistence. Adult hard scales and nymphs attached to a vegetative surface can persist in the environment within the protection afforded by their armour. They cannot, however, move from their point of attachment and thus will die as the plant tissue to which they are attached decays. Mobile crawlers are extremely vulnerable, and will be killed by climatic variations beyond those generally classified as tropical or subtropical. Even under the most favourable climatic conditions, crawlers must find, within several days after hatching, a point on a host surface to attach and insert their mouthparts into the vascular tissue.

Distance and dispersal. As discussed, crawlers may enter the environment directly from purchased fruit, or from fruit at the point of sale, or after hatching from a gravid female attached to discarded banana waste. Although dispersal by wind is likely to be relatively effective as a means of dispersal within a banana plantation, crawlers will need to hatch quite close to commercial plants in order to stand a meaningful chance of reaching those plants. Given this, the scenario of greatest concern as regards to direct exposure of commercial bananas would be the disposal of banana waste infested with a gravid female, on a roadside adjacent a banana plantation. Waste that is disposed of through a managed refuse disposal system, or through garden composting systems, may present some hazard to either wild or household plants (see: Dist4 and Dist5 below), but is extremely unlikely to lead to crawlers that have a meaningful chance of directly reaching commercial banana plants.

Exposure of a susceptible host: To successfully infest an exposed commercial banana plant, nymphs would need to develop into adults and attach themselves to a vegetative surface.

On balance, the likelihood that commercial banana plants would be exposed directly to crawlers released from fruit or from banana waste from a tonne of imported fruit, was considered negligible.

Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), Dist4 is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden plant.

The persistence of hard scales, the conditions needed for infestation of susceptible host plants and their means of dispersal have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the distance likely to lie between fruit or discarded waste and a susceptible household plant. Because crawlers are capable of moving short
distances either passively or by their own locomotion, exposure of susceptible garden plants is more likely to occur than exposure of commercial plants. Indeed, the factor limiting the exposure of garden plants in Australia is less likely to be access to suitable hosts, than a poor tolerance of vulnerable crawlers to climatic conditions in much of Australia.

The majority of Australians live in the temperate southern and south-eastern areas of the country, and much of the balance lives in dry hot parts of inland Eastern Australia or coastal Western Australia. Aside from larger centres on the north coast of New South Wales and south coast of Queensland (including Brisbane), a relatively small proportion of the population lives in tropical or subtropical parts of the country. Crawlers released into a tropical or subtropical garden environment would stand a favourable chance of locating and attaching to a vegetative surface on a suitable host. Crawlers of *A. excisus* may have some chance of locating a citrus plant in the temperate areas but crawlers of *A. coryphae* and *P. musae* released into any of Australia’s temperate, arid or semi-arid zones would be unlikely to survive.

On balance, the likelihood that susceptible household or garden plants would be exposed directly to crawlers released from fruit or from banana waste from a tonne of imported fruit was considered extremely low.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

**Dist5** is again similar to Dist3, although focussed on the exposure of susceptible wild (native or feral) plants, including amenity plants and susceptible plants growing on urban or rural roadways. Dist5 also encompasses the exposure of commercially grown plants other than bananas. The factor limiting the exposure of these plants to crawlers released from fruit or from fruit waste is more likely to be the prevailing climatic conditions, than the availability of suitable hosts. In particular:

- Crawlers released into a tropical or subtropical environment would stand a favourable chance of locating and attaching to a vegetative surface on a suitable host; whilst
- Crawlers released into any of Australia’s temperate, arid or semi-arid zones would be unlikely to survive.

On balance, the likelihood that susceptible wild (native or feral) plants, or commercially grown plants other than bananas, would be exposed directly to hard scale crawlers was considered extremely low.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to hard scales that had entered Australia with imported Philippines bananas. These separate estimates were termed 'partial probabilities of distribution'. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Negligible
- Partial probability of distribution for susceptible household plants = Extremely low
- Partial probability of distribution for susceptible wild/commercial plants = Extremely low
Probability of establishment

The probability of establishment examines factors relevant to successful multiplication of the pest, and establishment of disease amongst the exposed plant, or group of plants. The initiation point for establishment of the hard scales from imported fruit in Australia is exposure of host plants to nymphs and adults and the end-point is the successful establishment of these hard scales on any of the exposed plants. To establish on an exposed host plant, nymphs would need to develop into adults and either mate or produce offspring for a second and subsequent generations.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

Commercially cultivated banana plants

If crawlers were to find a host within a commercial banana plantation, the abundance of surfaces on that plant, and the abundance of plants in the immediate proximity, would strongly favour their establishment. Because commercial banana plantations are found in tropical or subtropical parts of Australia, the environment would also favour establishment, and there would be no need for adaptation.

The reproductive strategy and, thus, the persistence of this pest, are based largely on the protective armour of the sedentary gravid female and the ability of the crawlers to disperse through crawling, vectors or wind and locate new hosts. Some species may reproduce parthenogenetically (Philippines Dept. Agriculture, 2001). Eggs and newly hatched crawlers are hidden beneath the female scale. Once outside the protective casing, crawlers are very vulnerable. It is only after attachment of a nymph to a vegetative surface and the formation of armour that the pest is once again protected from the environment. Given this, the likelihood of establishment will be determined to a large degree on the ease with which crawlers can find a suitable point of attachment. It is clear that having reached a commercial banana plantation, crawlers from the index female or its subsequent generations will have little difficulty locating and attaching to suitable hosts.

Cultural and management practices in Australian plantations are less likely to deter hard scales than similar practices undertaken in the Philippines. In particular, the many fewer applications of pesticide would favour hard scales’ ability to colonise new plants or plant surfaces.

On balance, the likelihood of establishment amongst commercial bananas was considered high.

Susceptible household plants

The ability of hard scales to establish within exposed household or garden plants will be governed by similar factors to those discussed in relation to commercial plantations.

Although the precise climate tolerance of hard scales is unknown, they are considered tropical or subtropical pests, and are therefore less likely to establish in cool climates, or hot and dry climates.
In support of this, most known host plants occur predominantly in tropical and subtropical areas. The cultural or management practice relevant to the establishment of scales on household plants is primarily the use of pesticides. Here it is clear that while households do use pesticides, the rate of application is likely to be considerably lower than is the case in Australian commercial plantations.

Overall, the likelihood that hard scales would establish amongst exposed susceptible household or garden plants was considered to be moderate.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

The likelihood of establishment of hard scales on exposed wild (native or feral) plants, or on commercially grown plants other than bananas, would again be dictated largely by climate tolerance. Because the dispersal of hard scales over long distances will be governed by the distribution of gravid adult females attached to banana fruit, their geographic distribution in Australia will approximate the geographic distribution of individual consumers. As discussed previously, most Australian consumers live in temperate parts of Australia where establishment would be less likely than in tropical or subtropical parts.

Overall, the likelihood that hard scales would establish among susceptible wild plants or other commercially cultivated plants was considered to be moderate.

**Probability of spread**

The probability of spread examines factors relevant to the movement of hard scales from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

In the case of hard scales, it is clear that the tropical or sub-tropical environment in the vicinity of commercial banana plantations would favour spread. Furthermore, it is likely that scales would be moved within and between plantations with the movement of equipment and personnel, and that crawlers may be dispersed with wind. The relevance of natural enemies in Australia is unknown, although it is unlikely that predators and parasitoids would be more effective than those in the Philippines.

Overall, the likelihood that hard scales would spread within Australia if they became established among commercial banana plants was considered high.
Susceptible household plants

The spread of hard scales from a point of establishment amongst exposed household or garden plants will be governed largely by their tolerance to the range of Australian climates. In particular, spread from exposed plants in tropical or subtropical areas would be very likely, while spread from exposed plants in temperate or arid or semi-arid areas would be less likely.

On this basis the likelihood that hard scales would spread from a point of establishment among exposed household plants was considered moderate.

Susceptible wild plants, or susceptible cultivated plants other than bananas

Environmental factors will dictate the likelihood of spread of hard scales from a point of establishment amongst exposed wild plants, or commercial plants other than bananas. Notably, whilst spread from a point of establishment in a tropical or subtropical area is likely to occur, spread from temperate or arid/semi-arid areas is less likely.

Overall, the likelihood that hard scales would spread from a point of establishment among wild plants was considered to be moderate.

Consequences

The consequences to the Australian community of the entry, establishment or spread of hard scales were assessed by considering their potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of hard scales was assessed on the basis of their potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of hard scales could be estimated by considering the degree of likely economic impact. For others, their effect could only be assessed in more subjective terms, such as the loss of social amenity.

The direct impact of hard scales

Animal or plant life, or health

This criterion describes production losses associated with the presence of hard scales in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of hard scales have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

Scales do not kill the host plant, nor detract appreciably from its growth. However, the presence of hard scales on banana fruit is considered a blemish and may lead to the rejection of affected fruit. Hard scales are generally localised and do not move over long distances. Further, the known host ranges of these hard scales are mostly restricted to plants growing in tropical or subtropical areas. Therefore their direct impact on plant life or health would be only on plants growing in tropical or subtropical areas including coconut, papaya and some citrus.

Overall, it was assumed that the direct impact of hard scales would be minor at the local level. This gave the pest a rating of A for this criterion.
Human life or health

There are no known direct impacts of hard scales on human life or health, and the rating assigned to this criterion was therefore A.

Any other aspects of the environment not covered above

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical environment or micro-organisms. There are no known direct impacts of hard scales in these directions, and the rating assigned to this criterion was therefore A.

The indirect impact of hard scales

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

The initial response to the detection of one of these species of hard scales in Australia would be to consider eradication and could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. This approach, however, would be unlikely to be adopted because of the low probability of success. Measures to minimise the impact of hard scales on the saleability of banana fruit are likely to include pre-harvest pesticide sprays, and sponging or brushing of individual harvested bananas within the packing station. These measures are, however, no more rigorous than are currently used in Australia, and would not present an additional cost to producers.

On balance, indirect impact of control or eradication of hard scales was considered likely to be minor at the local level, and a rating of A was assigned to this criterion.

Domestic trade or industry effects

Because hard scales are known to be dispersed through infested banana fruit, their presence on commercial banana plantations, or on other susceptible fruit crops, would lead to restrictions on the sale of fruit and in particular, on restrictions on the movement of fruit between affected and unaffected States or Territories. Trade restrictions of this sort can destabilise individual producers or groups of producers, and can impact on the stability of established domestic markets.

In view of this, the indirect impact of hard scales on domestic trade was considered likely to be minor at the district level, and a rating of B was assigned to this criterion.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market. However, the hard scale A. excisus is also a pest of coconut and citrus particularly growing in tropical and subtropical areas. Australia exports some citrus from tropical and sub-tropical areas. A. excisus has not been reported in the United States, and while hard scales are generally only considered in terms of fruit quality, its presence in Australian citrus orchards might complicate current trade arrangements. The other hard scales considered in this analysis are unlikely to have similar impacts.

Overall, the indirect impact of the hard scales on international trade was considered likely to be minor at the district level, and a rating of B was therefore assigned to this criterion.
Indirect effects on the environment

Although additional pre-harvest pesticide applications may be required to control scales on marketable fruit, this is unlikely to impact on the environment. A rating of A was therefore assigned to this criterion.

Conclusions — the overall impact of hard scales

The direct and indirect impacts of hard scales were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of hard scales are likely to be very low.

Unrestricted risk estimate — hard scales

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the Method for Import Risk Analysis. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with hard scales.

The results of these steps are summarised below.

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial probabilities of distribution</td>
<td></td>
</tr>
<tr>
<td>• Commercial bananas</td>
<td>= Negligible</td>
</tr>
<tr>
<td>• Household bananas or other susceptible household plants</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>• Susceptible wild/commercial plants</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>Partial probabilities of establishment</td>
<td></td>
</tr>
<tr>
<td>• Commercial bananas</td>
<td>= High</td>
</tr>
<tr>
<td>• Household bananas or other susceptible household plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>• Susceptible wild/commercial plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Partial probabilities of spread</td>
<td></td>
</tr>
<tr>
<td>• Commercial bananas</td>
<td>= High</td>
</tr>
<tr>
<td>• Household bananas or other susceptible household plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>• Susceptible wild/commercial plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Probability of entry, establishment or spread (1 tonne)</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>Annual probability of entry, establishment or spread</td>
<td>= High</td>
</tr>
<tr>
<td>Consequences</td>
<td>= Very low</td>
</tr>
</tbody>
</table>

**Unrestricted risk** = Very low

Because the unrestricted risk falls within Australia’s ALOP (very low) risk management would not be required for hard scales.
**Mealybugs**

Mealybugs are insect pests that feed by sucking plant sap through their tubular stylets. Heavy infestations may damage plants directly, while indirect damage may result from the ability of some mealybugs to vector plant viruses. Many mealybug species pose particularly serious problems to agriculture when introduced into new areas of the world without their specific natural enemies (Miller et al., 2002).

Three species of mealybugs were assessed in this analysis:

- *Dysmicoccus neobrevipes* Beardsley;
- *Pseudococcus jackbeardsleyi* Gimpel and Miller; and
- *Rastrococcus invadens* Williams.

All three species are considered polyphagous, in that they feed on a variety of host plants.

*Dysmicoccus neobrevipes*: this mealybug (also called the ‘Annona mealybug’ or ‘grey pineapple mealybug’) has been recorded on more than 50 plant host species in 33 genera (Ben-Dov and German, 2002). These include some economically important crops, such as bananas and pineapples (Philippines Dept. Agriculture, 2001; Kessing and Mau, 1992). It is known to be a pest of commercial bananas in the Philippines (Philippines Dept. Agriculture, 2001) and may be found on the aerial parts of plants including the fruit clusters (Kessing and Mau, 1992). Moreover, it is known to vector pineapple mealybug wilt-associated closterovirus (German et al., 1992) and it is also implicated as causing green spot on pineapple (Beardsley, 1965).

*D. neobrevipes* is considered to be native to Neotropical region (Miller et al., 2002) and has now been recorded in many other parts of the world such as North America, Southeast Asia and Italy (Ben-Dov and German, 2002).

*D. neobrevipes* has been detected during quarantine inspections of Philippine banana fruit imports into New Zealand (Spence, 2002).

*D. neobrevipes* is closely related to *D. brevipes*, which is found in Australia (Williams, 1985). Because it is generally *D. neobrevipes* that is responsible for the pineapple reaction ‘green spotting’, and because this physiological reaction has been reported in Australia (Carter, 1942), it has been suggested (Philippines Dept. Agriculture, 2001) that *D. neobrevipes* can also be found in Australia. However, Williams (1985) examined numerous specimens from Queensland, New South Wales, Western Australia and Northern Territory, and found only *D. brevipes*. In addition, Ben-Dov and German (2002) do not include Australia in the distribution of *D. neobrevipes* and show that whilst the two species do coexist in some countries, *D. brevipes* is substantially more widespread. On this basis, *D. neobrevipes* was considered as not present in Australia.

Most work on the biology of *D. neobrevipes* has been done in the context of pineapple production. Indeed, no reports of its biology and interaction with bananas were identified (Philippines Dept. Agriculture, 2001). Given this, the biological information summarised below is based largely on Ito (1938) and Beardsley (1959). Additional information on this pest can be found in the datasheet (see Appendix 1: Pest Data Sheets).

- *D. neobrevipes* reproduces sexually, and mating must occur for young to be produced. Eggs hatch within the body of the female, to give fully developed ‘first-instar’ nymphs, or ‘crawlers’.
- First-instar nymphs are the principal dispersal stage. They crawl on and between plants, and may also be dispersed by wind.
• The lifespan of females varies from 59 to 117 days, with an average of 90 days (Kessing and Mau, 1992). There are three female nympha stages, which develop over a period of 26 to 52 days (averaging about 35 days), and an adult stage, which persists for 48 to 72 days (averaging about 61 days). Gravid adult females produce nymphs for about 30 days. Each female typically produces about 350 nymphs, although up to 1000 is possible.

• The lifespan of males is shorter. The male moults four times during development, and, because the second, third and fourth moults take place inside a wax cocoon, feeding is limited to the first and second stages. The total male nymphal period varies from 22 to 53 days. When the adult male emerges from the cocoon, it is a fragile insect about 1mm long with a pair of membranous wings. It has no mouthparts, and lives for 2 to 7 days. It is widely assumed that most mealybug males locate females by a pheromone.

Pseudococcus jackbeardsleyi: this mealybug has been found on more than 110 plant host species in 45 genera (Ben-Dov and German, 2002). These include, commercially grown bananas, tomatoes, potatoes and peppers. *P. jackbeardsleyi* has been found in Philippines bananas exported to Japan (Sugimoto, 1994), although little is known of its distribution and occurrence on commercially grown bananas in the Philippines. It is found on each of the aerial parts of plants; including the fruit clusters.

*P. jackbeardsleyi* is considered to be native to Neotropical region (Miller et al., 2002) and has now been introduced into other countries in North America, Southeast Asia and pacific countries (Ben-Dov and German, 2002).

Reports on the biology of *P. jackbeardsleyi* on commercially grown bananas were not identified. However, *P. jackbeardsleyi* had been misidentified as *Pseudococcus elisae* in the literature (Ben-Dov and German, 2002). Thus much published information on *P. elisae* (including the study of *P. elisae* in the Philippines) should actually be related to *P. jackbeardsleyi* (CABI, 2002; Mau and Kessing, 1993b) and these data were used for the précis of pest biology below. Further details on *P. jackbeardsleyi* can be found in the data sheet (see Appendix 1: Pest Data Sheets).

• *P. jackbeardsleyi* belongs to a group of short-tailed mealybugs that reproduce by laying eggs (Mau and Kessing, 1993b).

• Females are pinkish in colour, and oval in shape. The adult female lays her eggs in a waxy ovisac attached to the host plant. Eggs are produced for 1 to 2 weeks, after which the females die. Mealybugs belonging to the short-tailed group can lay 300 to 600 eggs.

• Male second instars form a waxy sac and pass through two more non-feeding instars (the pre-pupa and pupa) before emerging as winged adults. Adult males cannot feed, and usually survive for little more than a day. It is assumed that most mealybug males locate females by a pheromone.

• First instar nymphs are the main dispersal stage. They crawl on and between plants but may also be dispersed by wind.

Rastrococcus invadens: this mealybug has been reported on more than 100 plant host species in 28 genera (Ben-Dov and German, 2002). In Africa, it is a major pest of mangos, citrus and many other plants (Agounké and Fischer, 1993). Whilst *R. invadens* has not been reported on Philippines bananas (Philippines Dept. Agriculture, 2002a) nor has it been recorded in quarantine interception data collected about Philippines bananas from New Zealand or Japan (Sugimoto, 1994; Spence, 2002), it has been recorded on bananas grown commercially in other countries (Ben-Dov and German, 2002). Because there have not been recent surveys of Philippines bananas for this pest, and because it is known to inhabit other fruit crops, *R. invadens* was considered relevant to this
analysis. A review of its status as a quarantine pest of Philippines bananas would be undertaken in the light of scientific evidence to the contrary.

*R. invadens* is considered to be native to the Orient and was introduced into Western Africa (Williams, 1986).

The précis of biological information provided below has been extracted from CABI (2002). Further details can be found in the datasheet (see *Appendix 1: Pest Data Sheets*).

- *R. invadens* reproduces sexually, and mating must occur for young to be produced. Eggs hatch within the body of the female, to give fully developed ‘first-instar’ nymphs, or ‘crawlers’.
- Slight differences can be observed between male and female second-instar nymphs.
- The lifespan of females may be as long as 225 days. There are three female nymphal stages, which develop over a period of 25 to 27 days, and an adult stage, which persists for up to 200 days. Each female may produce up to 200 first-instar nymphs.
- The male nymphal period varies from 28 to 31 days. Third instar nymphs form a cocoon, from which the winged and fragile adult male emerges. Adult males can mate on emergence, although live for no longer than a few days. It is widely assumed that most mealybug males locate females by a pheromone.

In this analysis, assessments for groups of similar arthropod pests have generally been combined (see Fruit Flies, Hard Scales, Spider Mites and Weevils). However, because there are some differences in the biology and occurrence of these three species of mealybug, and in the severity of the consequences associated with their introduction into Australia, some stages of the group assessment have been split into separate species-specific estimates. This has resulted in separate risk estimates.

**Probability of importation**

The risk scenario of most relevance to mealybugs is the presence of gravid females carried on hard green banana fruit, particularly in the protected spaces between the individual fingers in fruit clusters. Other life stages of mealybugs (egg sacs (*P. jackbeardsleyi*), adult females, nymphs and cocoons containing male nymphs) may also be associated with the importation pathway but have less chance of finding a mate in order to establish a second generation. These life stages will be considered where appropriate.

**Imp1 — The likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced**

Although their abundance in the Philippines varies with the season, and is likely to be highest during periods of higher rainfall. *D. neobrevipes* (Philippines Dept. Agriculture, 2001) and *P. jackbeardsleyi* (Sugimoto, 1994) are considered common pests of Philippines bananas. *R. invadens* has not been reported on Philippines bananas (Philippines Dept. Agriculture, 2002a), although, as explained above, is a pest of other tropical plants in the Philippines, and has been reported on bananas in other countries.

On balance, the likelihood that either *D. neobrevipes* or *P. jackbeardsleyi* would be present on a tonne of fruit was considered to be **high**, whilst the likelihood that *R. invadens* would be present was considered to be **very low**.
Imp2 — *The likelihood that a tonne of harvested fruit will be infected or infested with the pest*

Whilst it is acknowledged that the Philippines banana industry employs measures in the field to minimise infestation of export fruit with mealybugs, they are nevertheless found with hard green fruit at the point of harvest. This is borne out by the fact that mealybugs are identified and removed within packing stations (Philipine Dept. Agriculture, 2001) and have been intercepted on Philippines fruit imported into Japan (Sugimoto, 1994) and New Zealand (Spence, 2002).

More specifically, live *D. neobrevipes* were detected in 36 of 82 and 4 of 25 consignments of Philippines bananas inspected in New Zealand in the period 11 January 2001 to 21 March 2002 and 13 January to 14 May 2003, respectively while 16 of these 107 consignments were infested with unidentified species of Pseudococcidae (Spence, 2002; Herrera, 2003).

*R. invadens* has not been found on exported fruit, and its incidence on bananas at the point of harvest is likely to be much lower than that either *D. neobrevipes* or *P. jackbeardsleyi*.

On balance, the likelihood that either *D. neobrevipes* or *P. jackbeardsleyi* would be present in a tonne of harvested fruit was considered to be moderate, whilst the likelihood that *R. invadens* would be present was considered to be extremely low.

Imp3 — *The likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station*

The likelihood that harvested fruit would become infested during transport to the packing station may vary depending on whether the packing station is mobile or permanent.

- Where a mobile facility is used, bunch covers are removed, bunches are de-handed in the field and hands are carried to the packing station on padded stretchers. In this situation, it is was considered extremely unlikely that fruit could become infested with adult mealybugs or crawlers that have been dislodged from fruit, plants or leaves by the process of harvest, and have subsequently collected on stretchers or on the hands of plantation workers.

- Where a permanent facility is used, harvested bunches are placed on a cableway and transported without further handling to the packing station. Bunch covers remain in place until fruit arrives at the packing station. At that point, covers are removed and bunches are de-handed into a tank containing a chlorine and alum solution. In this situation infestation is considered negligible, because: (a) dislodged adults or crawlers would not collect on a common surface, (b) handling by plantation workers is minimal, and (c) bunch covers (most of which are impregnated with insecticide) remain in place until fruit reaches the packing station, and would protect the fruit from wind-borne crawlers.

When these opportunities for infestation were correlated with the fact that approximately 10% of Philippines plantations use mobile facilities\(^{41}\), the likelihood that a tonne of harvested fruit would become infested with *D. neobrevipes*, *P. jackbeardsleyi* or *R. invadens* during transport to the packing station was rated as extremely low.

\(^{41}\) The IRA team acknowledge that the Philippines Department of Agriculture have indicated in their submission to the June 2002 Draft IRA Report that field de-handing for mobile packing stations is being discontinued. This is contrary to advice (Philippines Scientific Delegation, 2002a) that the use of mobile packing stations is increasing. When the practice has stopped the likelihood estimate for this importation step may be revised.
**Imp4 — The likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station**

Infestation of fruit within the packing station would require adult female mealybugs or crawlers to be present in the de-handing tank or the flotation tank, or crawlers to be carried by wind from the plantation to fruit that has completed processing and is waiting to be packed. Although the chlorine and alum solution within both the de-handing and flotation tanks is unlikely to kill mealybugs, infestation during this process would require an unfeasibly high density of mealybugs. Likewise, it is not conceivable that crawlers borne by wind would by chance come to rest on processed bananas waiting to be packed. Overall, the likelihood of infestation at this step of the pathway was considered to be **negligible**.

**Imp5 — The likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station**

Inspection procedures carried out in the packing station are concerned primarily with quality standards of fruit as regards blemishes, obvious distortion in shape, premature ripening and visible splits or other lesions. Although all fruit are visually inspected, the procedures are not specifically directed at the detection of small arthropod pests present between the fingers of fruit clusters. This is borne out by the New Zealand interception data (Spence, 2002), which show that mealybugs remain undetected on exported fruit throughout all of the steps in the importation pathway.

Under these circumstances, it was considered that there is a **low** likelihood that all mealybugs present on a tonne of fruit would be detected and infested fruit removed as a result of visual quality inspection.

**Imp6 — The likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station**

Washing and brushing (or sponging) of fruit in the packing station is aimed at dislodging arthropod pests such as mealybugs, as well as at the removal of leaf trash and sooty mould. Washing and brushing would be likely to remove most mealybugs on the visible portions of banana fruit. Those lodged between individual fingers in fruit clusters would be protected.

Further, while mealybugs may be affected by the solution of chlorine and alum in the de-handing and flotation tanks, they are unlikely to be destroyed by it. This is particularly true of those adult females or nymphs that have found protective spaces between fingers or are protected by waxy cocoons.

Overall, it was considered that there is a **low** likelihood that all mealybugs present on a tonne of fruit would be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station.

**Imp7 — The likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf**

Although adult female mealybugs and larger nymphs on the surface of fruit are easily detected, the interception of mealybugs in Philippines bananas exported to Japan (Sugimoto, 1994) and New Zealand (Spence, 2002) indicates that adult females and nymphs can evade inspection.

On this basis, the likelihood that adult female mealybugs or nymphs in spaces between banana fingers would be detected by Philippines quarantine staff and subsequently removed from the pathway was considered to be **extremely low**.
Imp8 — The likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

Although the atmosphere surrounding fruit packed within a polyethylene bag in cartons would be modified by respiration and enclosure, it is not expected that either adult mealybugs or nymphs would be adversely affected. This is borne out by the reported detection of live mealybugs on arrival in Japan and New Zealand (Sugimoto 1984; Spence 2002).

On this basis, the likelihood that mealybugs would remain viable during transport to the wharf and after storage prior to export was considered high.

Imp9 — The likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks, and (b) bananas would be kept in cool storage (13°C) throughout the voyage. Evidence regarding the tolerance of adult mealybugs or crawlers to a prolonged period of modified atmosphere and cool storage could not be found. However, it is clear that the presence of viable mealybugs on fruit exported to New Zealand (Spence, 2002) would indicate that at least some of these pests must survive.

Overall, it was considered that there is a high likelihood that viable mealybugs present in a tonne of fruit at the point of departure from the Philippines would remain viable on arrival in Australia.

Imp10 — The likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

As explained above, fruit may take up to 2 weeks to travel from the Philippines to Australia and important changes in the population and distribution of mealybugs may have occurred during transport:

- adult males would be expected to die as they are short-lived but adult females, and male nymphs within cocoons would be likely to remain viable (female *R. invadens* may live for up to 225 days);
- crawlers and nymphs may advance to a later stage of development;
- female nymphs may become adults, and seek out protected spaces between the fingers of bananas or in other parts of the container; and
- male crawlers may develop into the dormant and cocooned later stage nymphs, or even into adults.

Overall, while some of these mealybugs would be visible to AQIS inspectors, many would have sought out spaces between the individual fingers in fruit clusters. On balance it was considered that there would be a very low likelihood that mealybugs in a tonne of bananas would be identified by AQIS inspection on arrival in Australia.

Conclusions – probability of importation

When these likelihoods were inserted into the simulation model, the overall probability that a tonne of hard green bananas would be infested with these mealybugs was found to be low for *D. neobrevipes* and *P. jackbeardsley* and extremely low for *R. invadens*.
Probability of distribution

The initiation point for distribution of mealybugs in Australia is the presence of mealybugs on imported fruit. The end-point of distribution is exposure of host plants to the nymphs and adults.

**Dist1 — The likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers**

Although reports on the survival of mealybugs on stored and ripened banana fruit were not identified, some species of mealybugs, for example, *Planococcus citri* (Risso), have been reared successfully in the laboratory on other fruit or vegetable substrates, in particular, pumpkin (Gullan, 2000). In addition, cool storage with 3-7 days of ripening at about 18°C and 95% humidity are unlikely to be fatal to mealybugs.

On balance, the likelihood that mealybugs that had survived to this point within a tonne of imported fruit, would persist through storage and ripening and distribution of fruit to wholesalers, was considered **high**.

**Prop1 — The proportion of imported bananas that is likely to be distributed to an area in which commercial bananas are grown**

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are raised commercially was considered to be **low**.

**Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found**

It was explained in the introductory text that mealybugs are polyphagous pests, and that the particular species considered in this assessment are known to feed on wide variety of hosts in a wide variety of genera. Whilst there are some differences in host range amongst the three species, hosts generally include tropical fruits, citrus and many common garden vegetables. These hosts can be found in households in tropical and subtropical parts of Australia, and, to a lesser extent, some temperate parts.

It was shown in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest specific to bananas, Prop2 would be described as moderate. However, because the host range for mealybugs is so broad, this proportion will be increased.

Overall, it was considered very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown, and Prop2 was therefore rated **high**.

**Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found**

It was explained in the Method for Import Risk Analysis, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood.

As stated above, the mealybugs of interest in this assessment are polyphagous with host ranges that include, aside from bananas, a great many fruits and vegetables as well as weed species. Many of
these plants may be found as amenity plants in urban public gardens, occurring naturally in parks and preserves or by urban or rural roadsides, and many are also grown commercially. Although these plants would be more common in tropical and subtropical areas of Australia, the range is sufficiently broad to be confident that at least one host species would be growing wild or commercially in most parts of the country.

Overall, it was considered very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts can be found. Prop3 was therefore rated as high.

**Dist2** — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Mealybugs may enter the environment through three scenarios:

- Adult females (sometimes with egg sac) and nymphs may be discarded with banana peel or fruit.
- Crawlers may be discarded with waste cartons and liners.
- Crawlers may be blown by wind, or carried by other vectors, from bananas at the point of sale or after purchase.

Given these pests would be present on the surface of discarded peel, cartons or liners, it was considered virtually certain that any mealybugs imported with bananas would enter the Australian environment.

**Dist3** — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of mealybugs to move from the point of entry into the environment to a suitable entry site on a commercial banana plant. Of particular relevance are:

- The persistence of mealybugs in or on fruit, or in the environment;
- The distance between discarded banana waste and a commercial banana plant;
- The means by which mealybugs might move from fruit or packaging to a commercial banana plant; and
- The conditions needed for exposure of commercial banana plants.

**Persistence.** The life span of female *D. neobrevipes* ranges from 59 to 117 days with an average of 90 days (Kessing and Mau, 1992). The lifespan of *R. invadens* may be even longer, while that of *P. jackbeardsleyi* may be only about 14 days. Adult males are winged and motile, and serve a reproductive purpose only. They are fragile and short lived and do not persist more than several days. A source of male mealybugs would depend on maturation of male nymphs, which hatch from gravid females or egg sacs that had been discarded with the banana waste.

Survival of motile life stages of mealybugs is dependent on the host substrate continuing to provide a source of food. In the case of bananas, waste is generally expected to decay within a few days, hence motile mealybugs associated with discarded imported bananas would have only a few days to find an alternative host substrate.

**Distance and dispersal.** As discussed above, crawlers may enter the environment directly from purchased fruit, from fruit at the point of sale, or after hatching from a gravid female or egg sac attached to discarded banana waste. Although dispersal by wind is likely to be relatively effective
as a means of dispersal within a banana plantation, crawlers would need to be hatched quite close to commercial banana plants in order to stand a meaningful chance of initially exposing those plants. There are no data to indicate the likely distance that a mealybug may crawl or be carried on wind but the general understanding is that the pest would need to be placed within a metre or two of a potential host plant in order to have any chance of successfully reaching it.

**Exposure of a susceptible host.** The mealybugs examined in this assessment are polyphagous, and thus able to derive substrate from a range of tropical and subtropical plants. To establish on an exposed host plant, a nymph would need to develop into an adult, mature and mate. Adult females would need to give birth to a second generation of crawlers (*D. neobrevipes* and *R. invadens*), or lay eggs in an ovisac (*P. jackbeardsleyi*) and the eggs then hatch to become crawlers to initiate this process.

Given this, the scenario of greatest concern as regards direct exposure of commercial bananas would be the disposal of banana waste infested with a gravid female or egg sac, on a roadside within a metre or two of a banana plant. Waste that is disposed of through a managed refuse disposal system, or through garden composting systems, may present some hazard to either susceptible wild or household plants (see Dist4 and Dist5 below), but is extremely unlikely to lead to crawlers that have a meaningful chance of reaching commercial banana plants. The likelihood is even less for older nymphs or adult females.

When these points were collated, it was considered that there would be an extremely low likelihood that commercial banana plants would be exposed directly to mealybugs released from fruit or from banana waste.

**Dist4** — *the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment*

As was the case for Dist3 (see above), **Dist4** is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant – in this case, a household or garden plant.

The persistence of mealybugs, the conditions needed for infestation of susceptible host plants and their means of dispersal have been discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the difference in climatic conditions among population centres in Australia where susceptible hosts may be found, and the distance likely to lie between fruit or discarded waste and a susceptible household plant. From the distribution records of these species, it is clear that they are found mainly in the tropical and subtropical areas of the world (see *Appendix 1: Pest Data Sheets*). However, considering that *R. invadens* is also a pest of citrus, it would be able to live in most areas where citrus is grown, including some temperate areas of Australia.

- Gravid adult female mealybugs introduced on fruit from the Philippines would be most fecund and persistent in tropical or subtropical conditions, and particularly during periods of higher rainfall. They are likely to persist in most Australian environments for the period required for crawlers to hatch and disperse. The survival of crawlers and nymphs to maturity is much less certain, although likely to extend to the period required for dispersal and the location of a suitable host. Adult males are short-lived and would have to be derived from gravid females or egg sacs associated with discarded banana waste.
- The distance likely to lie between a gravid female and a susceptible garden plant would be
determined largely by waste disposal patterns. It is known that most bananas would be consumed in the major population centres, and that most waste generated in these centres is managed through refuse disposal facilities. The balance is managed through garden compost, or discarded randomly into the environment. Mealybugs are unlikely to survive either managed refuse disposal sites or composting, and banana waste that is discarded randomly is more likely to lie in the general environment than within a household or garden.

- The distance likely to lie between crawlers hatched directly from an egg sac or gravid female on fruit at the point of sale or in households is extremely variable. Crawlers that are separated from fruit at the point of sale, are less likely to contact a susceptible household plant than those that stay on purchased fruit to the point of disposal. Bananas are not generally refrigerated, and opportunity would also exist for crawlers to be carried by wind from the household to its immediate environment, which may include susceptible plants.

Given this, the scenario of greatest concern as regards direct exposure of household bananas and other susceptible household plants would be the disposal of banana waste infested with a gravid female or egg sac within a metre or two of a susceptible host plant. While such waste may be discarded closer to these plants than to commercial bananas, it is very unlikely to lead to crawlers that have a meaningful chance of reaching a suitable host plant.

When these points were collated, it was considered very unlikely that household banana plants and other susceptible plants would be exposed directly to mealybugs released from fruit or from banana waste. Dist4 was therefore rated as **very low**.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

**Dist5** is again similar to Dist3 and 4, although focused on the exposure of susceptible wild (native or feral) plants or susceptible commercial plants (other than bananas). As stated above, the mealybugs of interest in this assessment are polyphagous with host ranges that include, aside from bananas, a great many fruits and vegetables as well as weeds. Many of these plants may be found as amenity plants in urban public gardens, occurring naturally in parks and preserves or by urban or rural roadsides, and many are also grown commercially. The factors limiting the exposure of these plants to mealybugs released from fruit or from fruit waste include the prevailing climatic conditions, the abundance of suitable hosts and the distance likely to lie between mealybugs and hosts have already been discussed and need not be re-iterated.

Given this, the scenario of greatest concern as regards direct exposure of wild or feral bananas, or other commercially grown crops would be the disposal of banana waste infested with a gravid female or egg sac, on a roadside or in a public park or garden within a metre or two of a susceptible host plant. Waste that is disposed of through a managed refuse disposal system, or through garden composting systems, may also present some hazard to other susceptible wild plants.

When these points were collated, it was considered very unlikely that susceptible wild (native or feral) plants or commercial plants other than bananas would be exposed to mealybugs associated with banana waste. Dist5 was therefore rated as **very low**.

**Conclusions – probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild or commercial plants (other than bananas)
would be exposed to mealybugs that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Extremely low
- Partial probability of distribution for susceptible household plants = Very low
- Partial probability of distribution for susceptible wild/commercial plants = Very low

**Probability of establishment**

The initiation point for establishment of mealybugs from imported fruit in Australia is the exposure of the host plants to the nymphs or adults and the end-point is the successful establishment of these mealybugs on any of the exposed plants. For mealybugs, establishment means that the nymphs that initially infested an exposed host plant have matured, mated and adult females have produced a second generation of crawlers on the host plant by giving birth directly (*D. neobrevipes* and *R. invadens*) or through the production of eggs (*P. jackbeardsleyi*).

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts
- The suitability of the environment
- The potential for adaptation of the pest
- The reproductive strategy of the pest
- The method of pest survival
- Cultural practices and control measures.

**Commercially cultivated banana plants**

If nymphs (crawlers) were to find a host within a commercial banana plantation, the abundance of surfaces on that plant, and the abundance of other plants in the immediate proximity, would strongly favour their establishment. Because commercial banana plantations are found in tropical or subtropical areas of Australia, the environment would also favour establishment, and there would be no need for adaptation.

The reproductive strategy, and thus persistence, of these pests is based largely on the longevity and fecundity of the adult female, the mobility of the short-lived adult male and the ability of the first-instar nymphs to disperse through crawling, vectors or wind and locate new hosts. This strategy is successful in banana plantations and fruit crops in the Philippines, where there are established populations of mealybugs, but would not be equally successful for a relatively very small number of mealybugs introduced into a new environment (in this case Australia) given the fragility of adult males and their very short life span (1 to 7 days depending on species). The many fewer applications of pesticides in Australian plantations compared to plantations in the Philippines, however, would favour the pests’ ability to colonise hosts.

Many mealybug are considered invasive and have been introduced into new areas and established (Miller *et al*., 2002). These three species belong to this group and have shown that they have the ability to establish after being introduced into new environments. For example, *D. neobrevipes* is native to the Neotropics (Miller *et al*., 2002) and has now established in North America, Southeast Asia and Pacifics.
Nevertheless, when these observations were collated, it was considered very unlikely that a female nymph would both survive to maturity on a commercial banana plant and mate successfully with a mature male to complete at least one generation after release into the environment. The likelihood of establishment at this point was therefore rated as very low.

**Susceptible household plants**

The ability of mealybugs to establish within exposed household plants would be governed by similar factors to those discussed in relation to commercial plantations, in particular, the environmental conditions that affect initial feeding and the reproductive strategy of mealybugs.

Mealybugs can find suitable hosts among most tropical and subtropical fruiting plants, as well as on various weed species. These hosts can be found in households in tropical and subtropical parts of Australia, and, to a lesser extent, some temperate and arid parts. As previously explained, the persistence and fecundity of adult females and the dispersal of crawlers dominate the reproductive strategy. However, while this strategy is successful in the Philippines, where there are established populations of mealybugs, it would not be equally successful for a relatively very small number of mealybugs introduced into a new environment (in this case Australia) given the fragility of adult males and their very short life span (1 to 7 days depending on species). Establishment would also hinge on the compatibility of the environment.

- Establishment would be very likely to occur under tropical or subtropical conditions, particularly during periods of higher rainfall.
- Establishment may also be likely to occur under some temperate conditions, as many host plants such as citrus are available in household situations.

This trend may be altered in some circumstances by the use of household insecticides or other practices.

When these observations were collated, it was considered very unlikely that a female nymph would both survive to maturity on a household banana or alternative garden plant and mate successfully with a mature male to complete at least one generation after release into the environment. The likelihood of establishment at this point was therefore rated as very low.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Because of their polyphagous nature, it is the reproductive strategy of mealybugs and the environment that would govern the establishment of mealybugs within exposed plants of this host group.

As was the case for household plants (see above), establishment would be very likely to occur under tropical or subtropical conditions and particularly during periods of higher rainfall, but less likely under some more temperate conditions, or in the drier and hotter areas. Whilst there are some differences in host range amongst the three species, hosts generally include tropical fruits, citrus and many common garden vegetables. These plants are grown commercially or as amenity plants in tropical and subtropical parts of Australia, and, to a lesser extent, some temperate parts. Of particular note are pineapples and citrus that are cultivated commercially in coastal areas of Queensland, New South Wales and Western Australia.

As previously explained, the persistence and fecundity of adult females and the dispersal of crawlers dominate the reproductive strategy. However, to reiterate, while this strategy is successful in the Philippines, where there are established populations of mealybugs, it would not be
equally successful for a relatively very small number of mealybugs introduced into a new environment (in this case Australia) given the fragility of adult males and their very short life span (1 to 7 days depending on species).

When these observations were collated, it was considered very unlikely that a female nymph would both survive to maturity and mate successfully with a mature male on a susceptible wild plant, or cultivated crop host (other than banana) to complete at least one generation after release into the environment. The likelihood of establishment at this point was therefore rated as very low.

**Probability of spread**

The probability of spread examines factors relevant to the movement of mealybugs from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia. The initiation point for spread of mealybugs is their successful establishment as defined above, and the end-point is the spread of nymphs to another host plant (adults and nymphs could be physically carried by ants etc from one plant to another).

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment on an exposed plant, or group of plants. These are:

- The suitability of the natural and/or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

**Commercially cultivated banana plants**

Once second and then subsequent generations of mealybugs are established on a commercial banana plant, mealybugs are likely to persist indefinitely and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and by the movement of plant material. It is very unlikely that mealybugs would be contained by management practices or by regulation.

Overall, there is a **high** likelihood that mealybugs would spread if they became established among commercial banana plants.

**Susceptible household plants**

Once second and then subsequent generations are established on a susceptible household plant, mealybugs are likely to persist indefinitely and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and by the movement of plant material. It is very unlikely that mealybugs would be contained by management practices or by regulation.

Overall, there is a **high** likelihood that mealybugs would spread if they became established among susceptible household plants.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Once second and then subsequent generations are established on susceptible wild plants, or commercially cultivated plants (other than bananas), mealybugs are likely to persist indefinitely
and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and, in the case of commercially cultivated crops, by the movement of plant material. It is very unlikely that mealybugs would be contained by management practices or by regulation.

Overall, there is a high likelihood that mealybugs would spread if they became established among commercial banana plants.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of mealybugs were assessed by considering their potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of mealybugs was assessed on the basis of their potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of mealybugs could be estimated by considering the scale of likely economic impact. For others, their affect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of mealybugs**

*Animal or plant life, or health*

This criterion describes the production losses associated with the presence of mealybugs in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of mealybugs have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

Mealybugs have two forms of direct impact on bananas and other susceptible crops.

- Firstly, through feeding on leaves, stems and fruit they reduce the quantity and quality of marketable product from a wide variety of tropical and subtropical crops. The severity of impact appears to differ in the countries in which the mealybugs considered in this analysis are found. For example, *R. invadens* is considered in Africa to be a serious insect pest of mangos, citrus, of various horticultural crops and of shade trees because of lack of natural enemies there. Many attempts have been made to introduce effective natural enemies into Africa and some have been successful (Moore and Cross, 1993). The same pest is not considered of economic importance in India (Williams, 1986), possibly because this species may have originated there and its natural enemies may keep it under control. The severity in Australia of this form of direct impact is thus difficult to estimate, but the situation may be similar to that in Western Africa where effective natural enemies were not present. In addition, the polyphagous nature of mealybugs is of concern.

- The second form of direct impact on crop production results from vectoring or transmission of plant diseases. *D. neobrevipes*, for example, is known to vector pineapple mealybug wilt-associated closterovirus (German *et al.*, 1992) and may vector banana streak disease (Lockhart and Jones, 2000). It is also implicated with a physiological reaction on pineapple known as green spot (Beardsley, 1965; Kessing and Mau, 1992). Introduction of this mealybug may therefore result in the entry, establishment or spread of these important diseases, and exacerbate the difficulty of their control in Australia.
Because the complete host range of these mealybugs is not known, their direct impact on the Australian environment was difficult to estimate. It is known, however, that many tropical and subtropical native species would be susceptible including native *Musa* species, and that environmental conditions where these plants grow would favour the establishment and spread of mealybugs.

As a counter to the direct effects of the three mealybug species considered in this assessment, bananas and other susceptible plants are already subject to infestation by a range of other mealybug species that cause direct damage and vector the nominated viruses. This diminishes the effects of the introduction of other mealybug species.

Overall, the direct impact of these three mealybugs was considered likely to be minor at the State or Territory level and the rating of C was assigned to this criterion.

**Human life or health**

There are no known direct impacts of mealybugs on human life or health, and the rating assigned to this criterion was therefore A.

**Any other aspects of the environment not covered above**

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical environment or micro-organisms. There are no known direct impacts of mealybugs in these directions, and the rating assigned to this criterion was therefore A.

**The indirect impact of mealybugs**

**New or modified eradication, control, surveillance/monitoring and compensation strategies/programs**

The initial response to the detection of one of these mealybug species in Australia would be to consider eradication and could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. This approach, however, would be unlikely to be adopted because of the low probability of success. The alternative would be to establish measures to minimise the impact of mealybugs on affected fruit crops. Such measures would be based on the use of pesticide sprays that are currently used against mealybug species already established in Australia. If present pesticide sprays were not sufficient to address the impact of these three mealybugs then additional pesticide applications would be likely. Pesticide sprays are costly, and additional applications may alter the economic viability of some crops. In addition, it is possible that with a ceiling on the number of pesticide applications tolerated by consumers, sprays targeting mealybugs may need to be used in the place of those previously targeting other pests. This may lead to an increase in other arthropod populations, a decrease in productivity and a further indirect loss associated with mealybugs.

Overall, the indirect cost of control programs for mealybugs was considered likely to be minor at the district level. This gave the pest a rating of B for this criterion.

**Domestic trade or industry effects**

The domestic trade effects associated with the entry, establishment or spread of mealybugs are likely to result from interstate trading restrictions. Interstate trading restrictions may lead to a loss of markets, which in turn would be likely to require industry adjustment. The scope and severity of
restrictions are difficult to estimate, but the polyphagous nature of these pests would suggest that impacts might not be accrued in the banana industry alone.

Overall, the indirect impact of mealybugs on domestic trade was considered likely to be minor at the district level. This gave them a rating of B for this criterion.

**International trade effects**

Australia exports only negligible quantities of bananas that go to a specialty market. However, Australia exports citrus fruit worth $40-60 million to the USA from the Riverland-Sunraysia-Riverina (R-S-R) area. Extension of this area has also been negotiated for the USA market. Consideration for export of citrus from areas in Queensland and New South Wales to the USA market is also underway.

In the past, the citrus trade from R-S-R area to the USA has incurred costly delays, fumigation treatment, additional handling charges and deterioration in fruit quality whenever unidentifiable (immature or damaged adult) mealybugs were found on the fruit by USA’s quarantine authority at its ports. In 2000, a project titled: *USA market facilitation for Riverland-Sunraysia-Riverina citrus: development of a case to demonstrate freedom from quarantinable mealybugs* was completed (Baker and Huynh, 2000). The study surveyed the mealybug fauna of commercial citrus groves in the R-S-R area and concluded that all the mealybugs from citrus in this area belong to three species: *Pseudococcus calceolariae, P. longispinus* and *P. viburni*. All these species also occur in mainland USA. As a result of these findings, USDA-APHIS accepted that unidentifiable mealybugs found associated with R-S-R citrus would no longer be quarantinable upon entry to the USA.

All three mealybugs considered in this analysis feed on citrus (see the respective datasheets). *D. neobrevipes* has been reported from Florida (Miller and Miller 2002) and *P. jackbeardsleyi* from Hawaii, Virgin Islands and Florida (Gimpel and Miller, 1996; Miller et al., 2002). These are not, therefore, likely to affect citrus trade with the USA. *R. invadens*, however, does not occur in the USA and, if it became established in the R-S-R area in Australia, would complicate citrus trade with the USA and might result in the reintroduction of fumigation for unidentifiable mealybugs or the necessity for another pest survey.

In consideration of the USA market for Australian citrus, the indirect impact of these mealybugs on international trade was considered to be pest specific. For *D. neobrevipes* and *P. jackbeardsleyi* the indirect impact was considered as likely to be minor at the district level giving them a rating of B for this criterion. For *R. invadens*, however, it was considered likely to have a minor impact at the State or Territory level, which gives it a rating of C for this criterion.

**Indirect effects on the environment**

Although additional pre-harvest pesticide application may be required to control mealybugs on susceptible crops, this is unlikely to impact on the environment any more than the present load of pesticides used to control mealybugs, and a rating of A was thus assigned to this criterion.

**Conclusions – the overall impact of mealybugs**

The direct and indirect impacts of mealybugs were combined using the decision rules discussed in the *Method for Import Risk Analysis*. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of *D. neobrevipes, P. jackbeardsleyi* and *R. invadens* are likely to be low.
Unrestricted risk estimate – mealybugs

Because importation assessment attributed to *D. neobrevipes* and *P. jackbeardsleyi*, differed from that attributed to *R. invadens*, two risk estimates were obtained. In each case, however, estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to two estimates for the probability of entry, establishment or spread associated with a single tonne of bananas. These were subsequently extrapolated to take account of the likely volume of trade in bananas, to give two further estimates for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the two annual probabilities of entry, establishment or spread with the assessment of consequences. This gave two overall estimates of the unrestricted annual risk associated with either: (a) *D. neobrevipes* and *P. jackbeardsleyi*; or (b) *R. invadens*.

The results of these steps are summarised below.

**Risk estimation for *D. neobrevipes* and *P. jackbeardsleyi***

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Low</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial probabilities of distribution</strong></td>
<td></td>
</tr>
<tr>
<td>- Commercial bananas</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>- Household bananas or other susceptible household plants</td>
<td>= Very low</td>
</tr>
<tr>
<td>- Susceptible wild/commercially grown plants</td>
<td>= Very low</td>
</tr>
<tr>
<td><strong>Partial probabilities of establishment</strong></td>
<td></td>
</tr>
<tr>
<td>- Commercial bananas</td>
<td>= Very low</td>
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<tr>
<td>- Household bananas or other susceptible household plants</td>
<td>= Very low</td>
</tr>
<tr>
<td>- Susceptible wild/commercially grown plants</td>
<td>= Very low</td>
</tr>
<tr>
<td><strong>Partial probabilities of spread</strong></td>
<td></td>
</tr>
<tr>
<td>- Commercial bananas</td>
<td>= High</td>
</tr>
<tr>
<td>- Household bananas or other susceptible household plants</td>
<td>= High</td>
</tr>
<tr>
<td>- Susceptible wild/commercially grown plants</td>
<td>= High</td>
</tr>
<tr>
<td><strong>Probability of entry, establishment or spread (1 tonne)</strong></td>
<td>= Extremely low</td>
</tr>
<tr>
<td><strong>Annual probability of entry, establishment or spread</strong></td>
<td>= High</td>
</tr>
<tr>
<td><strong>Consequences</strong></td>
<td>= Low</td>
</tr>
<tr>
<td><strong>Unrestricted risk</strong></td>
<td>= Low</td>
</tr>
</tbody>
</table>

Because the unrestricted risk exceeds Australia’s ALOP (very low) risk management would be required for *D. neobrevipes* and *P. jackbeardsleyi*.

**Risk estimation for *R. invadens***

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Extremely low</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Partial probabilities of distribution</strong></td>
<td></td>
</tr>
<tr>
<td>- Commercial bananas</td>
<td>= Extremely low</td>
</tr>
<tr>
<td>- Susceptible household plants</td>
<td>= Very low</td>
</tr>
<tr>
<td>- Susceptible wild/commercially grown plants</td>
<td>= Very low</td>
</tr>
</tbody>
</table>
Partial probabilities of establishment

- Commercial bananas = Very low
- Susceptible household plants = Very low
- Susceptible wild/commercially grown plants = Very low

Partial probabilities of spread

- Commercial bananas = High
- Susceptible household plants = High
- Susceptible wild/commercially grown plants = High

Probability of entry, establishment or spread (1 tonne) = Negligible
Annual probability of entry, establishment or spread = Very low
Consequences = Low

Unrestricted risk = Negligible

Because the unrestricted risk falls within Australia’s ALOP (very low) risk management would not be required for *R. invadens*.

**Spider mites**

Many species of the spider mites (Acarina: Tetranychidae) are important pests, causing damage or loss to agricultural crops. Three species of spider mites were included in this assessment:

- *Oligonychus orthius* Rimando;
- *Oligonychus velascoi* Rimando; and
- *Tetranychus piercei* McGregor.

Whilst there are some differences in the specifics of the biology of each of these three pests, the following general comments derived from Lui and Lui (1986); Cayme and Gapasin (1987); and CABI (2002) provided the basis for this assessment:

- The three mites are all of the family Tetranychidae, and develop through eggs, larvae, protonymphs, deutonymphs and adults. The time required to complete a life cycle from egg to adult varies between genera or species, but is approximately in the order of 7 to 14 days. The longevity of adult mites has not been reported but is thought to be in the order of several days. Gravid females each produce in the order of 155 eggs.
- In the case of *T. piercei* (Liu and Liu, 1986) and possibly the other tetranychid mites, unmated females produce only male progeny. This strategy may increase the likelihood of establishment when the number of female mites is low, provided the introduced females could survive long enough for their male offspring to reach sexual maturity. Otherwise establishment will require the introduction of one or more gravid females.
- These mites are phytophagous, meaning that they feed on plant tissue or fluids. Other mites in the Philippines are either predaceous, or feed on detritus, stored products, fungus, etc. The mites generally feed on the under surface of leaves. Nymphs and adults spin webbing that may assist with traction. Webbing resembles spider webs, and hence the name. Infestation usually begins at the lower parts of the plant, and then spreads upwards to include leaves and fruit.
- Mites feeding on fruit tend to seek out protected spaces, such as found between the fingers of banana fruit.
- The three spider mites of this assessment are polyphagous. Both *O. orthius* and *O. velascoi* have been associated with a range of plant hosts, including bananas and corn (Corpuz-Raros,
Additionally, *O. orthius* has been associated with sugarcane (Corpuz-Raros, 1989; Bolland *et al.*, 1998) whilst *O. velascoi* has been found on coconut (Cayme and Gapasin, 1987; Corpuz-Raros, 1989; Bolland *et al.*, 1998). The host range of *T. piercei* extends to more than 30 plant species, including bananas, papaya and sweet potato (Corpuz-Raros, 1989; Bolland *et al.*, 1998; CABI, 2002).

**Probability of importation**

The scenario of greatest concern in this assessment was the presence of spider mites, particularly gravid females, in protected spaces between the fingers of bananas.

**Imp1 — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced**

Each of the three species of spider mite has been recorded on bananas (Bolland *et al.*, 1998), and is assumed to be ubiquitous in the Philippines. Given the lack of evidence to contrary, the likelihood that spider mites would be present on the plantation from which a tonne of fruit was sourced, was considered **high**.

**Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest**

These species of spider mite tend to colonise lower stems and leaves first, moving up through the plant and eventually to the fruit, as their populations increase. Although the combination of weekly inspections, pesticide applications and bunch covers (most of which are impregnated with chlorpyrifos) can minimise the level of infestation, they are unlikely to eliminate the spider mites, and the likelihood that some would be present on bunches that make up a tonne of harvested fruit was considered **moderate**.

**Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station**

The likelihood that harvested fruit would become infested during transport to the packing station would depend on whether the packing station is mobile or permanent.

- Where a mobile facility is used, bunch covers are removed, bunches are de-handed in the field and hands are carried to the packing station on padded stretchers. In this situation, it is conceivable that fruit could become infested with spider mites that have been dislodged from fruit, plants or leaves by the process of harvest, and have subsequently collected on stretchers or on the hands of packing station workers.

- Where a permanent facility is used, harvested bunches are placed on a cableway and transported without further handling to the packing station. Bunch covers remain in place until fruit arrives at the packing station. At that point, covers are removed and bunches are de-handed into a tank containing a chlorine and alum solution. In this situation there would be little opportunity for infestation, because: (a) dislodged mites would not collect on a common surface; (b) handling by packing station workers is minimal; and (c) bunch covers (most of which are impregnated with insecticide) remain in place until fruit reaches the packing station.
When these opportunities for infestation were correlated with the fact that approximately 10% of Philippines plantations use mobile facilities, the likelihood that harvested fruit would become infested during transport to the packing station was rated extremely low.

**Imp4** — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

Bunches arriving at the permanent packing station by cableway are washed then de-handed into the chlorine and alum solution where visible pests, leaf tissue or sooty mould are removed by sponge or brush. Fruit are then exposed to the solution of chlorine and alum in the flotation tank for 25 minutes. Hands transported from the field to mobile packing stations on padded trays are washed and sponged or brushed on arrival. They are then immersed in a flotation tank containing the chlorine and alum solution (see below). Although spider mites could be transferred to fruit passing through the de-handing and flotation tanks, they are more likely to be removed or destroyed as a result of the process. On balance, Imp4 was considered negligible.

**Imp5** — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Visual inspection without magnification is likely to identify webbing or individual mites moving over the open surface of banana fruit. Spider mites, however, tend to seek out protected spaces, such as found between the fingers of a hand or cluster, and in this situation would be extremely difficult to detect. Overall there is a very low likelihood that all infestations of fruit that will make up an export tonne would be detected. Imp5 was rated as very low.

**Imp6** — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

Fruit are washed on arrival at the packing station, immersed in a chlorine and alum solution and subjected to sponging and washing. This process is aimed at dislodging arthropod pests such as spider mites, as well as the removal of leaf tissue and sooty mould. Sponging and brushing is likely to remove most spider mites moving over the open surface of the fruit. Those lodged in the inaccessible spaces between fingers might be protected.

After washing, fruit are exposed to the solution of chlorine and alum in the flotation tank for 25 minutes. Any mites moving over the open surfaces of fruit that had evaded sponging or brushing may become dislodged during this process. Those that were lodged in inaccessible spaces between fruit fingers and thus protected from inspection and brushing or sponging, would probably remain protected through the flotation process.

Overall, the likelihood that spider mites in a tonne of green bananas would be removed or destroyed as a result of packing station procedures was considered moderate.

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42 The IRA team acknowledge that the Philippines Department of Agriculture have indicated in their submission to the June 2002 *Draft IRA Report* that field de-handing for mobile packing stations is being discontinued. This is contrary to advice (Philippines Scientific Delegation, 2002a) that the use of mobile packing stations is increasing. When the practice has stopped the likelihood estimate for this importation step may be revised.
Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Because spider mites that had remained viable and undetected to this point would most probably be hidden within protective spaces between individual fingers, and because the proportion of infested fruit will be very small, the overall likelihood that residual infestation in a tonne of fruit would be detected by quarantine staff prior to loading was considered extremely low.

Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export

There is no evidence to suggest that a modified atmosphere (in partially vacuum-sealed cartons) during transport to the wharf and storage prior to export would be deleterious to adult or nymph stage spider mites. Indeed, the fact that other mites (from the families Acaridae and Tarsonemidae) that feed on detritus and stored products, have been detected on Philippines bananas imported into New Zealand (Spence, 2002), suggests that spider mites may be able to survive these conditions. Overall, it was considered very likely that spider mites that had persisted with fruit through packing station procedures, would remain viable during transport to the wharf and storage prior to export. Imp8 was therefore rated high.

Imp9 — the likelihood that the pest will remain viable during transport to Australia

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the journey. As mentioned above, there is no evidence to suggest that a modified atmosphere (in partially vacuum-sealed cartons) would be deleterious to adult or nymphal stage spider mites. Nor is there evidence to suggest that spider mites, if present with fruit, would not survive the transport conditions to Australia. Detection of other mites (from the families Acaridae and Tarsonemidae) on Philippines bananas arriving in New Zealand (Spence, 2002) adds weight to the conclusion that survival of spider mites in a tonne of fruit is very likely. Given this, Imp9 was rated as high.

Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia

There is some possibility that cryptic spider mites would have moved onto the open surface of banana fruit as a result of the perceived security offered by the closed environment of the carton. There is also some possibility that webbing may have appeared on the open surface of the fruit. Finally, spider mites exposed suddenly to light after 10-14 days of virtual darkness may become highly motile and, thus, more visible.

On balance, the likelihood that spider mites in a tonne of harvested fruit will be detected at on-arrival AQIS inspection was considered very low.

Conclusions — probability of importation

When these likelihoods were inserted into the simulation model, the overall probability that a tonne of hard green bananas would be infested with spider mites was found to be low.

Probability of distribution

The initiating step for the probability of distribution is the presence of spider mites on imported fruit, whilst the end-point is the exposure of host plants in Australia.
Dist1 — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers

The combination of cool storage with 3-7 day of ripening at about 18°C and 95% humidity would not be fatal to these spider mites, and there is a high likelihood that populations that had survived to this point would continue to persist to the next step in the pathway.

Prop1 — The proportion of imported bananas that is likely to be distributed to an area in which commercial bananas are grown

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

It was shown in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest specific to bananas, Prop2 would be described as moderate.

The spider mites of interest in this assessment, however, are polyphagous pests with host ranges that include many of the tropical and subtropical fruiting plants kept as ornamentals or as utility plants. These plants are ubiquitous among gardens in the tropical or subtropical population centres of Queensland. Although often less successful, they are also common garden plants in parts of Australia considered temperate or semi-arid.

Overall, it was considered very likely that imported bananas from the Philippines would be distributed to an area in which susceptible household plants are grown, and Prop2 was therefore rated as high.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was explained in the Method for Import Risk Analysis, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood. As stated above, the spider mites of interest in this assessment are polyphagous with host ranges that include most of the tropical and subtropical fruiting plants. Some of these are also commercially cultivated. Spider mites may also feed on a range of tropical and subtropical weeds species. Susceptible wild (native or feral) plants would include any of this group found as amenity plants in urban public gardens, as well as those that occur naturally in parks and preserves, by urban or rural roadsides, on farm or grazing land, etc. Although these plants will be more common in tropical and subtropical parts of Australia, the range is sufficiently broad to be confident that at least one species would be growing wild in most parts of the country.

Overall, it was considered very likely that imported bananas would be distributed to an area in which wild (native or feral) hosts or susceptible cultivated plants can be found. Prop3 was therefore rated as high.
**Dist2** — *the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment*

Spider mites may enter the environment by moving from ripening fruit at the point of sale, or from fruit that has been purchased. Adults and nymphs are mobile, but are often transferred by wind or a range of mechanical vectors, including human hands and clothing. Spider mites may also enter the environment through discarded waste. Through one means or the other, it was considered **virtually certain** that spider mites associated with imported fruit would enter the Australian environment.

**Dist3** — *the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment*

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of spider mites to move from discarded banana waste, to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of spider mites on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which spider mites can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

**Persistence.** Although studies on the persistence of spider mites were not discovered, it would be expected that spider mites carried on the discarded fruit surface would be sustained by this food source. Having left the fruit, however, spider mites would need to find a susceptible host in a short time, or otherwise succumb to desiccation.

**Distance and dispersal.** As discussed above, spider mites may enter the environment directly from purchased fruit or from fruit at the point of sale, or from discarded banana waste. Kennedy and Smitley (1985) list three categories of dispersal by spider mites: (a) crawling; (b) aerial dispersal; and (c) phoretic dispersal. Crawling is a common means of dispersal between various parts of a host plant and also to other plants. Aerial dispersal can take the spider mites to other plants as well as within the same plant. Phoretic dispersal has not been well documented but it refers to the spider mites being carried by other agents such as insects, birds, humans or machinery. Adults and nymphs may crawl over short distances under their own locomotion. Dispersal over greater distances will require aerial or phoretic dispersal. The scenario of concern is the association of the spider mites with waste discarded in close proximity to a commercial banana plantation. This is most likely to occur when banana waste is discarded from vehicles travelling on roads adjacent to banana plantations. They will be able to crawl, or be taken by aerial or phoretic dispersal directly from waste to banana plants.

**Exposure of a susceptible host:** The spider mites examined in this assessment are polyphagous and have been recorded on many species of host plants (see Appendix 1: Pest Data Sheets), and thus able to derive substrate from a range of tropical and subtropical fruiting plants.

Overall, there is a low likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), and Dist3 was therefore rated as **low**.
**Dist4** — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), Dist4 is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a pest to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden plant.

The persistence of spider mites, their ability to infest suitable hosts and their means of dispersal were discussed above and need not be reiterated. Specific to the likelihood of exposing susceptible household plants is the difference in climatic conditions among population centres in Australia where susceptible hosts may be found, and the distance likely to lie between fruit or discarded waste and a susceptible household plant.

- A high likelihood was assigned to Prop2 (see above) on the basis that susceptible host plants are ubiquitous among gardens in the tropical or subtropical population centres of Queensland, and are common in parts of Australia considered temperate or semi-arid.
- The distance likely to lie between a spider mite and a susceptible garden plant will be determined largely by waste disposal patterns. It is known that most bananas will be consumed in the major population centres, and that most waste generated in these centres is managed through refuse disposal facilities. The balance is managed through garden compost, or discarded randomly into the environment. These spider mites are unlikely to survive either managed refuse disposal sites or composting, and banana waste that is discarded randomly is more likely to lie in the general environment than within a household or garden.
- The distance likely to lie between fruit at the point of sale or in households is extremely variable. Spider mites that move or are carried from fruit at the point of sale are less likely to contact a susceptible household plant than those that move from purchased fruit. Bananas are not generally refrigerated, and opportunity would exist for mites to be carried by wind or various mechanical vectors from the household to its immediate environment, which may include susceptible plants.

Overall, vagaries regarding the persistence of these pests under various Australian conditions, their dispersal, and their polyphagous nature led to the assumption that given the entry of spider mites into the environment, exposure of susceptible household plants has a moderate likelihood. Dist4 was rated as moderate.

**Dist5** — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

Dist5 is again similar to Dist3 and Dist4, although focussed on the exposure of susceptible wild (native or feral) plants and commercially grown plants other than bananas, this host group includes amenity plants and as well as those that occur naturally in parks and preserves, by urban or rural roadides, on farm or grazing land, etc. The factors limiting the exposure of these plants to spider mites that have moved from fruit or from fruit waste include the prevailing climatic conditions, the abundance of suitable hosts and the distance likely to lie between the mites and hosts.

- These spider mites would be able to persist and reproduce in most Australian climates.
- These spider mites are polyphagous, and suitable hosts are widespread in Australia, at least in tropical Australia.
- Waste disposal patterns will govern the distance likely to lie between the spider mites
associated banana waste and susceptible wild plants. In this situation, random waste disposal is considered the most likely exposure scenario.

- The distance between spider mites that enter the environment directly from purchased fruit, or fruit at the point of sale, and susceptible wild hosts or cultivated hosts other than bananas, will be extremely variable. This distance is, however, unlikely to exceed that over which spider mites may be dispersed by wind and other vectors.

When collated, this evidence suggested that given the entry of spider mites into the environment, exposure of this group of susceptible hosts has a moderate likelihood. Dist5 was therefore rated as **moderate**.

**Conclusions — probability of distribution**

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to spider mites that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Very low
- Partial probability of distribution for susceptible household plants = Moderate
- Partial probability of distribution for susceptible wild/commercial plants = Moderate

**Probability of establishment**

The probability of establishment examines factors relevant to successful multiplication of the pest, and its establishment amongst the exposed plant, or group of plants. The initiation point for establishment of the spider mites from imported fruit in Australia is the exposure of the host plants to the nymphs and adults. To establish on an exposed host plant, larvae, protonymphs, deutonymphs would need to develop into adults. Adult females can reproduce through mating or without mating although unmated females produce only male progeny.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

**Commercially cultivated banana plants**

If spider mites were to find a host within a commercial banana plantation, the abundance of surfaces on that plant, and the abundance of plants in the immediate proximity, would strongly favour their establishment. Because commercial banana plantations are found in parts of Australia with a similar climate to the Province of Mindanao, there would be no need for adaptation.
The reproductive strategy of this pest is based largely on the fecundity of the adult female and its ability to produce male young when not mated. This reproductive strategy would increase the likelihood of establishment when the number of female mites is low, provided the introduced females could survive long enough for their male offspring to reach sexual maturity and mate with their parent. Consequently, the establishment of a breeding colony could result from either the importation of a gravid female, the presence of both a female and male, or the presence of several females of varying age.

One factor, which may counter the chance of successful establishment of exotic spider mites, is that predatory mites are already present in Australia. These generalist predators are likely to be relatively common in commercial banana plantations as they are encouraged through integrated pest management programs and would almost certainly prey on any exotic mites they encounter.

Overall, the likelihood of establishment, given the exposure of commercial banana plants, was considered high.

**Susceptible household plants**

The ability of spider mites to establish within exposed household or garden plants will be governed by similar factors to those discussed in relation to commercial plantations.

Spider mites can find suitable hosts among most tropical and subtropical fruiting plants, as well as on various weed species. These plants are considered ubiquitous in the tropical and subtropical population centres, and are widespread throughout the rest of country. The persistence and fecundity of adult females, and their ability to produce male young when not mated, mean that colonies are likely to arise from a single female or a small group of females. Given the exposure of a suitable plant, establishment would hinge on the compatibility of the environment.

- Establishment would be very likely to occur under tropical or subtropical conditions.
- Establishment may be less likely to occur under some more temperate conditions — particularly in cooler seasons.
- Establishment would be subject to the effects of predatory mites.

Overall, the likelihood of establishment, given the exposure of susceptible household plants, was considered high.

**Susceptible wild plants, or susceptible cultivated plants other than bananas**

Given their polyphagous nature and effective reproductive strategy, the establishment of spider mites on exposed wild plants or susceptible cultivated plants other than bananas, would be governed largely by the environment. As was the case for household plants (see above), establishment would be very likely to occur under tropical or subtropical conditions but may be less likely in some of the cooler places or seasons. However, establishment would also be subject to the effects of predatory mites.

Overall, the likelihood of establishment, given the exposure of susceptible wild plants and commercially cultivated plants, was considered high.
Probability of spread

The probability of spread examines factors relevant to the movement of spider mites from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

Commercially cultivated banana plants

In the case of these spider mites, it is clear that the tropical or sub-tropical environment in the vicinity of commercial banana plantations would favour spread. Furthermore, it is likely that mites would be moved within and between plantations with the movement of equipment and personnel, and may also be dispersed by wind. The relevance of natural enemies in Australia is unknown, although it is unlikely that predators would be more effective than those in the Philippines.

Overall, the likelihood of spread, given the establishment of spider mites on commercial banana plants, was considered high.

Susceptible household plants

As was the case for the exposure of susceptible household plants (see Dist4 above), and establishment on an exposed plant or group of plants (see: Probability of Establishment for Susceptible Household Plants), the spread of spider mites under this scenario will be governed largely by their tolerance to the range of Australian climates. Spread from exposed plants in tropical or subtropical places would be very likely while spread from exposed plants in cooler places may be less likely.

Overall, the likelihood of spread, given the establishment of spider mites among exposed household plants, was considered high.

Susceptible wild plants, or susceptible cultivated plants other than bananas

Spread from a point of establishment in wild (native or feral) plants or susceptible cultivated plants other than bananas is likely to be dictated largely by the environment.

- If spider mites have established in a warm tropical or subtropical environment, spread would be very likely.
- If spider mites had established in a cooler environment, fecundity may be lower and a higher proportion of dispersed nymphs or adults may die before reaching a suitable host. In this situation, spread may be less likely.

Overall, the likelihood of spread, given the establishment of spider mites on wild plants and commercially cultivated plants other than bananas, was considered high.
Consequences

The consequences to the Australian community of the entry, establishment or spread of spider mites were assessed by considering their potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of spider mites was assessed on the basis of their potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of spider mites could be estimated by considering the degree of likely economic impact. For others, their effect could only be assessed in more subjective terms, such as the loss of social amenity.

The direct impact of spider mites

**Animal or plant life or health**

This criterion describes the production losses associated with the presence of spider mites in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of spider mites have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

Spider mites in large numbers may drain sufficient nutrient from the host plant to reduce its productivity. They may cause severe damage and result in very heavy losses (Rabbinge, 1985). Because they are polyphagous, this effect may extend from commercial bananas to other fruit crops. There may also be an impact on susceptible native species. Some spider mites have shown that they can cause more damage in the introduced countries than in their native area. For example, the cassava green mite *Mononychellus tanajoa* was accidentally introduced into Africa from South America in 1970s. It was a pest responsible for between 30% and 50% yield loss of cassava, a starchy root crop in tropical Africa (Anonymous, 1997). It has now been brought under control through the introduction of a natural (biological) enemy. These considerations need to be balanced against the controls already in place against other spider mites already established in Australia, many of which rely on integrated pest management approaches.

Overall, the direct impact of spider mites was considered likely to be minor at the district level. This gave the pest a rating of **B** for this criterion.

**Human life or health**

There are no known direct impacts of spider mites on human life or health, and the rating assigned to this criterion was therefore **A**.

**Any other aspects of the environment not covered above**

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical environment or micro-organisms. There are no known direct impacts of spider mites in these directions, and the rating assigned to this criterion was therefore **A**.
The indirect impact of spider mites

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

The initial response to the detection of one of the designated spider mites in Australia would be to consider eradication and could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. This approach, however, would be unlikely to be adopted because of the low probability of success. The alternative would be to establish measures to minimise the impact of spider mites on affected fruit crops. Such measures would be based on the use of additional pesticide sprays, or the use of predatory mites in an integrated pest management program. Pesticide sprays are costly, and additional applications may alter the economic viability of some crops. In addition, it is possible that with a ceiling on the number of pesticide applications tolerated by consumers, sprays targeting spider mites may need to be used in the place of those previously targeting other pests. This may lead to an increase in other arthropod populations, a decrease in productivity and a further indirect loss associated with spider mites.

Overall, the indirect cost of control programs for spider mites was considered likely to be minor at the district level. This gave the pest a rating of B for this criterion.

Domestic trade or industry effects

The domestic trade effects associated with the entry, establishment or spread of the identified species of spider mites are likely to result from interstate trading restrictions. Interstate trading restrictions may lead to a loss of markets, which in turn would be likely to require industry adjustment. The scope and severity of restrictions are difficult to estimate, but the polyphagous nature of these pests would suggest that impacts might not be accrued in the banana industry alone.

Overall, the indirect impact of spider mites on domestic trade was considered likely to be minor at the district level. This gave the pest a rating of B for this criterion.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market. Although some other crops are exported, presence of spider mites is unlikely to disrupt bilateral trade arrangements. The rating assigned to this criterion was therefore A.

Indirect effects on the environment

Although additional pre-harvest pesticide application may be required to control spider mites on susceptible fruit crops, this is unlikely to impact on the environment, and a rating of A was thus assigned to this criterion.

Conclusions — the overall impact of spider mites

The direct and indirect impacts of spider mites were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of these pests are likely to be very low.
Unrestricted risk estimate — spider mites

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with spider mites.

The results of these steps are summarised below.

<table>
<thead>
<tr>
<th>Probability of importation</th>
<th>= Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Partial probabilities of distribution</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= Very low</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= Moderate</td>
</tr>
<tr>
<td>Partial probabilities of establishment</td>
<td></td>
</tr>
<tr>
<td>Commercial bananas</td>
<td>= High</td>
</tr>
<tr>
<td>Household bananas or other susceptible household plants</td>
<td>= High</td>
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<tr>
<td>Susceptible wild/commercial plants</td>
<td>= High</td>
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<tr>
<td>Partial probabilities of spread</td>
<td></td>
</tr>
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<tr>
<td>Household bananas or other susceptible household plants</td>
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</tr>
<tr>
<td>Susceptible wild/commercial plants</td>
<td>= High</td>
</tr>
<tr>
<td>Probability of entry, establishment or spread (1 tonne)</td>
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</tr>
<tr>
<td>Annual probability of entry, establishment or spread</td>
<td>= High</td>
</tr>
<tr>
<td>Consequences</td>
<td>= Very low</td>
</tr>
<tr>
<td><strong>Unrestricted risk</strong></td>
<td>= Very low</td>
</tr>
</tbody>
</table>

Because the unrestricted risk falls within Australia’s ALOP (very low) risk management would not be required for spider mites.

Weevils

Species of the genus *Philicoptus* (Order Coleoptera; Family Curculionidae; Sub-family Brachycerinae) are commonly called ‘peel-scarring weevils’ in Philippine banana plantations (Philippines Dept. Agriculture, 2001).

Five species of ‘peel scarring’ weevils, all only recorded from the Philippines, were included in this assessment:

- *Philicoptus demissus* (Heller) — recorded on bananas, avocados, cacao, coffee, durian and rambutan (Stephens, 1984; Philippines Dept. Agriculture, 2001);
- *Philicoptus iliganus* (Heller) — recorded on banana, avocado, cacao, coffee, durian, jackfruit, lansones, madre de cacao, mangosteen, mungbeans and rambutan (Stephens, 1984; Philippines
Dept. Agriculture, 2001) — this species is generally regarded as the most important of the five weevils examined;

- *Philicoptus* sp.1 (CN3 in Stephens, 1984) — recorded on 15 host plant species in Tadeco in 1976, including bananas (Stephens, 1984);
- *Philicoptus* sp.2 (CN9 and CN10 in Stephens, 1984) — recorded on coffee plants in the field, although feeds readily on banana fingers under laboratory conditions (Stephens, 1984); and
- *Philicoptus stringifrons* (Heller) — reported on banana followers and young fruit, and is suspected of feeding on hard green fruit, although this has not been observed in the field (Stephens, 1984).

Whilst there are some differences in the biology of each species, the following general comments, which have been adapted from information documented on *P. iliganus* and *Philicoptus* sp.1, provide the basis for this assessment:

- The Philicoptus weevils are generally considered polyphagous pests of tropical fruit crops, although they have also been reported on mungbeans.
- Weevils are generally long-lived, with a lifecycle of 111 to 176 days. Only adults are found on the leaves and fruit of susceptible hosts. Eggs are laid singly or in mass in soil, and larvae feed on the roots or rhizome (corm). The larvae form a soil-made chamber before developing to the pupal stage. Pupae remain in this protective ‘cocoon’ for up to 6 weeks before emerging as adult weevils. In a laboratory study (Stephens, 1984), eggs hatched in 6 to 10 days, larvae fed and developed over 104 to 165 days, the pupal stage lasted 42 to 58 days, and the adult survived for 33 to 128 days.
- Adult weevils are relatively large (5 to 8mm in length), flightless, slow moving and colourful. They hide in leaf axils, between touching leaves, and concealed among fruit. Periods of inactivity are interspersed with periods of active crawling. Adults feed on leaf veins near the base of the youngest leaf of non-fruited banana plants, and on lower bracts before the young banana fingers are exposed. When the bracts open, the adult weevils enter the flower bud and scar young fingers. Feeding on fruit continues up to the point of harvest, and even on the ridge of ripening fruit, leaving deep scars that remain visible on the fruit peel. Damaged fruit cannot be marketed as export quality.
- Philicoptus weevils do not have an effective means of dispersal. Adults are relatively immobile and not able to move long distances. When disturbed, they fall to the ground and feign death, thus minimising opportunities to be carried inadvertently with fruit or leaf materials. In the Philippines, weevils tend to be found in discrete populations.

**Probability of importation**

The scenario of concern in this assessment was the presence of adult peel-scarring weevils in protected spaces between fingers of harvested banana fruit.

*Imp*₁ — the likelihood that the pest will be present on the plantation from which a tonne of fruit will be sourced

Data were not available on the precise distribution of weevils within the Philippines. It is known, however that unlike many other arthropods pests, peel-scarring weevils do not have an effective means of dispersal and tend to be found in discrete populations. For example, Stephens (1984) reported a high population of *P. iliganus* at sea level near Davao City, and also at a location about 700m above sea level near Guianga on the cool slopes of Mount Talomo. On balance, the
likelihood that weevils would be found on a particular plantation from which bananas for export are sourced was considered moderate.

Imp2 — the likelihood that a tonne of harvested fruit will be infected or infested with the pest

Only adult peel-scarring weevils are present on the leaves and fruit of bananas. When disturbed, adult weevils fall to the ground and feign death. This behaviour, in combination with regular insecticide applications, including nematicides that also control weevil larvae feeding on the corm (Philippines Dept. Agriculture, 2001), and the use of chlorpyrifos-impregnated bunch covers (Philippines Dept. Agriculture, 2001), leads to an extremely low likelihood that weevils will be present on bananas that make up a tonne of harvested fruit.

Imp3 — the likelihood that a tonne of harvested fruit will be infected or infested during transport to the packing station

The large size and the flightless behaviour of adult weevils mean that they would not be likely to move onto clean harvested fruit. Over and above this, the majority of bananas will be transported by cableway, and thus would not come into physical contact with the ground or transport equipment. On balance, Imp3 was rated as negligible.

Imp4 — the likelihood that a tonne of harvested fruit will be infected or infested during routine procedures undertaken within the packing station

The evasive behaviour of adult weevils, and the disturbance provided by the general handling of fruit, its immersion in the chlorine and alum solution in the de-handing and flotation tanks, and washing, brushing or sponging, etc, mean that there would be negligible opportunity for infestation within the packing station.

Imp5 — the likelihood that the pest will be detected, and infected or infested fruit removed, as a result of routine visual quality inspection procedures within the packing station

Adult weevils are relatively large (adults of *P. demissus* are 6-7 mm in length), brightly coloured and easily detected. The scarring of fruit caused by weevils is also easy to identify. Overall it was considered very likely that quality inspectors within the packing station would detect infestation, and Imp5 was therefore rated as high.

Imp6 — the likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station

Washing and either brushing or sponging is likely to remove weevils on exposed surfaces of the fruit. Although unlikely to be fatal, the chlorine and alum solution in the de-handing and flotation tanks will be a very unfavourable environment, and will exacerbate the weevils’ natural tendency to leave fruit when disturbed. Only those weevils protected within spaces between banana fingers are likely to remain with fruit.

Overall, it was considered very likely that the pest would be removed or destroyed by routine procedures carried out in the packing station, and Imp6 was rated as high.

Imp7 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during quarantine inspection prior to loading and transport to the wharf

Although weevils are visible and generally considered easy to detect, those remaining with fruit at this stage in the pathway are likely to be scarce, and to be hidden within protective spaces between
fruit fingers. In addition, quality inspectors in the packing station would have removed any scarred fruit, which otherwise may have alerted quarantine staff to the presence of weevils.

Overall it was considered very unlikely that inspection by quarantine staff at the point of loading would lead to the detection of weevils in a tonne of fruit, and Imp7 was rated as very low.

**Imp8 — the likelihood that the pest will remain viable within a tonne of (partially) vacuum-packed cartons during transport to the wharf and storage prior to export**

There is no evidence to suggest that conditions within partially vacuum-packed cartons during transport to the wharf and storage prior to export would be deleterious to weevils. A high likelihood was assigned to this step.

**Imp9 — the likelihood that the pest will remain viable during transport to Australia**

The differences between transport to the wharf, and transport to Australia, are that: (a) transport to Australia may take up to 2 weeks; and (b) bananas would be kept in cool storage (13°C) throughout the voyage. Given this, there is no evidence to suggest that cool storage or reduced atmosphere would be fatal to weevils, and Imp9 was rated as high.

**Imp10 — the likelihood that a tonne of cartons that contain infected or infested fruit will be detected during AQIS inspection on arrival in Australia**

Weevils would not reproduce during transport to Australia, although they may have had sufficient opportunity to cause some visible damage to fruit. They may also move about within the carton during shipment, drop to the bottom of the carton, and be detected on examination of the packing materials. The factor limiting the efficacy of on-arrival inspection in Australia will be the scarcity of weevils — i.e. the likelihood that inspectors would examine the particular carton(s) that contained infested fruit.

On balance, it was considered unlikely that weevils within a tonne of fruit would be detected on-arrival in Australia, and a low likelihood was assigned to Imp10.

**Conclusions — probability of importation**

When these likelihoods were inserted into the simulation model, the overall probability that a tonne of hard green bananas would be infested with peel-scarring weevils was found to be extremely low.

**Probability of distribution**

The initiating step for distribution of peel-scarring weevils in Australia is the presence of adults on imported fruit. The end-point is exposure of suitable host plants to fertile female adults.

**Dist1 — the likelihood that a pest will survive storage and ripening of fruit, and its distribution to wholesalers**

The combination of cool storage with 3-7 days of ripening at about 18°C and 95% humidity would not be fatal to weevils, and it was considered very likely that populations that had survived to this point would continue to persist to the next step in the pathway. Dist1 was therefore rated as high.
Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially

It was stated in the Method for Import Risk Analysis that the proportion of imported fruit likely to be distributed to an area in which bananas are grown commercially was considered low.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (i.e. non-commercial) banana plants, or other susceptible garden plants (including weeds) are found

It was shown in the Method for Import Risk Analysis that, if distributed according to the distribution of the Australian population, then approximately 32% of imported bananas would be distributed to an area in which household banana plants are found. Thus, for a pest specific to bananas, Prop2 would be described as moderate. Although the host range for the weevils considered in this analysis extends beyond bananas, the affected plants, with the exception of avocado, are not commonly found in households or gardens and particularly not in the more temperate and populous parts of southern Australia. Thus, a moderate likelihood was assigned to Prop2.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants, or susceptible cultivated plants other than bananas are found

It was explained in the Method for Import Risk Analysis, that approximately 11% of imported bananas are likely to be distributed to an area in Australia where susceptible wild (native or feral) bananas are found. For pests specific to bananas, this corresponds to a low likelihood.

As stated above, the peel-scarring weevils of interest in this assessment are polyphagous with host ranges that include, aside from bananas, mainly tropical and some subtropical fruiting plants. Many of these plants, however, are grown commercially — e.g. coffee, avocado, cacao, durian and mungbean and may also be found as amenity plants in urban public gardens, occurring naturally in parks and reserves or by urban or rural roadsides.

Overall, the likelihood that imported bananas would be distributed to an area in which wild (native or feral) hosts or susceptible commercially grown plants can be found was considered to be moderate.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment

Weevils are comparatively large and visible pests (6-7mm in length) that tend to release their hold on a host plant when disturbed, to fall to ground and to feign death. This scenario suggests that weevils would be most likely to enter the environment directly from fruit that is repacked or sorted at the point of sale, or from fruit that has otherwise been handled. Whether the environment into which they fall is compatible is the subject of subsequent steps in the pathway. At this step, it was considered virtually certain that weevils imported with bananas would enter the Australian environment.
Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

This step in the pathway encompasses biological and epidemiological factors that may contribute to the ability of weevils to move from discarded banana waste, to a suitable entry site on a susceptible commercially grown banana plant. Of particular relevance are:

- The persistence of weevils on fruit, in discarded waste or in the soil;
- The distance between discarded banana waste and a commercial banana plant;
- The mechanism(s) by which weevils can move from discarded banana waste to a commercial banana plant; and
- The conditions needed for exposure of a suitable site on the plant.

Persistence. Peel-scarring weevils are long-lived, and persist well on commercial banana plants.

Distance and dispersal. Weevils are likely to move directly into the environment from fruit that is being handled and be discarded with waste, primarily from retail outlets. However, because adults are flightless, and because larvae and pupae reside in soil, peel-scarring weevils have a relatively low capacity for active dispersal, and thus the distance between the point at which they enter the environment and a commercial banana plant is critical to the likelihood of exposure.

Exposure of a susceptible host. No special conditions are required.

On balance, the likelihood that commercial banana plants would be exposed to weevils that had entered the environment was considered negligible.

Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment

As was the case for Dist3 (see above), Dist4 is a complex variable that encompasses those biological and epidemiological factors that may contribute to the ability of a peel-scarring weevil to move from fruit, or from discarded banana waste, to a suitable point of entry on a susceptible plant — in this case, a household or garden plant.

The host ranges of the peel-scarring weevils examined in this assessment include ornamental and fruiting plants kept by households mostly in tropical and subtropical Australia. The likelihood that a weevil might enter the environment in which these plants are grown (Prop2) was considered moderate. However, the lack of an effective dispersal mechanism for adult weevils means that weevils would need to enter the environment in the immediate proximity of a susceptible plant. Given that these pests tend to move directly from fruit at the point of handling (whether sale or after purchase) and it is expected that most weevils will be discarded with waste through municipal disposal systems, there is an extremely low likelihood that household plants would be exposed. Dist4 was therefore rated as extremely low.

Dist5 — the likelihood that susceptible wild plants, or susceptible cultivated plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or a pest that had otherwise entered the environment

Dist5 is again similar to Dist3 and Dist 4, although focussed on the exposure of susceptible wild (native or feral) plants, including amenity plants and susceptible plants grown commercially or growing on urban or rural roadways. Given that most of the weevils will enter the environment through municipal waste systems, that suitable hosts are found mainly in the tropical and
subtropical areas, and that the adults lack an effective dispersal mechanism, there is an extremely low likelihood that susceptible wild (native or feral) plants and other cultivated plants would be exposed to the pest.

Conclusions — probability of distribution

Separate estimates were obtained for the probability that: (a) commercial banana plants; (b) susceptible household plants; and, (c) susceptible wild plants (including bananas) or susceptible commercial plants (other than bananas) would be exposed to weevils that had entered Australia with imported Philippines bananas. These separate estimates were termed ‘partial probabilities of distribution’. The derivation of the partial probabilities of distribution was explained in Table 12.

- Partial probability of distribution for commercial banana plants = Negligible
- Partial probability of distribution for susceptible household plants = Extremely low
- Partial probability of distribution for susceptible wild/commercial plants = Extremely low

Probability of establishment

The probability of establishment examines factors relevant to successful multiplication of the pest, and establishment of disease amongst the exposed plant, or group of plants. The initiation point for establishment of peel-scarring weevils from imported fruit in Australia is the exposure of the host plants to fertile female adults and the end-point is the completion of the emergence of adult weevils from the first colonising generation. To establish on an exposed host plant, introduced weevils would need to have mated and laid eggs near a suitable host plant, and larvae would need to develop into adults.

IPPC describe six factors that may be relevant to the ability of a pest to establish in an exposed plant, or group of plants. These are:

- The availability, quantity and distribution of hosts;
- The suitability of the environment;
- The potential for adaptation of the pest;
- The reproductive strategy of the pest;
- The method of pest survival; and
- Cultural practices and control measures.

Commercially cultivated banana plants

If adult peel-scarring weevils were to find a host within a commercial banana plantation, the abundance of surfaces on that plant, and the abundance of plants in the immediate proximity, would strongly favour their establishment. A critical factor in this scenario is whether or not mating has occurred. Given the low numbers of weevils likely to be present in a tonne of fruit at this point, the chance of successful mating is improbable. However, a gravid female would be able to lay eggs. Because commercial banana plantations are found in tropical or subtropical parts of Australia, the environment would favour establishment, and there would be no need for adaptation.

Given these facets, the likelihood that weevils would establish in an Australian banana plantation was considered very low.
Suspicious household plants

The ability of peel-scarring weevils to establish within exposed household or garden plants will be governed by factors similar to those discussed in relation to commercial plantations. This likelihood also was considered very low.

Suspicious wild plants, or suspicious cultivated plants other than bananas

The ability of peel-scarring weevils to establish within exposed plants of this group of hosts will be governed by similar factors to those discussed in relation to commercial plantations and household plants. This likelihood also was considered very low.

Probability of spread

The probability of spread examines factors relevant to the movement of weevils from a point of establishment in an exposed plant, or group of plants, to susceptible plants in other parts of Australia.

IPPC describe several key factors that may be relevant to the ability of a pest to spread from a point of establishment in an exposed plant, or group of plants. These are:

- The suitability of the natural or managed environment for natural spread;
- Presence of natural barriers;
- The movement of the pest with the commodity or with conveyances;
- The intended use of the commodity;
- Potential vectors for the pest in the PRA area; and
- Potential natural enemies of the pest in the PRA area.

Commercially cultivated banana plants

It is clear that the tropical or subtropical environment in the vicinity of commercial banana plantations would favour spread. This would occur slowly over time, either by the natural spread of the weevils themselves, or by the movement of infested propagation material or other host plant material.

On this basis, the likelihood of spread from a point of establishment in a commercial banana plantation was considered moderate.

Suspicious household plants

The spread of weevils from a point of establishment in an exposed household plant will be governed by similar factors as for commercial bananas. However, the opportunity for spread on propagation material from hosts other than bananas will be limited and, on this basis, likelihood of spread from a point of establishment in a household host plant was considered moderate.

Suspicious wild plants, or suspicious cultivated plants other than bananas

The spread of weevils from a point of establishment in an exposed wild or native plant, or cultivated hosts other than banana, will be governed by similar factors as for commercial bananas and household plants. The opportunity for spread on propagation material from commercial hosts other than bananas would be higher than it would for these same hosts grown as household plants.
Nevertheless, on balance, the likelihood of spread from a point of establishment was considered moderate.

**Consequences**

The consequences to the Australian community of the entry, establishment or spread of weevils were assessed by considering their potential impact at the local, district, State or Territory and national level, on a range of direct and indirect criteria. Impact was assessed using four qualitative terms — unlikely to be discernible, minor, significant and highly significant.

It is important to reiterate that at each level, the impact of weevils was assessed on the basis of their potential effect on the entire local, district, State or Territory or national community. For some criteria, the effect of weevils could be estimated by considering the degree of likely economic impact. For others, their effect could only be assessed in more subjective terms, such as the loss of social amenity.

**The direct impact of weevils**

*Animal or plant life or health*

This criterion describes the production losses associated with the presence of peel-scarring weevils in commercial bananas, as well as any loss in productivity of other susceptible species. The direct effects of weevils have to be considered in the context of existing horticultural practices for control of pests and diseases. Costs associated with control measures or trade restrictions are considered within the discussion of ‘indirect impacts’.

In banana plantations, adult peel-scarring weevils feed on leaf veins near the bases of the youngest leaves, and on lower bracts before the young banana fingers are exposed. When the bracts open, the weevils enter the flower bud and scar young fingers. Scarring occurs over the period up to harvest time. Adults may also feed on the ridge of ripening fruit, leaving deep scars that remain visible on the fruit peel. *Philicopus iliganus* was considered the most economically important banana peel-scarring pest in Mindanao and high population were observed near sea level in Lapanday Farm near Davao City, and at about 700m above sea level in the Davao Fruit Company’s plantation one near Guianga on the cool slopes of Mount Talomo’ (Stephens, 1984). *Philicoptus* sp.1 is ‘second in importance as a banana peel-scarring pest in the Davao banana zone’ (Stephens, 1984). Damage to fruit reduces the marketability or value of a crop.

The weevils also feed on many other tropical and subtropical plants such as coffee, durian, cacao, mangosteens, rambutan, etc. The impact of weevils on other fruit species will vary, although in all cases may be cosmetic and unlikely to be deleterious to health of the host plant. These considerations are countered by the localised distribution of weevils within crops and the relative ease with which they can be controlled by existing usage of pesticides for related insects already established in Australia.

Overall, it was considered that the direct impact of weevils would be minor at the local level. This gave the pest a rating of B for this criterion.

*Human life or health*

There are no known direct impacts of these weevils on human life or health, and the rating assigned to this criterion was therefore A.
Any other aspects of the environment not covered above

This criterion addresses the possible direct impact of pests on ‘other aspects’ of the natural or built environment, such as the physical environment or micro-organisms. There are no known direct impacts of these weevils in these directions, and the rating assigned to this criterion was therefore A.

The indirect impact of weevils

New or modified eradication, control, surveillance/monitoring and compensation strategies/programs

The initial response to the detection of one of these species of weevil in Australia would be to consider eradication and could be initiated under the national Generic Incursion Management Plan approved by the Primary Industries Standing Committee. This approach, however, would be unlikely to be adopted because of the low probability of success. The alternative would be to establish measures to minimise the impact of weevils on affected fruit crops. Such measures would be based on the use of pesticide sprays or, in the case of commercially grown bananas, bell-injection or pesticide impregnated bunch covers, as currently practiced in Australia to control scab moth and other insect pests.

Overall, the indirect cost of control programs for weevils was considered likely to be minor at the district level. This gave a rating of B for this criterion.

Domestic trade or industry effects

The domestic trade effects associated with the introduction and spread of weevils are likely to be minimal. The evasive behaviour of adult weevils and the disturbance provided by the general handling of fruit during harvesting and packing means that weevils are unlikely to contaminate bananas packed in cartons for transport to market. The fact that adult weevils are relatively large (6-7 mm in length) and brightly coloured also means that they are highly likely to be noticed by packing station staff and removed.

Overall, the indirect impact of weevils on domestic trade was considered to be minor at the local level. This gave a rating of A for this criterion.

International trade effects

Australia exports only negligible quantities of bananas that go to a specialty market. Although some other crops, such as avocado, are exported, the presence of peel-scarring weevils is unlikely to disrupt bilateral trade arrangements for the same reasons discussed above. The rating assigned to this criterion was therefore A.

Indirect effects on the environment

Although pesticides may be required to control peel-scarring weevils on susceptible fruit crops, this is unlikely to impact on the environment, and a rating of A was thus assigned to this criterion.

Conclusions — the overall impact of weevils

The direct and indirect impacts of weevils were combined using the decision rules discussed in the Method for Import Risk Analysis. This led to the conclusion that the overall consequences to the Australian community of the entry, establishment or spread of these pests are likely to be very low.
Unrestricted risk estimate — weevils

Estimates for the probability of importation and the partial probabilities of distribution, establishment and spread, were combined using the simulation-based approach described in the *Method for Import Risk Analysis*. This led to an estimate for the probability of entry, establishment or spread associated with a single tonne of bananas. This was subsequently extrapolated to take account of the likely volume of trade in bananas, to give an estimate for the annual probability of entry, establishment or spread.

The decision rules in the risk estimation matrix (Table 15) were then used to combine the annual probability of entry, establishment or spread with the assessment of consequences, to give an overall estimate of the unrestricted annual risk associated with weevils.

The results of these steps are summarised below.

Probability of importation = Extremely low

Partial probabilities of distribution

- Commercial bananas = Negligible
- Household bananas or other susceptible household plants = Extremely low
- Susceptible wild/commercial plants = Extremely low

Partial probabilities of establishment

- Commercial bananas = Very low
- Household bananas or other susceptible household plants = Very low
- Susceptible wild/commercial plants = Very low

Partial probabilities of spread

- Commercial bananas = Moderate
- Household bananas or other susceptible household plants = Moderate
- Susceptible wild/commercial plants = Moderate

Probability of entry, establishment or spread (1 tonne) = Negligible

Annual probability of entry, establishment or spread = Negligible

Consequences = Very low

Unrestricted risk = Negligible

Because the unrestricted risk falls within Australia’s ALOP (very low) risk management would not be required for weevils.
RISK MANAGEMENT FOR QUARANTINE PESTS

The unrestricted biosecurity risk of each quarantine pest was estimated in the previous section, *Risk Assessment for Quarantine Pests*, to ascertain whether it exceeded Australia’s ALOP (‘very low’). In cases where the unrestricted risk was found to be ‘very low’ or ‘negligible’, the risk was considered acceptable and it was concluded that no risk management measures were required in respect of that pest. The unrestricted biosecurity risk of Moko, freckle and mealybugs in relation to the importation of commercially produced fresh hard green Cavendish bananas originating from areas of Mindanao in the Philippines was estimated in each case to exceed Australia’s ALOP and thus it was concluded that risk management measures would be required for those pests.

This section evaluates those measure available to manage the biosecurity risk of Moko, freckle and mealybugs to meet Australia’s ALOP. Risk management ‘options evaluation’ methodology is described in the *Method for Import Risk Analysis*.

The measures discussed below are in addition to the risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in the Philippines Department of Agriculture responses to the IRA team questions and the *Draft IRA Report* regarding the proposal to import Philippine bananas (Philippines Dept. Agriculture, 2001; 2002a; 2002b). These practices are discussed in the *Method for Import Risk Analysis* and in the various pest risk assessments.

The least trade restrictive of the measures discussed below for Moko, freckle and mealybugs, in conjunction with standard practices used in the Philippines in the production of commercially grown bananas, form the basis of proposed import conditions for Philippine bananas that are detailed in the section entitled *Quarantine Conditions*.

**MOKO**

Because the scenario of concern for Moko (*Ralstonia solanacearum* Race 2) is ‘symptomless’ infection of banana fruit, alteration of harvesting procedures (Imp3), processing steps in the packing station (Imp4 and Imp6), quarantine inspection parameters (Imp7), transport conditions (Imp8 and Imp9) and on-arrival inspection in Australia (Imp10) would not influence the likelihood of entry, establishment or spread.

No technically and economically feasible physical or chemical treatment is currently available to mitigate the risk of Moko bacterium present in symptomless infected fruit.

Nevertheless, the likelihood that the Moko bacterium would enter, establish or spread in Australia by way of imported Philippines Cavendish bananas could be reduced by the following four strategies:

- Source bananas for export from pest free areas (area freedom)
- Source bananas for export from areas of low pest prevalence
- Inspection for internal peduncle symptoms of Moko by quality assurance staff
- Restrict the distribution of imported bananas to parts of Australia in which bananas are not grown commercially.
Area freedom

Area freedom as described in the IPPC ISPM 4 – *Requirements for pest free areas* and ISPM 10 – *Requirements for the establishment of pest free places of production and pest free production sites* was recognised, in principle, as a risk management measure. Area freedom would require, among other things, systems to establish, maintain and verify freedom, including assurance that the pest was absent at the time of harvest and that it had not been reported within a specified period prior to harvest. A buffer zone may also be required, for example a bordering area in which all banana plants (commercial, native or feral) should be free from the pest for a specified period.

Freedom from Moko within the area from which bananas for export to Australia would be sourced would influence the first step in the importation pathway (Imp1). This step describes the likelihood that the pest would be present in the plantation from which a tonne of fruit would be sourced.

It was considered that under area freedom arrangements, the likelihood that Moko would be present in a plantation from which a tonne of harvested fruit would be sourced (Imp1), and the likelihood that a tonne of harvested fruit would be infected with Moko (Imp2) would be negligible. When these modified (restricted) likelihoods were placed in the risk simulation model, and the assessment for Moko repeated, the restricted annual likelihood of entry, establishment or spread was found to be very low. When this was combined with the estimate of disease consequences, the restricted risk for Moko was found to be negligible. Because this satisfies Australia’s ALOP, bananas could, in theory, safely be imported from pest free areas.

The efficacy of area freedom as a risk management strategy for Moko is summarised in Table 18 below.

<table>
<thead>
<tr>
<th>Importation Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp1</td>
<td>High</td>
<td>Negligible</td>
</tr>
<tr>
<td>Imp2</td>
<td>Extremely low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>Moderate</td>
<td>Very low</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

However, while the principle of area freedom is theoretically available as a risk management measure for Moko, delimitation, establishment and maintenance of a pest free area would need to...
be relevant to the biology of Moko, including its survival potential and means of spread, as well as the characteristics of production places/sites. The epidemiology of Moko is such that it might be difficult to meet the requirements of ISPM 4 and 10. As such, this measure may not be a technically feasible option in the current circumstances in the Philippines. Other measures were considered to be technically feasible and these are discussed in more detail below.

Areas of low pest prevalence

The concept of “area of low pest prevalence” is accepted internationally by phytosanitary experts, and is a recognised pest management measure under the SPS Agreement (Article 6).

There is currently no international standard established by the IPPC specifically devoted to low pest prevalence. At the April 2003 Interim Commission for Phytosanitary Measures (ICPM), low pest prevalence was included on the ICPM work program. Accordingly, the May 2003 meeting of the Standards Committee Working Group developed a ‘Specification’ for a standard and the Working Group that will develop a draft standard held its first meeting 4-12 December 2003. Nevertheless, the North American Plant Protection Organization (NAPPO) has developed a Regional Standard for Phytosanitary Measures (RSPM) for low pest prevalence, “Guidelines for the Establishment, Maintenance and Verification of Areas of Low Pest Prevalence for insects” (RSPM 20). This standard has been used as guide for the following discussion.

In this IRA Report, the concept of low pest prevalence is applied to a production area. A production area could be a place of production (i.e. a plantation) or a production site (i.e. a portion of a place of production or of a plantation) that is managed as a single unit.

The prevalence of Moko in the plantation from which export bananas would be sourced would influence the likelihood that a tonne of fruit would be infected with the Moko bacterium (Imp2).

In the Moko risk assessment, Imp2 was estimated using the equation

\[ \text{Imp2} = 1-(1-P)^N \]

where:

- \( P \), the likelihood that a harvested bunch will bear a symptomless infection calculated as:
  prevalence of Moko ((Moko infected mats (cases) per hectare per week)/number of mats per hectare (1700)) x Moko incubation period (12 weeks) x likelihood that an infected plant would bear a symptomless but infected bunch (0.15) x proportion of a symptomless infected bunch bearing symptomless but infected fruit (0.5); and

- \( N \), the number of bunches required for a tonne of export quality fruit = 50

Under standard Philippines plantation practice, Imp 2 was estimated to be \( 6.7 \times 10^{-4} \) using 0.025 Moko cases per hectare per week. This number of Moko cases per hectare per week was estimated from data provided by BPI (Philippines Dept. Agriculture, 2001).

Working down from 0.025 cases per hectare per week, it was determined, using the above equation, that if bananas were sourced from an area where the Moko prevalence (per 1700 mats per hectare) was no higher than 0.005 cases (infected mats) per hectare per week, which is about 1 case per 4 hectares per year, the point estimate for Imp2 would be 0.00013 (or \( 1.3 \times 10^{-4} \)).

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43 The term ‘low’, as used by the SPS Agreement in the context of a low pest prevalence area, is not the same concept as used in Biosecurity Australia’s formal definition of a low likelihood

When this point estimate was placed in the risk simulation model, and the assessment for Moko repeated, the restricted annual likelihood of entry, establishment or spread was found to be low. When this likelihood was combined with the estimate of disease consequences, the restricted risk for Moko was found to be very low. Because this satisfies Australia’s ALOP, bananas could safely be imported from areas of low pest prevalence provided that the prevalence is at or below 0.005 cases (infected mats) per hectare per week.

The efficacy of areas of low pest prevalence as a risk management strategy for Moko is summarised in Table 19 below.

Table 19  Moko: establishment of low pest prevalence areas in the Philippines

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp2</td>
<td>Extremely low</td>
<td>1.3 x 10^-4</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Very low</td>
</tr>
</tbody>
</table>

Requirements of an area of low pest prevalence

Using the NAPPO RSPM 20, the IRA team has developed an outline of the requirements for an area of low pest prevalence for Moko that may be used as a basis for export of fresh hard green Philippines bananas to Australia. The details would need to be agreed between the Philippines BPI and Biosecurity Australia (BA). BA would consider proposals from the Philippines that can be objectively demonstrated to offer an equivalent level of protection.

An area of low pest prevalence (ALPP) would be established under the auspices of the Philippines BPI as the relevant National Plant Protection Organisation. In accordance with Article 6.3 of the SPS Agreement, BPI would provide the necessary evidence in order to objectively demonstrate to BA that the designated area is, and is likely to remain, a low pest prevalence area during the course of export of bananas to Australia from the designated area.

The fundamental requirements for establishing and maintaining an ALPP and verification of low pest prevalence area status are summarised below. Following BPI demonstration of an ALPP, BPI and BA would jointly prepare a bilateral arrangement document covering these requirements.

General requirements

General information relating to the application of phytosanitary measures and procedures may be sourced from International Standards for Phytosanitary Measures. In particular, ISPM 4, 5, 6, 8, 10, 13 and 14 are relevant. Before designating an ALPP, BPI would need to ensure that the area would meet the specific requirements described below.

Specific requirements

1. Establishment of an area of low pest prevalence

The average disease prevalence in an ALPP would be less than or equal to 0.005 infected mats per hectare per week, as demonstrated by weekly surveys of banana plants within the ALPP over a
minimum period of two years — BPI would produce 2 years of survey reports for the area prior to recognition of the ALPP status by Australia for that area.

Low pest prevalence (LPP) would be achieved through the application of phytosanitary measures and procedures aimed at reducing and maintaining a specified LPP for Moko. As described in the Method for Import Risk Analysis all plants in commercial Cavendish plantations in the Philippines are inspected weekly and therefore the requirement for weekly inspections would not be an additional impost. The proposed two-year period for demonstrating LPP is based on reports that the B strain of Moko can survive in the soil for up to two years (Stover, 1972; Sequeira, 1962).

The phytosanitary measures and procedures to achieve LPP would include control of disease spread to and within the ALPP and details would be covered in the bilateral arrangement document between BPI and BA.

1.1. Geographic description

- BPI would describe the designated ALPP with supporting maps showing boundaries of the area (including precise grid references) and also location of banana and heliconia plants in proximity to the ALPP.
- BPI would also describe, with supporting maps and documentation, the buffer zones adjacent to the designated area.
- BPI would determine appropriate buffers between an ALPP and other banana plants to maintain the ongoing LPP of Moko in the ALPP. The size of the buffer zone for Moko would depend on disease prevalence, environmental conditions and other biological and epidemiological factors and feasibility. It is noted that the Philippines has adopted a 50-metre buffer zone around commercial plantations to prevent spread of bunchy top disease to those commercial plantations by insect vectors.

1.2. Surveillance activities

BPI would document survey data to demonstrate that the prevalence of Moko in each ALPP did not exceed the LPP level specified by BA, i.e. an average prevalence level of less than or equal to 0.005 cases per hectare per week, over a continuous period of two years.

1.3. Phytosanitary control measures

BPI would verify that the phytosanitary control measures and procedures are applied to achieve the pest prevalence at or below the LPP level specified by BA. BPI would also verify that control measures used to achieve the LPP for Moko are documented and the efficacies of these measures have been recorded.

1.4. Other technical information

BPI would retain historical records of detection and survey activities in every designated ALPP and document phytosanitary control measures and procedures applied and the efficacy of the measures to prevent spread of Moko into or within the ALPP.

1.5. Registration

BPI would register each ALPP and enter into an agreement with the plantation and packing station manager(s) to ensure that phytosanitary measures and procedures aimed at meeting the ALPP requirements are properly applied.
2. **Maintenance of an area of low pest prevalence**

- The specified average LPP level for Moko of less than or equal to 0.005 cases per hectare per week in a registered ALPP would be maintained by the continued application of phytosanitary control measures.

- The status of the area would be confirmed by the ongoing weekly monitoring surveys. The location of each case of Moko would be recorded on a plan of the ALPP.

- BPI would put in place regulatory measures as necessary to minimise the likelihood of spread of Moko into and within the ALPP.

- To achieve this objective, one of the measures would be that any Moko case (infected mat) in the ALPP would be eradicated within 48 hours of the disease detection in the ALPP and the buffer area. This time period was considered to be both reasonable and expeditious taking into account standard plantation management practices. It is noted that in the Philippines, the common practice in commercial banana plantations is to remove, expeditiously, the infected mat and also mats immediately surrounding the infected plant (Philippines Dept. Agriculture, 2002a) and mats within a radius of 5 to 6 m from the infected plant (PCARRD, 1988). According to Stover (1972) and Lehmann-Danzinger (1987), a plant-to-plant buffer area could be up to 10 m to prevent spread of the disease. BPI would determine the appropriate plant-to-plant buffer zone depending on conditions affecting the spread of Moko in a given area.

### 2.1. Phytosanitary control measures

BPI would ensure that phytosanitary control measures and procedures are applied to maintain the prevalence of Moko at or below the LPP level specified by BA and that the phytosanitary control measures and procedures are documented. BPI would maintain an audit and monitoring program to ensure that the control measures are properly applied.

### 2.2. Surveillance activities

BPI would maintain a quality control program for the survey to confirm and document that all protocols are met.

### 2.3. Movement controls

BPI would put in place controls on movement of plants and plant products to minimise the likelihood of entry of the Moko bacterium into an ALPP. BPI would identify the pathways and articles that require phytosanitary control and establish an audit and monitoring program for nominated articles (e.g. soil, used machinery, tools and planting material, etc.) moving into the ALPP.

### 3. Verification of an area of low pest prevalence

BPI would verify that the requirements to maintain the ALPP continue to be met. In addition to the surveillance activities, phytosanitary control measures, and movement controls detailed in the bilateral arrangement document, BPI would conduct audits of field and packing station inspections.

### 4. Change in the status of an area of low pest prevalence

- The detection of Moko that exceeds the specified LPP level within the designated ALPP would result in the implementation of the emergency action plan as described at point 6 below and immediate notification of BA and AQIS.
• This situation would result in the immediate suspension of fruit exports from the affected ALPP. An ALPP status may be terminated if appropriate emergency actions are not taken in response to the detection of Moko above the specified LPP level.

• BPI would take appropriate emergency action to delimit, contain, control and/or eradicate Moko detected in an ALPP according to the bilateral arrangement document.

• Suspension of an ALPP would remain in place until it is proven that prevalence is at or below the specified LPP for a minimum period of two years (based on the survival time of the Moko bacterium in the soil). If prevalence is exceeded in a limited area that can be identified and isolated, then the ALPP may be redefined to exclude that area. Identification of such areas of prevalence must include mapping (by techniques such as aerial photography) of all detections within a two-year period on the plan of the designated area.

• Failure of BPI to take appropriate emergency actions would result in termination of the low pest prevalence status of an area.

5. Reinstatement of the status of an area of low pest prevalence

Implementation of required phytosanitary measures that achieve verifiable reduction in the prevalence of Moko to the specified LPP level for a continuous period of two years or more would be eligible for reinstatement of the ALPP status. Following bilateral discussions and review, the size of an ALPP area may be redefined as described at point 4 above.

6. Emergency action plan

BPI would prepare a documented plan of emergency actions to be implemented if Moko exceeds the specified LPP level of prevalence in the ALPP. The emergency action plan would include the delimiting survey, inspections and testing, phytosanitary control measures, and control of the movement of fruit for Australia from the ALPP. The emergency actions would be initiated within 48 hours of confirmation that the specified LPP level has been exceeded in the ALPP in order to minimise the spread of the Moko bacterium by the application of phytosanitary control measures and procedures at the infection foci. BPI would notify Australia immediately upon initiation of the emergency action plan. Failure to implement emergency actions would result in termination of the ALPP status.

7. Administration by the NPPO

BPI would ensure availability of necessary legislation, administrative infrastructure, qualified personnel, and material resources to comply with the provisions of the bilateral arrangement document.

8. Documentation

BPI would make available to BA, immediately upon request, the documentation supporting the LPP status of a designated area(s), including establishment, maintenance, verification and reinstatement of the ALPP.

9. Bilateral arrangement document

As noted above, requirements would be addressed in a bilateral arrangement document for recognition of an ALPP as a basis for export of fresh hard green Philippines bananas to Australia. There would be consultation in the early stages of the process in order to ensure that all of Australia’s biosecurity requirements are met. The transportation, integrity of consignments, financial responsibilities, roles and responsibilities of BPI, AQIS and BA and producers, among
other things, would be addressed in the bilateral arrangement document. BPI would establish a quality control program for the survey, laboratory diagnosis and eradication of Moko cases, including the surveyor and diagnostician competency.

**Inspection for internal peduncle symptoms of Moko by quality assurance staff**

It is well documented that Moko infection causes vascular discolouration irrespective of whether external disease symptoms develop (Rorer, 1911; Ashby; 1926; Martyn, 1934; Sequeira, 1958; Buddenhagen, 1961; Power, 1976; Kastelein and Gangadin, 1984; Soguilon et al., 1994b; Jeger et al., 1995; Soguilon, 2003a). Buddenhagen (1961) claimed that peduncle discolouration is a distinctive symptom of Moko. However, it is also well documented that the degree of discolouration varies from cream or yellow through reddish brown, brown and black. The colour variation is likely to depend on the time elapsed since infection and the severity of the infection. In some cases there may be no discolouration if the peduncle is examined in cross section within the ‘lag period’ between when bacteria in the vascular bundles pass the examination point and the first visible signs of vascular discolouration.

Nevertheless, it was considered that an examination of the cut peduncle surface of banana bunches harvested for export to Australia would be a means of detecting at least some Moko infected banana bunches not expressing visible symptoms and thus a means of reducing the likelihood of importing ‘symptomlessly infected’ banana fruit.

Inspection for internal Moko symptoms in freshly cut cross sections of peduncles could be conducted within the packing station after receipt of the bunches from the plantation by quality assurance staff trained to detect vascular discolouration caused by the Moko bacterium. This inspection would be in addition to the routine quality assurance regimes targeted at ensuring the removal of fruit with blemishes, obvious distortion in shape, premature ripening and visible splits. While quality assurance staff may not detect all occurrences of discolouration, if peduncle tissue from all harvested bunches for export to Australia were examined, it was considered that there would be a moderate likelihood that ‘symptomless infected’ bunches would be detected and removed by routine quality inspection at Imp5.

When this restricted likelihood was placed in the risk simulation model, and the assessment for Moko repeated, the restricted annual likelihood of entry, establishment or spread was found to be moderate. When this likelihood was combined with the estimate of disease consequences, the restricted risk for Moko was found to be low, which exceeds Australia’s ALOP. The use of targeted inspection for internal peduncle Moko symptoms would, therefore, not be an effective risk management measure.

The efficacy of inspecting the cut peduncle for internal (vascular) symptoms of Moko infection is summarised in Table 20 below.
Table 20  Moko: inspection of cut peduncle for vascular Moko symptoms

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp5</td>
<td>Negligible</td>
<td>Moderate</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Restricting the distribution of imported bananas

Restricting the port of importation and limiting the distribution of imported bananas to areas in which bananas are not grown commercially would reduce the likelihood of Moko entering, establishing or spreading within Australia.

If undertaken, movement restrictions could be based on delineating the parts of Australia where bananas are grown commercially, from other parts of Australia. Not independently, this would also provide for delineation between tropical or subtropical parts of Australia where Moko could establish or spread, and temperate, arid or alpine zones where climate would limit establishment or spread. A demarcating line has been drawn across Australia for this purpose (Figure 13).

In placing this line, the IRA team has ensured that parts of Australia where State declared quarantine areas/zones in respect to banana pests and diseases lie to the north. Lower risk areas lie to the south. Specifically, the demarcation meant that all of Queensland and Northern Territory, parts of New South Wales north of 32°30’S, and parts of Western Australia north of 26°S were included in the higher risk northern zone.

The 26th parallel was chosen as the starting point for the demarcation line on the west side of Australia because this is the line that separates the area in Western Australia where non-Western Australian grown bananas can be marketed from the area where they cannot (described previously in Proposal to import bananas from the Philippines). The South Australian border was chosen as the most convenient line to link the 26th parallel in the west with the 32nd 30’ parallel in eastern Australia, a convenient line below the New South Wales Banana Protection Area (described previously in Proposal to import bananas from the Philippines).
Restricting the distribution of Philippines bananas in Australia in the manner described above could be implemented by the Commonwealth Government using the Quarantine Act 1908 (the Act) and its subordinate legislation.

**Ports of entry**

The entry of Philippines bananas into Australia could be restricted to ports in that part of Australia south of the demarcation line.

Paragraphs 13(1)(a) of the Act provides that the Governor-General may declare any ports in Australia to be first ports of entry for overseas vessels. Paragraph 13(1)(b) of the Act provides that the Governor-General may declare any ports in Australia to be ports where imported animals, plants or other goods, or imported animals, plants or other goods of a particular kind or description or having a particular use may be landed.

An amendment to the Quarantine Proclamation 1998 (the Proclamation) would be required to restrict the ports at which Philippines banana fruit could be landed. Those ports would be the ports in the States of South Australia, Victoria, New South Wales, Tasmania and Western Australia south of the 26th parallel as specified in section 13 of the Proclamation. Once this amendment is made, a person would be guilty of an offence under section 20D of the Act if he/she lands the banana fruit at a port other than a port declared by the Proclamation to be a port at which it may be landed. The maximum penalty for this offence is imprisonment for 10 years.
Distribution of imported fruit

After the Philippines bananas have been released from Quarantine Approved Premises (designated for the purpose of on-arrival inspection by AQIS) the imported Philippines banana fruit would be free to be moved anywhere in that part of Australia south of the demarcation line. Movement to that part of Australia north of the demarcation line would be prohibited unless a permit is granted. If a permit is granted, movement to and within that part of Australia north of the demarcation line would then be subject to the permit and any conditions set out in the permit.

Subsection 13(1)(g) of the Act provides that the Governor-General may, by proclamation, prohibit the removal of, amongst other things, any plants or parts of plants from any part of the Commonwealth to any other part of the Commonwealth. Subsection 13(2A) of the Act provides that a proclamation prohibiting the removal of anything from one part of Australia to any other part may provide that the removal is prohibited unless a permit to remove the thing is granted by a Director of Quarantine. Subsection 13(2B) provides that such a permit may be granted subject to compliance with conditions or requirements that are set out in the permit. Under section 67 of the Act it is an offence to remove a thing from one part of Australia to another part without a permit (if the Proclamation states that one is required) or in contravention of the conditions or requirements set out in the permit. The maximum penalty for this offence is imprisonment for 10 years.

An amendment to the Proclamation would be required to prohibit the removal of Philippines bananas from that part of Australia south the demarcation line to that part of Australia north of the demarcation line unless a permit is granted. It is envisaged that a permit would only be granted under special circumstances and would be for a specific location within the area north of the demarcation line on case-by-case basis. In deciding whether to grant a permit to move fruit to that location, the Director of Animal and Plant Quarantine would, among other things, take into account the level of Moko biosecurity risk at that location. Section 70 (1) of the Proclamation would also be amended to include “removal of a thing from one part of Australia to another part of Australia”.

An awareness campaign would also be undertaken to inform the Australia community about the restrictions on the movement of Philippines bananas within Australia and the penalties that apply if they are moved illegally from one part of Australia to another part of Australia across the demarcation line. This campaign would particularly focus on participants in the distribution chain (wholesalers and retailers) and seek their cooperation.

To ensure that imported fruit could be readily distinguished from domestic fruit, quarantine conditions would need to include a requirement that imported fruit cartons (lid and box) are appropriately labelled. Additionally, because banana fruit is generally separated from cartons when it is presented to consumers at the point of sale, it may be necessary to identify imported Philippines banana fruit so that they could be readily distinguished from domestically grown fruit. This could be achieved by affixing labels to individual banana hands as part of the pre-packing arrangements or perhaps dipping the tips of fingers into a particular coloured wax as is done presently in Australia to distinguish some types of domestic banana production.

Restricting the distribution of bananas in Australia to areas south of the demarcation line (Figure 13) would have an impact on many of the likelihoods contributing to the probability of Moko distribution in Australia, the partial probabilities of Moko establishment and the partial probabilities of Moko spread. Estimation of these likelihoods is described in detail in Method for Import Risk Analysis and in the Moko risk assessment.

The impacts on these likelihoods are discussed individually below.
Dist1 — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers. Restriction of the distribution of fruit is unlikely to alter Dist1 from its unrestricted rating of high.

Prop1 — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially. Because commercial banana-growing areas lie to the north of the demarcation line, Prop1 would, with complete compliance, be zero. The IRA team, however, recognises that by virtue of complex wholesale and retail distribution networks and unaware travelling consumers an extremely low proportion of imported fruit might be moved north of the demarcation line.

Prop2 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (non-commercial) banana plants, or other susceptible garden plants (including weeds) are grown. Because Moko may utilise as host plants, heliconias and some common garden weed species (e.g. B. pilosa and S. nigrum) that are found in most parts of Australia, restricting the distribution of Philippines bananas in Australia will not greatly alter Prop2. The restricted likelihood for Prop2 will thus remain high.

Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants or susceptible cultivated plants other than bananas are found. For the reason as outlined for Prop2 (see above) Prop3 will remain high.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment. Restriction of the distribution of fruit is unlikely to alter Dist2 from its unrestricted rating of certain.

Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment. Dist3 pre-supposes that the pest has entered the environment in an area where this group of susceptible hosts can be found. The extremely low likelihood that imported bananas will be distributed to an area where commercial bananas can be found has been incorporated in Prop1. However, if bananas were to be distributed to such an area, then the likelihood that commercial bananas would be exposed to the pest would be unchanged from its unrestricted rating of low.

Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment. The scenario of concern for the exposure of susceptible household plants was the discarding of infected peel at a site adjacent to a susceptible plant. Although there are fewer household banana plants in the area south of the demarcation line, susceptible weed species are common and widespread, and Dist4 is unlikely to be altered from the unrestricted rating of low.

Dist5 — the likelihood that susceptible wild (native or feral) plants or other susceptible commercial plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or that had otherwise entered the environment. For the reasons outlined above, Dist5 was also unlikely to be altered from the unrestricted rating of low.

PPE Commercial — the partial probability of establishment for commercial bananas. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of moderate.

PPE Household — the partial probability of establishment for susceptible household plants. Under these restrictions, establishment will be limited largely to populations of household banana plants.
and alternative hosts in unfavourable temperate, arid or alpine environments. This is likely to reduce establishment potential for household plants from moderate to extremely low.

**PPE** _Wild_ — the partial probability of establishment for wild plants or cultivated plants other than _bananas_. For the reason above, establishment potential for wild plants, or for commercially cultivated plants other than heliconias, will also be reduced to extremely low.

**PPS** _Commercial_ — the partial probability of spread for commercial bananas. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of high.

**PPS** _Household_ — the partial probability of spread for susceptible household plants. Under these restrictions, establishment will have been limited to populations of household banana plants and alternative hosts in unfavourable temperate, arid or alpine environments. The likelihood of subsequent spread of the Moko bacterium from a point of establishment in these environments will also be reduced to extremely low.

**PPS** _Wild_ — the partial probability of spread for wild plants or cultivated plants other than bananas. For the reasons above, spread potential for wild plants, or for commercially cultivated plants other than heliconias, will also be reduced to extremely low.

**Summary: restricting the distribution of imported bananas in Australia**

When the modified (restricted) likelihoods described above were placed in the risk simulation model, and the assessment for Moko repeated, the restricted annual likelihood of entry, establishment or spread was found to be extremely low. The restricted annual likelihood of entry, establishment or spread was subsequently combined with the estimate of disease consequences, to give the restricted risk for Moko under this management scenario.

The restricted risk for Moko if the distribution of Philippines bananas is limited to parts of Australia south of the demarcation line was found to be negligible. Because this satisfies Australia’s ALOP, bananas could, in principle, safely be imported under this risk management option.

This process is summarised in Table 21 below.
Table 21  Moko: restricting the distribution of Philippines bananas in Australia

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist1</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Prop1</td>
<td>Low</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Prop2</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Prop3</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Dist2</td>
<td>Certain</td>
<td>Certain</td>
</tr>
<tr>
<td>Dist3</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Dist4</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Dist5</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>PPE</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>PPE</td>
<td>Moderate</td>
<td>Extremely low</td>
</tr>
<tr>
<td>PPS</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>PPS</td>
<td>Moderate</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Annual</td>
<td>Moderate</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Risk</td>
<td>Low</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

Conclusions: risk management for Moko

Two feasible risk management measures were identified for Moko:

- The designation of low pest prevalence areas; and
- Restriction of the distribution of Philippines bananas in Australia

Each of these measures would provide security sufficient to meet Australia’s ALOP. The major difference between these two measures is likely to be in relation to the time required and the administrative complexity of providing for their implementation. The administration of the restriction on the movement of Philippines banana fruit would require additional arrangements and resources to address such issues as monitoring, auditing and non-compliance. The cost of these arrangements and resources would be borne by importers or wholesalers also necessitating the need to develop infrastructure for cost recovery.

It was considered that the time required to develop the suite of legal, administrative and operational arrangements that would be necessary to give the restricted distribution of Philippines banana fruit practical application in Australia is likely to be longer than the time required to demonstrate areas with Moko prevalence at or below the specified LPP level. On this basis, the use of ALPP was considered to be the least trade restrictive of the two risk management options.
FRECKLE

Because the main scenario of concern for freckle (*Guignardia musae*) is symptomless infection of banana fruit, alteration of procedures for transport of harvested fruit to the packing station (Imp3), processing steps in the packing station (Imp4 and Imp6), and transport conditions (Imp8 and Imp9) would not influence the likelihood of entry, establishment or spread through this pathway. Management of the likelihoods assigned to these steps was, therefore, not considered further.

The likelihood that (freckle) would enter, establish or spread in Australia by way of imported Philippines bananas could be reduced through the following four separate measures:

- Source bananas for export from pest free areas (area freedom)
- Source bananas for export from low pest prevalence areas
- Augment quarantine inspection (Imp7 and Imp10)
- Restrict the distribution of imported bananas to parts of Australia in which bananas are not grown commercially.

**Area freedom**

Freedom from freckle within the area from which bananas for export to Australia would be sourced would influence the first step in the importation pathway (Imp1). This step describes the likelihood that the pest would be present in the plantation from which a tonne of fruit would be sourced.

Area freedom as described in the IPPC ISPM 4 and 10 and as discussed above, would require, among other things, systems to establish, maintain and verify freedom, including assurance that the pest was absent at the time of harvest and that it had not been reported within a specified period prior to harvest. A buffer zone may also be required, for example a bordering area in which all banana plants (commercial, native or feral) should be free from the pest for a specified period.

Freedom from freckle could be established by regular inspections prior to de-leafing and be subject to audit.

It was considered that under area freedom arrangements, the likelihood that freckle would be present in a plantation from which a tonne of harvested fruit would be sourced (Imp1), and the likelihood that a tonne of harvested fruit would be infected with freckle (Imp2) would be negligible. When these modified (restricted) likelihoods were placed in the risk simulation model, and the assessment for freckle repeated, the restricted annual likelihood of entry, establishment or spread was found to be extremely low. When this was combined with the estimate of disease consequences, the restricted risk for freckle was found to be negligible. Because this satisfies Australia’s ALOP, bananas could, in theory, safely be imported from pest free areas.

The efficacy of area freedom as a risk management strategy for freckle is summarised in Table 22 below.
Table 22  Freckle: establishment of pest free areas in the Philippines

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp1</td>
<td>High</td>
<td>Negligible</td>
</tr>
<tr>
<td>Imp2</td>
<td>Low</td>
<td>Negligible</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>High</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Negligible</td>
</tr>
</tbody>
</table>

However, while the principle of area freedom is available as a risk management measure for freckle, delimitation, establishment and maintenance of a pest free area would need to be relevant to the biology of freckle, including its means of spread, as well as the characteristics of production places/sites. As such, this measure may not be a technically feasible option in the current circumstances in the Philippines. Other measures were considered to be technically feasible and these are discussed in more detail below.

Areas of low pest prevalence

An ALPP could be established, maintained and verified for freckle in the same manner as described for Moko. BPI may use various measures to maintain LPP level, including cultural practices or fungicide sprays.

As discussed in importation step 2 of the freckle risk assessment (Imp2) and based on information presented in Meredith (1968), the likelihood of symptomless freckle infection occurring on a bunch was considered to be very low in commercial plantations in the Philippines. Further, and as previously discussed in Imp2, the proportion of a bunch that may carry symptomless infected fruit is expected to be low.

The current prevalence of freckle in Philippines plantations has not been calculated. However, the IRA team has determined that if bananas were sourced from an area where the prevalence of freckle was no higher than 1 case (infected mat) per hectare per week, the point estimate for Imp2 would be 0.0018 (or 1.8 x 10⁻³) based on the equation below.

\[ \text{Imp2} = 1 - (1 - P)N \]

Where:
- A case is defined as the detection of freckle symptoms on any part of a mat from which a bunch could be harvested;
- \( P \) is the likelihood that a harvested bunch will bear a symptomless infection = 3.5 x 10⁻⁵ calculated as: prevalence of freckle ((1 infected mat (cases) per hectare per week)/number of mats per hectare (1700)) x freckle incubation period (4 weeks) x likelihood that an infected plant would bear a symptomless but infected bunch (0.05\(^*\)) x proportion of a symptomless infected bunch bearing symptomless but infected fruit (0.3\(^*\)); and
- \( N \) is the number of bunches required for a tonne of export quality fruit (50).

\(^*\) For the purposes of this analysis the upper limit of Biosecurity Australia’s likelihood category of ‘very low’ or ‘low’ was used.
When the point estimate for Imp2 (i.e. $1.8 \times 10^{-3}$) was placed in the risk simulation model, and the assessment for freckle repeated, the restricted annual likelihood of entry, establishment or spread was found to be low. When this likelihood was combined with the estimate of disease consequences, the restricted risk for freckle was found to be very low. Because this satisfies Australia’s ALOP, bananas could safely be imported from an ALPP.

The efficacy of ALPP as a risk management strategy for freckle is summarised in Table 23 below.

**Table 23 Freckle: establishment of low pest prevalence areas in the Philippines**

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp2</td>
<td>Low</td>
<td>$1.8 \times 10^{-3}$</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Very low</td>
</tr>
</tbody>
</table>

**Requirements of an area of low pest prevalence**

The key variations to arrangements for an ALPP for freckle as compared to Moko would be as follows:

- The specified LPP level for freckle is less than or equal to 1 case (infected mat) per hectare per week.
- The specified LPP level must be demonstrated by weekly surveys over a minimum period of four (4) weeks before registering an ALPP. A four-week period was considered reasonable for demonstrating the specified LPP level for freckle in a designated area taking into account the most likely incubation period.
- In the event the ALPP status is suspended or terminated, reinstatement would require a verifiable reduction in the prevalence of freckle back to at or below the specified LPP level for a continuous period of four (4) weeks or more.

**Augmenting quarantine inspection**

Inspection may be augmented at importation step Imp7 (quarantine inspection in the Philippines) or at importation step Imp10 (AQIS inspection on-arrival in Australia). Augmentation can be either by using magnification or increasing the number of fruit examined in a consignment (Imp7) or a lot (Imp10).

As explained in the *Method for Import Risk Analysis*, the effectiveness of inspection will be determined by the following expression:

\[
P(\text{at least one affected cluster is detected}) = 1 - P(\text{all affected clusters are not detected}) \\
= 1 - (1 - P \times S)^{\text{Number of clusters examined}}
\]

Where;

- P is the prevalence of affected clusters within the consignment or lot, which for Imp7 and Imp10 was considered to be extremely low
• S is the ‘sensitivity’ of the inspection process, or the likelihood that the pest would be identified during examination of an individual infected cluster.

The likelihood that a cluster of ‘symptomless’ fruit would be identified at quarantine inspection in the Philippines (Imp7) is negligible. Because small freckles are unlikely to increase to a size where they might be visible to the naked eye during the voyage to Australia, it was considered that the likelihood of detection at Imp10 would also be negligible.

With magnification, some of the small freckles previously invisible with the naked eye would become visible. This means that the likelihood that a cluster of infected fruit would be detected at quarantine inspection in the Philippines (Imp7) may no longer be negligible. Likewise, the likelihood that infected clusters would be detected at AQIS on-arrival inspection would also be increased (Imp10). It was considered that the degree of improvement in ability to detect an infected cluster would be greater for AQIS on-arrival inspection than for Philippines inspection because some small freckle lesions not visible at Imp7 would somewhat enlarge in transit and become visible under magnification during on-arrival inspection (Imp10). Overall, while the degree of improvement in ability to detect an infected cluster using magnification was difficult to estimate with precision, it was considered to be extremely low for Imp7 and very low for Imp10.

Under routine inspection procedures, 600 clusters would be examined from either a consignment (Imp7) or a lot (Imp10).

Placing 600 clusters into the above formula, the effect of magnification at each inspection step was calculated (Table 24). The use of magnification at quarantine inspection in the Philippines (Imp7) and in Australia (Imp10) would increase the overall effectiveness of the inspection process from negligible (without magnification) to extremely low and very low, respectively.

Repeating the calculation above with increased numbers of clusters sampled, it was found that the effectiveness of quarantine inspection would not improve even if 4000 clusters from each lot or consignment were examined.

Table 24 Effectiveness of quarantine inspection for freckle

<table>
<thead>
<tr>
<th>Step</th>
<th>Sensitivity</th>
<th>Number of clusters examined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>600</td>
</tr>
<tr>
<td>Imp7</td>
<td>Visual inspection</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td>Magnification</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Imp10</td>
<td>Visual inspection</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td>Magnification</td>
<td>Very low</td>
</tr>
</tbody>
</table>

* Cells in this table were calculated using the Uniform probability distributions described in the Method for Import Risk Analysis.

When the modified likelihoods for Imp7 and/or Imp10 for inspection under magnification of 600, 1000 or 4000 clusters were placed in the risk simulation model, and the assessment for freckle repeated, the restricted overall risk was found to be low (Table 25). This level of risk exceeds Australia’s ALOP and therefore augmented quarantine inspection cannot be used as a single measure to mitigate the biosecurity risk of freckle.
Table 25  Freckle: augmentation of quarantine inspection in the Philippines and in Australia

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imp7</td>
<td>Negligible</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Imp10</td>
<td>Negligible</td>
<td>Very low</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Restricting the distribution of imported bananas

Restricting the port of importation and limiting the distribution of imported bananas to areas in which bananas are not grown commercially would reduce the likelihood of freckle entering, establishing or spreading within Australia.

The principles and practical difficulties of limiting the distribution of Philippines banana fruit in Australia were explained in the discussion of risk management for Moko (see above). Also explained was the demarcation of Australia into higher and lower risk parts of Australia (Figure 13). To reiterate, the IRA team chose that demarcation line to ensure that parts of Australia where State declared quarantine areas/zones in respect to banana pests and diseases lie to its north - representing areas in Australia where bananas are commercially grown. Areas where bananas are either not grown or not grown commercially (lower risk areas) lie to the south of the line (See Appendix 2: Survey of households for banana plants in Australia). Specifically, the demarcation meant that all of Queensland and Northern Territory, parts of New South Wales north of 32°30’S, and parts of Western Australia north of 26°S were included in the higher risk northern zone.

Restricting the distribution of Philippines bananas to parts of Australia south of this line would have an impact on several of the likelihoods contributing to the probability of distribution of freckle.

These likelihoods are discussed individually below.

**Dist1** — the likelihood that a pest will survive storage and ripening of fruit and its distribution to wholesalers. Restriction of the distribution of fruit is unlikely to alter Dist1 from its unrestricted rating of high.

**Prop1** — the proportion of imported bananas that is likely to be distributed to an area in which bananas are grown commercially. Because commercial banana-growing areas lie to the north of the demarcation line, Prop1 would, with complete compliance, be zero. The IRA team, however, recognises that by virtue of complex wholesale and retail distribution networks, and unaware travelling consumers, an extremely low proportion of imported fruit might be moved north of the demarcation line.

**Prop2** — the proportion of imported bananas that is likely to be distributed to an area in which susceptible household (non-commercial) banana plants, or other susceptible garden plants (including weeds) are grown. Because freckle is specific to bananas, restricting the distribution of imported fruit to parts of Australia below the demarcation line will reduce Prop2 from moderate to low.
Prop3 — the proportion of imported bananas that is likely to be distributed to an area in which susceptible wild plants or susceptible cultivated plants other than bananas are found. For the reason outlined for Prop2 (see above) Prop3 will be reduced from low to extremely low.

Dist2 — the likelihood that the pest will be discarded with banana waste (fruit and peel) from fruit purchased by, or intended for purchase by, persons or households — or otherwise enter the environment. Restriction of the distribution of fruit is unlikely to alter Dist2 from its unrestricted rating of certain.

Dist3 — the likelihood that commercially cultivated bananas would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment. Dist3 pre-supposes that the pest has entered the environment in an area where this group of susceptible hosts can be found. The extremely low likelihood that imported bananas will be distributed to an area where commercial bananas can be found has been incorporated in Prop1. However, if bananas were to be distributed to such an area, then the likelihood that commercial bananas would be exposed to the pest would be unchanged from its unrestricted rating of very low.

Dist4 — the likelihood that household (non-commercial) banana plants or other susceptible garden plants (including weeds) would be exposed to the pest discarded with banana waste (fruit and peel), or that had otherwise entered the environment. The scenario of concern for the exposure of susceptible household plants was the discarding of infected peel at a site adjacent a susceptible plant. The low likelihood that imported bananas will be distributed to an area where household bananas can be found has been incorporated in Prop2. Additionally, because there are many fewer household banana plants in these areas south of the demarcation line, and because freckle does not have alternative hosts, Dist4 will be lowered from an unrestricted rating of very low, to a restricted rating of extremely low.

Dist5 — the likelihood that susceptible wild (native or feral) plants or susceptible commercial plants other than bananas would be exposed to the pest associated with banana waste (fruit and peel), or that had otherwise entered the environment. The extremely low likelihood that imported bananas will be distributed to an area where wild (native or feral) bananas can be found has been incorporated in Prop3. However, if imported bananas were to be distributed to such an area, then the likelihood that susceptible hosts in this group would be exposed to the pest would be unchanged from its unrestricted rating of very low.

PPE Commercial — the partial probability of establishment for commercial bananas. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of low.

PPE Household — the partial probability of establishment for susceptible household plants. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of moderate.

PPE Wild — the partial probability of establishment for susceptible wild plants, or cultivated plants other than bananas. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of moderate.

PPS Commercial — the partial probability of spread for commercial bananas. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of high.

PPS Household — the partial probability of spread for susceptible household plants. Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of moderate.
**PPS**<sub>Wild</sub> — *the partial probability of spread for wild plants or cultivated plants other than bananas.* Restriction of the distribution of fruit is unlikely to alter this likelihood from its unrestricted rating of moderate.

**Summary: restricting the distribution of imported bananas in Australia**

When the modified (restricted) likelihoods described above were placed in the model, and the assessment for freckle repeated, the restricted annual likelihood of entry, establishment or spread was found to be very low. The restricted annual likelihood of entry, establishment or spread was subsequently combined with the estimate of disease consequences, to give the restricted risk for freckle under this mitigation scenario.

The restricted risk for freckle if the distribution of Philippines bananas is limited to parts of Australia south of the demarcation line was found to be negligible. Because this satisfies Australia’s conservative ALOP, bananas could be imported under this condition.

This process is summarised in Table 26 below.

**Table 26  Freckle: restricting the distribution of Philippines bananas in Australia**

<table>
<thead>
<tr>
<th>Step</th>
<th>Unrestricted likelihood</th>
<th>Restricted likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dist1</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Prop1</td>
<td>Low</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Prop2</td>
<td>Moderate</td>
<td>Low</td>
</tr>
<tr>
<td>Prop3</td>
<td>Low</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Dist2</td>
<td>Certain</td>
<td>Certain</td>
</tr>
<tr>
<td>Dist3</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>Dist4</td>
<td>Very low</td>
<td>Extremely low</td>
</tr>
<tr>
<td>Dist5</td>
<td>Very low</td>
<td>Very low</td>
</tr>
<tr>
<td>PPE&lt;sub&gt;Commercial&lt;/sub&gt;</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>PPE&lt;sub&gt;Household&lt;/sub&gt;</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>PPE&lt;sub&gt;Wild&lt;/sub&gt;</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>PPS&lt;sub&gt;Commercial&lt;/sub&gt;</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>PPS&lt;sub&gt;Household&lt;/sub&gt;</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>PPS&lt;sub&gt;Wild&lt;/sub&gt;</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Annual likelihood</td>
<td>High</td>
<td>Very low</td>
</tr>
<tr>
<td>Risk estimate</td>
<td>Low</td>
<td>Negligible</td>
</tr>
</tbody>
</table>
**Conclusions: risk management for freckle**

Two feasible risk management measures were identified for freckle:

- The designation of low pest prevalence areas (ALPP);
- Restriction of the distribution of Philippines bananas in Australia; and

Each of these measures provided security sufficient to meet Australia’s ALOP. As previously noted, while designating areas free of freckle (area freedom) is an acceptable risk management option, it would be more difficult to achieve than the option of using ALPPs. Consequently, ALPP was considered to be more feasible and the least trade restrictive of these two measures.

As discussed in the Moko risk management section, the major difference between using ALPPs and restricting the distribution of Philippines banana fruit in Australia is likely to be in relation to the time required and the administrative complexity of providing for their implementation. The time required to develop the suite of legal, administrative and operational arrangements that would be necessary to give the restricted distribution of Philippines banana fruit practical application in Australia is very likely to be longer than the time required to demonstrate areas with freckle prevalence at or below the specified LPP level. On this basis, the use of ALPP was considered to be the least trade restrictive of these two risk management options.

**MEALYBUGS**

Three mealybug species were examined in this analysis. Of the three, only the risk associated with *Dysmicoccus neobrevipes* and *Psuedococcus jackbeardsleyi* exceeded Australia’s ALOP and required risk management.

The likelihood that these mealybugs would enter, establish or spread in Australia by way of imported Philippines bananas could be reduced through the following measures:

- The use of permanent packing stations only (Imp3);
- Targeted inspection for the mealybugs by quality assurance staff (Imp 5)
- Augmentation of the routine washing and decontamination procedures in the packing station (Imp 6) by:
  - the use of an insecticidal treatment; and
  - targeted sponging and brushing of the spaces between banana fruit
- Augmentation of on-arrival AQIS inspection (Imp10).

The scenario of concern for mealybugs is infestation of spaces between banana fingers.

- Measures that might reduce the high likelihood that *D. neobrevipes* and *P. jackbeardsleyi* are present on the source plantation (Imp1) such as area freedom were not identified. Area freedom was not considered a feasible measure based on the reproductive strategy and thus persistence of mealybugs, and their dispersal ability;
- Despite the use of chlorpyrifos-impregnated bunch covers in many Philippines plantations, mealybugs are considered a contaminant of hard green fruit at the point of harvest (Imp2) given that mealybugs have been intercepted on Philippines bananas in Japan and New Zealand (Spence, 2002; Sugimoto, 1994). Additional field management measures that might reduce the likelihood assigned to this step were not identified and hence the use of low pest prevalence areas was not considered a feasible measure;
- The likelihood that harvested fruit would become contaminated within the packing station
(Imp4) was considered negligible, and, thus could not be further reduced; and

- The likelihoods that surviving mealybugs would remain viable during transport to the wharf (Imp8) and subsequently to Australia (Imp9) were considered high. Measures that might reduce these likelihoods were not identified.

In addition, because these mealybugs are polyphagous pests whose hosts include many species of fruiting plant in a range of climate zones, limiting the distribution of imported fruit to areas in which bananas are not grown commercially was not explored as a possible means of reducing risk.

**Permanent packing stations**

It was considered that when bunches are de-handed in the field, as occurs where mobile packing stations are used, there may be a higher likelihood of infestation with mealybugs (see mealybug risk assessment). The likelihood that infestation would occur during transport to the packing station could, therefore, be reduced by requiring that all bunches be transported to the packing station on overhead cableways. This would mean that only permanent packing stations could be used for fruit for export to Australia.

The relative impact of mobile and permanent packing stations on the likelihood assigned to this step (Imp3) can be calculated using the formula below. As stated in the *Method for Import Risk Analysis*, approximately 10% of bananas are packed in mobile packing stations.

\[
\text{Imp3 Overall} = (10\% \times \text{Imp3 Mobile packing stations}) + (90\% \times \text{Imp3 Permanent packing stations})^{45}
\]

In this expression, \(\text{Imp3 Mobile packing stations}\) is the likelihood of infestation where a mobile packing station is used. This was considered to be extremely low. Likewise, \(\text{Imp3 Permanent packing stations}\) is the likelihood of infestation where a permanent packing station is used. This was considered to be negligible.

When *all* packing stations are permanent, the likelihood of infestation (Imp3 Overall) would be negligible.

When the modified likelihood for Imp3 was placed in the model, and the assessment for *D. neobrevipes* and *P. jackbeardsleyi* was repeated, the restricted annual likelihood of entry, establishment or spread was found to be high. Because the restricted annual likelihood of entry, establishment or spread remained the same as the unrestricted annual likelihood of entry, establishment or spread, the overall restricted risk for *D. neobrevipes* and *P. jackbeardsleyi* would remain above Australia’s ALOP and therefore the use of only permanent packing stations would not be an effective risk management measure.

**Targeted inspection for the mealybugs by quality assurance staff**

Routine quality assurance regimes are targeted at ensuring the removal of fruit with blemishes, obvious distortion in shape, premature ripening and visible splits.

It was considered that if quality assurance staff were to specifically target the spaces between banana fingers as part of their quality inspections, that there would be a high likelihood that *D. neobrevipes* and *P. jackbeardsleyi* would be seen and hence these mealybugs would be removed from the fruit at this stage of the importation pathway. When the modified likelihood for Imp5 was

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45 The calculations on Imp3 were performed by simulating the probability ranges described in the *Method for Import Risk Analysis*
placed in the simulation model, and the assessment for *D. neobrevipes* and *P. jackbeardsleyi* was repeated, the restricted annual likelihood of entry, establishment or spread was found to be moderate. When this was combined with the estimate of consequences of *D. neobrevipes* and *P. jackbeardsleyi*, the restricted risk for these mealybugs was found to be low, which exceeds Australia’s ALOP. The use of only targeted inspection of the spaces between banana fingers would, therefore, not be an effective risk management measure.

**Augmentation of the routine washing and decontamination procedures in the packing station**

**Insecticidal treatment**

Insecticidal treatment by way of a dip or spray at the packing station could be used to kill *D. neobrevipes* and *P. jackbeardsleyi* present on harvested fruit. While an insecticide is unlikely to be completely effective in killing all *D. neobrevipes* and *P. jackbeardsleyi* individuals in the spaces between banana fruit fingers, it is considered that it would be highly effective. Thus the rating assigned to Imp6 — *The likelihood that the pest will be removed from fruit or destroyed as a result of routine washing and decontamination procedures undertaken within the packing station would be increased from low to high*. When the modified likelihood for Imp6 was placed in the model, and the assessment for *D. neobrevipes* and *P. jackbeardsleyi* was repeated, the restricted annual likelihood of entry, establishment or spread was found to be moderate. When this likelihood was combined with the estimate of consequences of *D. neobrevipes* and *P. jackbeardsleyi*, the restricted risk for these mealybugs was found to be low, which exceeds Australia’s ALOP. The use of only an insecticide dip or spray would, therefore, not be an effective risk management measure.

**Targeted sponging and brushing of the spaces between banana fingers**

The routine cleaning procedures for bananas include hosing fruit bunches with water, immersion of de-handed fruit in water treated with chlorine and alum and, finally, sponging and brushing of visibly contaminated fruit.

Hosing the fruit bunches is intended to remove dirt and admixed organic matter. This is relevant for pests loosely attached to the surface of fruit or associated with soil or organic matter but augmentation at this stage is unlikely to remove mealybugs between banana fingers. Sponging or brushing, on the other hand, is used to clean fruit, and to remove contaminants such as mealybug pests. All fruit pass through this cleaning procedure. Nevertheless, unless specifically targeting the spaces between banana fruit fingers, it was considered that sponging or brushing would not remove all mealybugs that might be lodged in those spaces.

It was considered, however, that if packing station staff were to specifically focus at Imp6 on cleaning the spaces between banana fingers as part of their cleaning regime, that there would be a high likelihood that *D. neobrevipes* and *P. jackbeardsleyi* would be removed from the fruit at this stage of the importation pathway. When the modified likelihood of high for Imp6 was placed in the simulation model, and the assessment for *D. neobrevipes* and *P. jackbeardsleyi* was repeated, the restricted annual likelihood of entry, establishment or spread was found to be moderate. When this likelihood was combined with the estimate of consequences of *D. neobrevipes* and *P. jackbeardsleyi*, the restricted risk for these mealybugs was found to be low, which exceeds Australia’s ALOP. The use of only targeted sponging and brushing of the spaces between banana fingers would, therefore, not be an effective risk management measure.
**Augmentation of inspection**

Inspection may be augmented at importation step Imp7 (quarantine inspection in the Philippines) or at importation step Imp10 (AQIS inspection on-arrival in Australia). Inspection augmentation that was considered appropriate for mealybugs was an increase of the number of fruit examined in a consignment (Imp7) or a lot (Imp10) rather than magnification because mealybugs are already readily visible on bananas. The reason for selecting Imp10 over Imp7 (quarantine inspection by BPI in the Philippines) is that fruit may take up to 2 weeks to travel from the Philippines to Australia, and, during this time, important changes in the populations of *D. neobrevipes* and *P. jackbeardsleyi* mealybugs may have occurred — in particular:

- Adult females are likely to remain alive, while crawlers may have advanced to later stages of development;
- Female crawlers may have become adults, and sought out spaces between the fingers of bananas; and
- Male crawlers may have developed into the dormant and cocooned later stage nymphs, or even into adults. Male nymphs within cocoons are likely to remain viable, while adult males are fragile and short-lived and would have died in transit. Both the waxy cocoons and dead winged adult males are macroscopic and, if present in opened cartons, would be likely to be observed by AQIS inspectors.

The effectiveness of inspection will be determined by the following expression:

\[
P(\text{at least one pest or effected cluster detected}) = 1 - P(\text{all pests or effected clusters not detected})
\]

\[
= 1 - (1 - P \times S)^{\text{Number of clusters examined}}
\]

Where:

- \(P\) is the prevalence of affected clusters within the consignment or lot, which, for Imp10 was considered extremely low;
- \(S\) is the ‘sensitivity’ of the examination process, or the likelihood that the pest would be identified during the examination of an individual infested cluster.

As discussed in the risk assessment for mealybugs, the effectiveness of AQIS on-arrival inspection if 600 clusters of Philippines bananas were to be inspected, was considered to be very low. By increasing the sampling number of clusters in the calculation above, it was found that the effectiveness of quarantine inspection would not improve until 4000 clusters from each lot were examined (Table 27).

**Table 27 Effectiveness of quarantine inspection for mealybugs**

<table>
<thead>
<tr>
<th>Step</th>
<th>Number of clusters examined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600</td>
</tr>
<tr>
<td>Imp10</td>
<td>Very low</td>
</tr>
</tbody>
</table>

When the modified likelihood of moderate for Imp10 using 4000 clusters was placed in the model, and the assessment for these mealybugs repeated, the restricted annual likelihood of entry, establishment or spread was found to be high. Because the restricted annual likelihood of entry,
establishment or spread remained the same as the unrestricted annual likelihood of entry, establishment or spread, the overall restricted risk for \textit{D. neobrevipes} and \textit{P. jackbeardsleyi} would remain above Australia’s ALOP and therefore increasing the sampling number of banana clusters inspected by AQIS to 4000 at on-arrival inspection would not be an effective risk management measure. In any event, it was concluded that an examination of more than six times the routine sample number used by AQIS at on-arrival inspection was likely to be viewed as trade restrictive in terms of the added costs (both time and money) that would flow from such a measure so it was not considered further.

**Conclusions: risk management for \textit{D. neobrevipes} and \textit{P. jackbeardsleyi}**

There were no individual measures identified that would reduce the risk associated with \textit{D. neobrevipes} and \textit{P. jackbeardsleyi} to within Australia’s ALOP.

Risk was then estimated using various combinations of the risk management measures discussed above (except augmented inspection) and the results are summarised in Table 28. It was found that the minimum combination of measures that would reduce the biosecurity risk associated with \textit{D. neobrevipes} and \textit{P. jackbeardsleyi} to an acceptable level was a combination of targeted inspection of the spaces between banana fingers by quality assurance staff (Imp 5) and either targeted sponging and brushing between banana fingers by packing station staff or an insecticide treatment as part of the routine procedures undertaken within the packing station (Imp6). It was considered that the least trade restrictive risk management measure combination that would bring the risk within Australia’s ALOP would be targeted inspection of the spaces between banana fingers by quality assurance staff and targeted sponging and brushing between banana fingers by packing station staff assigned to these duties.

**Table 28  Risk management measures for mealybugs**

<table>
<thead>
<tr>
<th></th>
<th>Imp3</th>
<th>Imp 5</th>
<th>Imp6</th>
<th>Imp6</th>
<th>Restricted risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Permanent packing stations</td>
<td>Targeted quality inspection</td>
<td>Targeted sponging and brushing</td>
<td>Insecticidal treatment</td>
</tr>
<tr>
<td>1.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Low</td>
</tr>
<tr>
<td>2.</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Low</td>
</tr>
<tr>
<td>3.</td>
<td>-</td>
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CONTAMINANTS OF BANANA SHIPMENTS FROM THE PHILIPPINES

Contaminants include all organisms, except quarantine pests that have been identified as being pests of banana fruit, which may enter Australia with shipments of Philippines bananas i.e. may be on the entry pathway\(^{46}\). Shipments include packaging materials.

WEEDS

**Method**

An analysis was made of the biosecurity risk associated with 247 plant species that were identified as weeds in the Philippines, and that might occur in or near Philippines banana plantations.

The analysis was carried out in three discrete steps:

- **Weed categorisation:** classification of each identified weed as a ‘quarantine pest’ or not.
- **Weed risk assessment:** for each weed classified as a quarantine pest, an assessment of its likelihood of entry, establishment or spread and the consequences of entry, establishment or spread was made. The unrestricted biosecurity risk was then determined and compared with Australia’s ALOP. Risks exceeding the ALOP were unacceptable.
- **Weed risk management:** for weeds with an unacceptable biosecurity risk, measures were identified that would allow the risk to be managed to meet Australia’s ALOP.

**Method for weed categorisation**

The 247 plant species identified as weeds in the Philippines were obtained from literature searches, information provided by the Philippines BPI and banana industry, the Northern Australia Quarantine Strategy (NAQS) and through visits by TWG members to banana growing areas of the Philippines.

Categorisation of these weeds as quarantine pests or not is presented in Table 29. Categorisation was done in accordance with the IPPC’s ISPM 11 – Rev. 1 definition of a quarantine pest\(^{47}\) and was based on the following series of classification steps. All identified weed species were considered to have the potential for adverse consequences in Australia because the National Weeds Strategy (ARMCAN and ANECCFM, 1999) has estimated that weeds cost the Australian agricultural industry up to $3.3 billion per year.

- Any weed species for which there is an established policy allowing its unrestricted entry in to Australia was automatically categorised as a ‘non-quarantine pest’ in respect to its weed potential. No further consideration was given to these species.

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\(^{46}\) “Pathway” defined by the IPPC as “any means that allows the entry or spread of a pest”.

\(^{47}\) “A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled”.
Any weed species present in Australia for which there is no such policy and is not ‘declared’ on State or Territory noxious weed legislation was categorised as a ‘non-quarantine pest’ in respect to its weed potential.

Any weed species present in Australia for which there is no such policy and is ‘declared’ on State or Territory noxious weed legislation was categorised as a ‘quarantine pest’ in respect to its weed potential. Where a species was declared in legislation, it was taken to be under ‘official control’.

Method for risk assessment of weeds

A risk assessment was carried out on each weed species of Philippines bananas classified as a quarantine pest. These assessments were based on the likelihood of entry (as seeds), establishment or spread and consequences of those weeds, and an evaluation of the unrestricted risk.

Likelihood of entry, establishment or spread

This likelihood encompasses two steps — the likelihood of seed entry and the likelihood of establishment or spread of the weed in Australia.

- **Entry**: although a complex variable, the likelihood that weed seeds of each species would enter Australia as a contaminant of Philippines bananas will depend largely on the environment in which each weed may be found, and its means of dispersal. In particular, a seed from a weed that grows in or around plantations, and that can be blown by wind or distributed with water splash, will be more likely to become lodged within bunches or enter unenclosed packing stations than one that does not. Further, the likelihood that weed seeds of each species would enter Australia as a contaminant of Philippines bananas will depend on the likelihood of a weed seed passing through the various washing and decontamination steps in the packing station, and procedures associated with packing, transport to the wharf and on to Australia.

- **Establishment or spread**: because Australia has such a broad range of tropical, subtropical and temperate environments, the likelihood of establishment or spread for each of the weed species identified in Table 29 was considered high. The reason for this is twofold (a) if weed seeds were to enter Australia with imported Philippines banana fruit, they would certainly end up, with banana waste, in the natural environment via municipal refuse facilities, household comports or directly via random disposal of banana waste; and (b) weeds, by definition, may possess a variety of specific biological and ecological characteristics (e.g. rapid growth rate, abundant reproduction and dispersal mechanisms, long-lived propagules, periodicity of flowering and germination, chemical composition, wide tolerance of climatic and edaphic factors) that allow them to adapt and grow to the prevailing conditions where they are not wanted (Auld et al., 1987).

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48 The presence or absence of a pest in Australia was obtained from Henderson (2002); Hnatiuk (1990); Holm et al. (1979); Lazarides and Hince (1993); Lazarides et al. (1997); Randall (2002) and Waterhouse (1997).


50 Under IPPC and FAO terminology, ‘official control’ means the active enforcement of mandatory phytosanitary regulations and the application of mandatory phytosanitary procedures with the objective of eradication or containment of quarantine pests or for the management of regulated non-quarantine pests.
The likelihood of entry, establishment or spread was determined to be the product of the likelihood of entry, and establishment or spread. Because the likelihood of establishment or spread was considered high (i.e. close to 1), the likelihood of entry, establishment or spread could be approximated by the likelihood of entry alone.

It was considered that most of the weeds seeds that may become lodged within bunches or enter unenclosed packing stations would be removed or destroyed by the washing and decontamination procedures in the packing station. This judgement is borne out by New Zealand interception data between 11/01/2001 to 21/03/2002 and 13/01/2003 to 14/05/2003 where there was only one weed seed found in 82 consignments and no weed seeds found in 25 consignments of imported Philippines bananas, respectively (Spencer, 2002; Herrera, 2003). On this basis it was considered that there would be a very low annual likelihood that those weed seeds that may become lodged within bunches or enter unenclosed packing stations would enter Australia.

The likelihood of entry, establishment or spread obtained for each weed identified as a quarantine pest of Philippines banana is shown in Table 30 below. It can be seen from this table that a consequence assessment was carried out for each weed species for which the likelihood of entry was considered very low.

Consequences

The consequence assessment was based on three criteria. A weed species that satisfied any of these three criteria was considered to have at least high consequences in Australia

- Listed in The World’s Worst Weeds (Holm et al., 1991). This is a list of 76 plants considered by internationally recognised experts in the field of weed science as the most serious troublesome “worst” weeds in the world based on their biology and ecology, distribution and agricultural and environmental importance.
- Listed in World Weeds Natural Histories and Distribution (Holm et al., 1997). This is a list of more than 100 plants considered by internationally recognised experts in the field of weed science to cause 90% of the worlds losses of food due to weeds in agriculture – this is a companion volume to The Worlds Worst Weeds and the two lists do not overlap.
- Listed in Northern Australian Quarantine Strategy, Weeds Target List (Waterhouse and Mitchell, 1998). This is a list of plants considered by the NAQS to be exotic weeds that present a serious threat to aspects Australia’s productivity, environment and export markets. The list is periodically reviewed and currently stands at 4151.

Unrestricted risk

Unrestricted risk is the combination of the likelihood and consequences of entry, establishment or spread. Any risk greater than Australia’s ALOP (very low) is unacceptable and a weed species with an unacceptable risk would require management.

Weed categorisation and assessments

Of the 247 weed species identified, 52 were classified as quarantine pests (Table 29).

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51 The NAQS target list of weeds is available on the AQIS website at www.affa.gov.au
Risk assessments were carried out for the 52 weeds identified as quarantine pests. The likelihood of entry of seeds, establishment or spread was considered very low for 19 of these. Of the 19, 11 weeds were considered to have high consequences in Australia (Table 30).
<table>
<thead>
<tr>
<th>Weed genus and species</th>
<th>Established policy allowing entry in to Australia</th>
<th>In Australia</th>
<th>Distribution (States and Territories)</th>
<th>Declared weed</th>
<th>Quarantine pest</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

Species identified as † may be known by a different name in Australia.
<table>
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<th>Weed genus and species</th>
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The Importation of Philippines bananas: Draft IRA Report

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### Table 30  Risk assessments

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<th>World Weeds&lt;sup&gt;54&lt;/sup&gt;</th>
<th>NAQS Weeds list&lt;sup&gt;55&lt;/sup&gt;</th>
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<sup>53</sup> Listed in The World’s Worst Weeds (Holm et al., 1991)<br> <sup>54</sup> Listed in World Weeds Natural Histories and Distribution (Holm et al., 1997)<br> <sup>55</sup> Listed in Northern Australian Quarantine Strategy, Weeds Target List (Waterhouse and Mitchell, 1998)
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<td>Yes</td>
<td>Negligible</td>
</tr>
</tbody>
</table>
## Likelihood of entry, establishment or spread

<table>
<thead>
<tr>
<th>Weed species</th>
<th>Likelihood of entry, establishment or spread</th>
<th>Consequences of entry, establishment or spread</th>
<th>Risk acceptable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dispersal mechanism</td>
<td>Compatible with Australian environment</td>
<td>Worlds Worst Weeds&lt;sup&gt;53&lt;/sup&gt;</td>
</tr>
<tr>
<td><strong>Forrestia hispida</strong></td>
<td>Dispersal mode unknown</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Gonostegia hirta</strong></td>
<td>Seeds dispersed by birds</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Hyptis brevipes</strong></td>
<td>Seeds dispersed by livestock, vehicles and human activities</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Lantana camara</strong></td>
<td>Seeds dispersed by birds and mammals</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Leptochloa chinensis</strong></td>
<td>Seeds dispersed by livestock, water, as a contaminant of produce and possibly by wind</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Lindernia procumbens</strong></td>
<td>Seeds dispersed by floodwaters</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Ludwigia erecta</strong></td>
<td>Seeds dispersed by floodwaters</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Malachra capitata</strong></td>
<td>Seeds adhere to livestock, clothing, vehicles, machinery</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Mikania cordata</strong></td>
<td>Seeds dispersed by wind, water and as contaminants of vehicles and produce</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Mikania micrantha</strong></td>
<td>Seeds dispersed by wind, water and as contaminants of vehicles and produce</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Mikania scandens</strong></td>
<td>Seeds dispersed by wind, water and as contaminants of vehicles and produce</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td>Weed species</td>
<td>Likelihood of entry, establishment or spread</td>
<td>Compatible with Australian environment</td>
<td>Likelihood of entry, establishment or spread</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------------------------------------------</td>
<td>----------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Dispersal mechanism</td>
<td></td>
<td>Worlds Worst Weeds[^33]</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>NAQS Weeds list[^55]</td>
</tr>
<tr>
<td><strong>Mimosa invisa</strong></td>
<td>Seeds spread by livestock, floodwaters, vehicles and as contaminants of soil</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Myriophyllum spicatum</strong></td>
<td>Vegetative fragments and seeds spread by moving water and waterfowl</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Oxalis repens</strong></td>
<td>Seeds dispersed locally by rupture of capsule. Longer distances as soil contaminant</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Paederia foetida</strong></td>
<td>Seeds dispersed by birds and mammals</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td>(P. scandens)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Panicum attenuatum</strong></td>
<td>Probably dispersed by livestock and agricultural practices</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><strong>Phyllanthus niruri</strong></td>
<td>Seeds dispersed as contaminants of soil, agricultural equipment and vehicles</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Pistia stratiotes</strong></td>
<td>Seeds and vegetative fragments dispersed by water</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Rorippa indica</strong></td>
<td>Seeds dispersed in soil and running water</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td><strong>Rotala indica</strong></td>
<td>Seeds dispersed by water and waterfowl</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Weed species</td>
<td>Likelihood of entry, establishment or spread</td>
<td>Consequences of entry, establishment or spread</td>
<td>Risk acceptable</td>
</tr>
<tr>
<td>-------------------</td>
<td>---------------------------------------------</td>
<td>---------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td></td>
<td>Dispersal mechanism</td>
<td>Compatible with Australian environment</td>
<td>Worlds Worst Weeds</td>
</tr>
<tr>
<td>Scirpus erectus</td>
<td>Seeds dispersed by moving water, waterfowl, vehicles and agricultural equipment</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Scirpus grossus</td>
<td>Seeds and vegetative fragments spread by water, waterfowl, vehicles and agricultural equipment</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Scirpus juncoides</td>
<td>Seeds dispersed by moving water, waterfowl, vehicles and agricultural equipment</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td></td>
<td>[Schoenoplectus juncoides]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scirpus maritimus</td>
<td>Seeds dispersed by water, and birds. Vegetative fragments by water and cultivation.</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td>Scirpus mucronatus</td>
<td>Seeds dispersed by moving water, waterfowl, vehicles and agricultural equipment</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Scirpus supinus</td>
<td>Seeds dispersed by moving water, waterfowl, vehicles and agricultural equipment</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Senna occidentalis</td>
<td>Seeds dispersed by livestock, vehicles, floodwaters</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Senna tora</td>
<td>Seeds dispersed by livestock, vehicles, floodwaters</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Stellaria uliginosa</td>
<td>Seeds dispersed as contaminant of</td>
<td>Yes</td>
<td>Negligible</td>
</tr>
<tr>
<td>Weed species</td>
<td>Dispersal mechanism</td>
<td>Compatible with Australian environment</td>
<td>Likelihood of entry, establishment or spread</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td><em>Torenia concolor</em></td>
<td>soil, water</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><em>Trichachne insularis [Digitaria insularis]</em></td>
<td>Dispersal mechanism uncertain, possibly wind</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><em>Typha angustifolia</em></td>
<td>Seeds dispersed by wind, machinery, vehicles, livestock</td>
<td>Yes</td>
<td>Very low</td>
</tr>
<tr>
<td><em>Xanthium strumarium</em></td>
<td>Hooked disseminules become attached to fur, clothing, agricultural equipment</td>
<td>Negligible</td>
<td>-</td>
</tr>
</tbody>
</table>
**Weed risk management**

Weed categorisation and risk assessment led to identification of 11 weed species that would require management.

Risk has two components, likelihood and consequences. Risk management measures are generally restricted to the likelihood component, and here there are two common strategies:

- Reduce the likelihood that a quarantine pest will enter Australia in imported goods by imposing conditions on one or more of the steps in the importation scenario i.e. ‘pre-import measures’; and
- Reduce the likelihood that a quarantine pest will establish or spread in Australia, i.e. ‘post-import measures’.

The measures proposed in this IRA are targeted at the first of the two strategies. They are intended to modify the likelihood of entry of weeds. There are no feasible measures available to reduce the likelihood that a weed will establish or spread in Australia given the wide diversity of climatic and edaphic conditions in Australia. The measures proposed are targeted against the 11 weed species considered to pose an unacceptable risk to Australia; however, they are not specific to individual weed species. They are general conditions that could be used by the Philippines to reduce the level of contamination of imported bananas with weed seeds to a level that would lead in turn, to an acceptable overall risk.

The measures have been classified according to the step in the importation pathway at which they would be applied (Table 31). These steps provide a simplified version of the ‘importation pathway’ used as the framework for the pest risk assessments discussed in the *Method for Import Risk Analysis*.

The measures are additional to the plantation, packing station and transport management practices outlined in documentation provided by the Philippines Department of Agriculture in its proposal to import Philippines bananas (Philippines Dept. Agriculture, 2001; 2002a; 2002b). These practices have been discussed in the *Method for Import Risk Analysis* and in the various pest risk assessments.

**Table 31 Managing the likelihood of importation for identified weeds**

<table>
<thead>
<tr>
<th>Importation step</th>
<th>Weed risk management measure(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source plantation</td>
<td>No additional measures</td>
</tr>
<tr>
<td>Harvest and transport to packing station</td>
<td>No additional measures</td>
</tr>
<tr>
<td>Packing station</td>
<td><strong>Packing materials</strong></td>
</tr>
<tr>
<td></td>
<td>Cartons assembled immediately prior to packing – <em>to reduce the time period and hence opportunity for contamination by weed seeds prior to packing bananas</em></td>
</tr>
<tr>
<td></td>
<td>Storage and handling areas at packing station</td>
</tr>
<tr>
<td></td>
<td>Packed cartons to be loaded directly into a shipping container – <em>to reduce the opportunity for contamination by weed seeds after bananas are</em></td>
</tr>
<tr>
<td>Importation step</td>
<td>Weed risk management measure(s)</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>packed</td>
<td><strong>packed</strong></td>
</tr>
<tr>
<td>OR</td>
<td>Packed cartons to be loaded on to a vehicle immediately after packing and transported to the wharf.</td>
</tr>
<tr>
<td></td>
<td>If packed cartons are not to be loaded on to a vehicle immediately after packing, then, packed cartons are to be stored in a room or enclosure which is dry and practically free(^{56}) from weed seeds— to reduce the opportunity for contamination by weed seeds after bananas are packed.</td>
</tr>
<tr>
<td>Inspection</td>
<td><strong>Phytosanitary inspection</strong></td>
</tr>
<tr>
<td></td>
<td>All clusters and all packing materials to be practically free from weed seeds – This measure is included because seeds are not specifically mentioned as items looked for by Philippines inspectors. Although only 11 weeds present an unacceptable risk, it would be unlikely that quarantine inspectors would be able to immediately distinguish the seeds of these species from other plant seeds.</td>
</tr>
<tr>
<td>Transport to wharf /</td>
<td><strong>Pallets and containers</strong></td>
</tr>
<tr>
<td>storage at wharf</td>
<td>Pallets and containers to be practically free from weed seeds – reason as above</td>
</tr>
<tr>
<td></td>
<td><strong>Transport vehicles (non-containerised transport)</strong></td>
</tr>
<tr>
<td></td>
<td>Vehicle cargo area to be practically free from weed seeds – reason as above</td>
</tr>
<tr>
<td></td>
<td>If fruit not containerised at the packing station, vehicle cargo area covered against entry of weed seeds</td>
</tr>
<tr>
<td></td>
<td><strong>Storage and handling areas at wharf</strong></td>
</tr>
<tr>
<td></td>
<td>If fruit is not containerised, palletised fruit stored separately from domestic or other export fruit in a clean area – to reduce the opportunity for contamination of the palletised fruit by weeds from other material at the wharf or from outside the wharf area</td>
</tr>
<tr>
<td>Transport to Australia</td>
<td><strong>Ship or aircraft</strong></td>
</tr>
<tr>
<td></td>
<td>If fruit is not containerised, the ship or aircraft hold to be practically free from weed seeds - to reduce the opportunity for contamination of the palletised fruit by weeds from other material in the hold</td>
</tr>
<tr>
<td>On-arrival inspection</td>
<td><strong>Routine inspection</strong></td>
</tr>
<tr>
<td>in Australia</td>
<td></td>
</tr>
</tbody>
</table>

\(^{56}\) ‘Practically free’ as defined by the IPPC ISPM Number 5 Glossary of Phytosanitary Terms
NON-WEEED CONTAMINANTS OF BANANA SHIPMENTS

Method

Non-weed contaminants of shipments of Philippines bananas (so-called ‘hitchhikers’) were
categorised into the broad phylogenetic groups shown below.

- Mammals (e.g. rats, mice and bats)
- Amphibians (e.g. frogs and toads)
- Reptiles (e.g. snakes and lizards)
- Molluscs (e.g. snails)
- Arthropods (e.g. spiders and ants)

For each group, an assessment of the likelihood of its entry, establishment or spread and the
consequences was carried out. The unrestricted risk was then determined and compared with
Australia’s ALOP. The likelihood estimates took into account the risk management practices used
in the production, processing, quality control, packing, transport and shipment of fruit from the
specified areas in the Philippines, as described in documentation provided by Philippines
Department of Agriculture in its proposal to import Philippines bananas (Philippines Dept.
Agriculture, 2001; 2002; 2002b). These practices have been discussed in the Method for Import
Risk Analysis and in the various pest risk assessments.

Likelihood of entry, establishment or spread

- The likelihood of entry was based on the likelihood that hitchhikers would enter the pathway
  for Philippines bananas, and remain on the pathway after completion of steps required for the
  importation of bananas (the importation scenario).
- The likelihood of establishment or spread was derived from the compatibility of hitchhikers
  with the Australian climate and environment. Because Australia has a wide range of climate
  and environment conditions, it was assumed that all hitchhikers with bananas from the
  Philippines would be able to establish or spread.

The likelihood of entry, establishment or spread was determined to be the product of the likelihood
of entry and the likelihood of establishment or spread. Because the likelihood of establishment or
spread was considered high (i.e. close to 1), the likelihood of entry, establishment or spread could
be approximated by the likelihood of entry alone.

Consequences of entry, establishment or spread

Each of the five groups of hitchhikers examined in this assessment was considered to have
potential for adverse consequences in Australia.

Unrestricted risk

Unrestricted risk is the combination of the likelihood and consequences of entry, establishment or
spread under the plantation, packing station and transport management practices outlined in
documentation provided by the Philippines Department of Agriculture in its proposal to import
Any risk greater than Australia’s ALOP (very low) is unacceptable and a non-weed contaminant with an unacceptable risk would require management.

**Mammals**

**Likelihood of entry, establishment or spread**

The Philippines has a range of native and introduced rat, mouse and bat species.

Although these small mammals could gain access to banana bunches, it is not conceivable that they would remain with fruit after harvest, transport to the packing station and processing (including quality assurance inspection and at least 25-minute in a chlorine and alum solution in de-handing and flotation tanks) within the packing station. If contamination of banana shipments with small mammals were to occur, it would be a result of individual rats, mice or bats climbing into empty cartons or packed but unsealed cartons or into spaces between cartons or between pallets.

All fruit entering Australia would be subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that may be associated with it. Mammals can be seen easily without magnification, and it is very likely that they would be detected at on-arrival AQIS inspection.

Overall, the likelihood of entry, establishment or spread for rats, mice and bats was considered negligible.

**Consequences**

Many of the mammals considered here would be considered pests of significant potential impact on the Australian environment or primary industries.

**Unrestricted risk**

Because likelihood of entry, establishment or spread was considered negligible, the overall risk was not considered sufficient to require management beyond that already proposed for weeds except that fruit, packing materials and transport vehicles must also be free from mammals.

**Amphibians**

The Philippines has a range of native and introduced amphibian species.

The movement of amphibian species with commercial fruit is a topic of some importance to Australian banana growers, many of whom are actively engaged in Australian green tree frog relocation programs. For this reason, a comprehensive search of museum records of frog and toad species reported on the island of Mindanao was obtained from the California Academy of Science (CAS) database.

This search revealed the following 41 species:

*Ansonia mcgregori*  
*Occidozyga laevis*  
*Rana cancrivora*

57 Available at: [http://www.calacademy.org/research/herpetology/catalog/search.html](http://www.calacademy.org/research/herpetology/catalog/search.html)
Although the CAS database records the occurrence of the cane toad (Bufo marinus) in the Philippines, there are no records of this species on the island of Mindanao. However, in the absence of rigorous regional surveys, it was assumed that B. marinus could also be found on Mindanao.

Two amphibian species were of particular interest. The first was the cane toad, because of its high profile as an invader of many Australian natural environments. The second was the common green tree frog (banana frog), Polypedates leucomystax. This is extremely prevalent throughout the Philippines and, of the species identified, is the most likely to be a contaminant of export bananas.

**Likelihood of entry, establishment or spread**

The likelihood that these or other amphibian species would enter Australia undetected, was evaluated by considering the importation pathway.

The following points are relevant:

- Although amphibia (in particular, the green tree frog) might climb banana plants, penetrate bunch covers and live in banana bunches, it is almost certain that they would not remain with fruit after harvest, transport to the packing station and processing (including quality assurance inspection and at least 25-minute in a chlorine and alum solution in de-handing and flotation tanks) within the packing station.
- Frogs and toads might, however, climb into empty cartons or packed but unsealed cartons, or into spaces between cartons or between pallets.

All fruit entering Australia would be subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that may be associated with it. Frogs and toads can be seen easily without magnification, and although they have a propensity for hiding in small spaces, it is likely that they would be detected at on-arrival AQIS inspection.

Overall, the likelihood that frogs or toads would enter Australia undetected with Philippines bananas was considered negligible. This position is supported by the fact that there have been no interceptions of frogs or toads in shipments of Philippines bananas into either New Zealand or...
Japan. This is in contrast to the high number of frogs translocated through domestic trade in both the Philippines and Australia, where quarantine and quality assurance parameters, as well as the logistics of packing, palletisation and containerisation, are such that frogs and other hitchhikers are able to move relatively freely.

**Consequences**

The consequences for Australian primary industries and the environment of introducing Philippines amphibia are largely unknown. Of some concern, however, is the potential for Philippines species to carry diseases not present in Australian amphibians.

- In 2001, OIE added two diseases of amphibians to its Wildlife Diseases List\(^{58}\), the first time diseases of amphibians have been included on this list.
- These diseases, amphibian chytridiomycosis and amphibian ranaviral disease, were added in recognition of the severe impact they can have on amphibian populations and on captive amphibian husbandry.
- Whether amphibian chytridiomycosis and amphibian ranaviral disease occur in the amphibian populations of Mindanao is unknown.
- It is known, however, that pathogens that do not kill or seriously harm a host are likely to survive with that host through a translocation process. This could result in pathogens being exported with amphibians from the Philippines, and being distributed in Australia.
- Some pathogens (e.g. ranaviruses) may be able to survive outside amphibian hosts in excretions or secretions, or associated with dead amphibians.

Overall, it was recognised that the undetected entry of amphibia into Australia may have significant consequences for Australian amphibians and, more generally, for the Australian environment.

**Unrestricted risk**

Because the likelihood of entry, establishment or spread for frogs or toads was considered negligible, the overall risk was not considered sufficient to require management beyond that already proposed for weeds except that fruit, packing materials and transport vehicles must also be free from amphibians.

**Reptiles**

**Likelihood of entry, establishment or spread**

According the CAS database, 65 species of lizards and 45 species of snake have been reported on the island of Mindanao.

Although it is conceivable that snakes and lizards might find sheltered hiding places within a covered banana bunch, they would not remain associated with fruit after harvesting, transport to the packing station and completion of the various steps in processing bananas for export (including quality assurance inspection and at least 25-minute in a chlorine and alum solution in de-handing

and flotation tanks). If contamination were to occur, it would be through individual snakes or lizards moving into empty cartons, into packed but unsealed cartons or into spaces between cartons or between pallets.

All fruit produce entering Australia would be subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that might be associated with it. The likelihood that imported snakes or lizards would be detected at on-arrival inspection depends on their size and behaviour. Large lizards and most snakes would be extremely easy to detect. Some smaller lizards and well-camouflaged snakes might be less easily detected, but would be considerably easier to detect than weed seeds and most other contaminants.

Overall, the likelihood of entry, establishment or spread was considered negligible.

**Consequences**

Some lizard and snake species would be considered pests of significant potential impact on the Australian environment or primary industries.

**Unrestricted risk**

Because the likelihood of entry, establishment or spread was negligible, the overall unrestricted risk was not considered sufficient to require risk management beyond that already proposed for weeds except that fruit, packing materials and transport vehicles must also be free from reptiles.

**Molluscs**

**Likelihood of entry, establishment or spread**

The molluscs of concern with regard to the importation of Philippines bananas are the terrestrial gastropods, i.e. the hard snails. Although unlikely to penetrate bunch covers, it is conceivable that snails might gain access to maturing bananas. However, snails would not remain with banana hands or clusters after completion of the steps undertaken in harvesting fruit, transporting them to the packing station and completing the various procedures therein (including quality assurance inspection and at least 25-minute in a chlorine and alum solution in de-handing and flotation tanks). Snails might, however, move into empty cartons, into packed but unsealed cartons or into spaces between cartons or between pallets.

All fruit produce entering Australia would be subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that may be associated with it. Snails within or between cartons and pallets would be extremely easy to detect at on-arrival AQIS inspection. They are macroscopic and relatively immobile, and would tend to gravitate to the cool, protected niches that AQIS inspectors routinely investigate.

Overall, the likelihood of entry, establishment or spread was considered negligible.

**Consequences**

The consequences of entry, establishment or spread would be variable, but for most species there was considered some potential for adverse impacts in Australia.
Unrestricted risk

Because the likelihood of entry, establishment or spread was negligible, the overall risk was not considered sufficient to require management beyond that already proposed for weeds except that fruit, packing materials and transport vehicles must also be free from molluscs.

**Arthropods**

**Likelihood of entry, establishment or spread**

This is a large and heterogeneous group, and differs from the arthropod pests examined in the main body of this analysis because the species concerned are *not* considered pests of bananas, i.e. they are incidental contaminants that may be associated with shipments of banana fruit.

Of particular interest are various Philippines species of ants and spiders. These species may move into empty cartons, into packed but unsealed cartons or into spaces between cartons or between pallets.

All fruit produce entering Australia would be subject to AQIS on-arrival inspection procedures. These procedures are focussed on both the commodity (packed fruit) and any packing materials that may be associated with it. Ants or spiders can be seen without magnification, and although some may seek out protected spaces, it is very likely that they would be detected at on-arrival AQIS inspection.

Overall, the likelihood of entry, establishment or spread was considered negligible.

**Consequences**

Although little known, and likely to vary between the relevant insect and arachnid genera, for most species there was considered some potential for adverse impacts in Australia.

Unrestricted risk

Because the likelihood of entry, establishment or spread was negligible, the overall risk was not considered sufficient to require management beyond that already proposed for weeds except that fruit, packing materials and transport vehicles must also be free from arthropods.
QUARANTINE CONDITIONS

INTRODUCTION

The quarantine conditions described below are based on the conclusions from this IRA. Specifically, they are based on the risk management options evaluation described in Risk Management for Quarantine Pests and the risk assessment and risk management of shipment contaminants described in Contaminants of Banana Shipments from the Philippines. The conditions are in addition to the risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in the Philippines Department of Agriculture responses to the IRA team questions and the Draft IRA Report regarding the proposal to import Philippine bananas (Philippines Dept. Agriculture, 2001; 2002; 2002b). These practices are discussed in the Method for Import Risk Analysis and in the various pest risk assessments.

Biosecurity Australia considers that the quarantine conditions i.e. risk management measures recommended below are the least trade restrictive means of ensuring that Australia’s ALOP would be met and are commensurate with the identified risks. Biosecurity Australia invites technical comments on the economic and practical feasibility of the measures.

Alternative measures for managing risk may be accepted, generally or on a case-by-case basis if the proponent can demonstrate that they provide an equivalent level of quarantine protection. Those seeking to propose alternative risk management measures should provide a submission for consideration. Such proposals are welcome and should include supporting scientific information and describe how the alternative measures would meet Australia’s ALOP.

A bilateral arrangement document would be signed between the Bureau of Plant Industry (BPI) and Biosecurity Australia to ensure that Australia’s biosecurity requirements are satisfied.

Recognition of the competent authority

The Bureau of Plant Industry (BPI) is the Philippines’ designated National Plant Protection Organization (NPPO) under the auspices of the International Plant Protection Convention (IPPC). BPI is the official plant protection organisation responsible, inter alia, for inspection of plants and plant products moving in international trade and the issuance of certificates relating to phytosanitary condition and origin of consignments of plants and plant products.

Systems for monitoring and surveillance

Monitoring and surveillance systems used in commercial banana plantations, packing stations and transportation in the Philippines are described in the Method for Import Risk Analysis and individual pest risk assessments. All export banana plantations are inspected weekly for pests and diseases. Fruit is subject to quality assurance and quarantine inspection. In addition to specific pests, the hard green condition of the fruit is monitored in quality assurance and quarantine inspections.
CERTIFICATION REQUIREMENTS

Pre-import measures

Import Permit

1. A valid ‘Permit to Import Quarantine Material’ is required to be obtained from the Australian Quarantine and Inspection Service (AQIS).

Quarantine Entry

2. A Quarantine Entry must be lodged with AQIS for fresh hard green bananas. The Quarantine Entry may be lodged by an importer or their agent or broker.

Export areas

3. These conditions apply to sea and air shipments of fresh hard green Cavendish bananas grown in approved commercial plantations, which are located in approved areas of Mindanao in the Philippines. Registered packing stations will also be located in the approved areas at or in the vicinity of the registered plantations.

Export Plantations

4. The bananas will only be permitted from approved plantations.
   4.1. All bananas for export to Australia must be sourced only from approved plantations. BPI is required to register all plantations for export to Australia prior to commencement of exports to enable trace back in the event of non-compliance. BPI will maintain a register of plantations ‘Approved for Export to Australia’ consisting of the following information.
      4.1.1. Ownership details
      4.1.2. Management details
      4.1.3. Precise geographical/physical location of approved plantations, including block boundaries and numbers.

5. All plants in export plantations will be inspected weekly, and complete records will be maintained for external audit.
6. Operation of participating plantations will be approved under ISO 9002 Certification or an approved equivalent, and will cover all relevant aspects of these import conditions.
Low pest prevalence for Moko in a plantation

7. The bananas will only be permitted from an approved area with demonstrated low pest prevalence of Moko (*Ralstonia solanacearum* Race 2).
   7.1. An area of low pest prevalence (ALPP) would be established under the auspices of BPI and boundaries identified by precise grid references.
   7.2. The low pest prevalence (LPP) level for Moko in an approved ALPP will not exceed 0.005 cases per hectare per week, which is about 1 case per 4 hectares per year. A case is defined as an infected mat. This LPP level would be demonstrated by weekly surveys over a minimum period of two (2) years immediately preceding harvest of fruit intended for export to Australia.
   7.3. BPI would ensure the availability of legislation, administrative infrastructure, competent personnel and other resources necessary to meet the requirements of the ALPPs.
   7.4. In the event that the prevalence of Moko exceeds the set LPP level, the affected area shall be suspended from export to Australia for a minimum period of two (2) years.

Low pest prevalence for freckle in a plantation

8. The bananas will be sourced from an approved area with demonstrated low prevalence of freckle (*Guignardia musae* Racib.; anamorph, *Phyllostictina musarum* (Cooke) van der Aa).
   8.1. An ALPP would be established under the auspices of BPI and boundaries identified by precise grid references.
   8.2. The LPP level for freckle in an approved ALPP will not exceed 1 infected mat per hectare per week. A case is defined as the detection of freckle symptoms on any part of a mat from which a bunch could be harvested. This LPP would be demonstrated by weekly survey data over a minimum period of four (4) weeks immediately preceding harvest of fruit intended for export to Australia.
   8.3. BPI would establish a quality control program for the survey, laboratory diagnosis and eradication of freckle cases, including the assessment of surveyor and diagnostician competency. BPI would regularly audit and verify pest survey records and make this information available to Australia as required.
   8.4. In the event the prevalence of freckle exceeds the set LPP level, the affected area shall be suspended from export to Australia for a minimum period of four (4) weeks.

Packing station measures to address the risk associated with the mealybugs *D. neobrevipes* and *P. jackbeardsleyi*

9. Quality assurance inspectors will specifically examine the spaces between individual banana fingers on clusters of bananas eligible for export to Australia for the presence of the mealybugs *D. neobrevipes* and *P. jackbeardsleyi.*
10. Packing station staff responsible for cleaning banana fruit as it passes through the packing station will specifically target the spaces between individual banana fruit fingers for cleaning by sponging and brushing to remove \textit{D. neobrevipes} and \textit{P. jackbeardsleyi} mealybugs.

**Packing stations**

11. BPI is required to register all export packing station facilities prior to commencement of exports to enable trace back in the event of non-compliance.

12. The manager of the packing station will ensure that equipment and storage areas used for handling export bananas are clean and are practically free from quarantine pests or other regulated articles before being used to process export fruit.

13. BPI will inspect packing stations during the packing and storage of export bananas to monitor and verify that the necessary requirements are met, including measures to prevent contamination of fruit and packing materials with quarantine pests and other regulated articles.

14. BPI will conduct unannounced random audit checks on approved packing stations to monitor the measures taken to prevent mixing or substitution of bananas eligible for export to Australia with non-export bananas.

15. The solution in de-handing and flotation tanks in the packing station will be continuously maintained at 20ppm available chlorine and 200ppm alum. Concentration of chlorine and alum will be monitored by an approved technique, and records will be audited by BPI.

16. The bananas will be packed in clean new packaging. The bananas will be partially vacuum packed in polyethylene bags and then placed into vented cartons, which will be assembled immediately prior to packing.

17. Operation of participating packing stations will be approved under ISO 9002 Certification or an approved equivalent.

18. Quality assurance inspection will be carried out after each ‘lot’ has been packed, and 600 clusters from each lot will be inspected. A lot is the quantity of bananas packed for export to Australia by a packing station on a day.

19. BPI will suspend exports from non-compliant packing stations.

20. BPI will make available to AQIS, on request, information on its supervisory activities in relation to packing stations.

**Labelling**

21. Identification of origin of fruit will be displayed on each carton – including

21.1. Plantation identification number (as per register)

21.2. Block identification number

21.3. Packing facility number

21.4. Date of packing

21.5. Packing line number

21.6. Packer identification number

21.7. BPI Inspection stamp/No.

21.8. Should restricted distribution of Philippines banana fruit in Australia be approved
then both the lid and the box must be labelled clearly - For restricted distribution in
Australia and/or describe those parts of Australia where the fruit can and cannot be
distributed, and indicate that it is a serious offence under the Quarantine Act to
contravene this regulation.

22. In the event that restricted distribution of bananas within Australia is used as an alternative to
areas of low pest prevalence for Moko and freckle, each hand would be clearly labelled to
identify the origin of the fruit as from the Philippines or each finger would be coded for
example, by dipping in a coloured wax.

23. Palletised product will be identified by attaching a uniquely numbered pallet card to each
pallet or part pallet. Pallet cards will be marked with the plantation registration number.

Storage

24. Any packed cartons that are not immediately transported to the wharf will be stored in
approved premises practically free from quarantine pests or other regulated articles.

Loading and transport

25. Packed cartons will be immediately loaded into a shipping container, or on to a vehicle and
transported to the wharf.

26. If packed fruit is not containerised at a packing station, the vehicle cargo area will be
covered to prevent contamination with quarantine pests or other regulated articles.

27. If fruit is not containerised, palletised fruit at the wharf will be stored separately from
domestic or other export fruit in areas practically free from quarantine pests or other
regulated articles.

28. Cartons, containers, pallets, transportation vehicle cargo areas, and ship or aircraft holds will
be practically free from quarantine pests and other regulated articles.

29. A consignment will not be split or have its packaging changed while in transit to Australia or
while in another country en route to Australia.

Pre-export quarantine inspection

30. All consignments will be subject to pre-export inspection by BPI

30.1. Inspection will occur prior to loading the shipment into containers or ships.

30.2. From each consignment, the BPI officer will randomly select 600 clusters for
inspection. Where a consignment incorporates more than a single lot, then each
individual lot would be sampled.

30.3. A nil tolerance will apply to quarantine pests and other regulated articles.

30.4. A nil tolerance will apply to fruit that is not in mature hard green condition or is
damaged in order to ensure freedom from fruit flies.
Phytosanitary documents

31. A single Phytosanitary Certificate and other relevant documents will accompany each banana consignment, and will be endorsed by BPI.
   31.1. BPI will verify that fruit for Australia has been sourced from a registered plantation(s), and complies with Australia’s biosecurity requirements as set out in the bilateral arrangement document.
   31.2. The relevant Notice of Intent (NOI) number(s) to export bananas, annotated with the pallet card numbers of pallets will be included in the consignment.
   31.3. Timber packaging and pallets must be certified on the Notice of Intent to export bananas (NOI) as having been inspected and cleared by BPI.
   31.4. The shipping container number(s) and container seal number(s) must be supplied by BPI.
   31.5. Each consignment will be accompanied by the following additional declaration:
   
   “The bananas in this consignment have been produced in an approved area(s) of Mindanao in accordance with the conditions governing the entry of bananas from the Philippines to Australia”

Notification

32. BPI will notify AQIS immediately of any notifiable non-compliance, including detection of Moko or freckle in registered plantations above the specified pest levels and details of deregistered plantations.

Post-import measures

Verification of phytosanitary documents

33. AQIS staff will inspect and verify documentation concerning the shipment.
   33.1. The shipment must have a valid import permit.
   33.2. The shipment must have a phytosanitary certificate that identifies registered plantations and bears the above additional declaration.
   33.3. Any shipment with incomplete documentation or certification that does not conform to specifications must be refused entry, with the option of re-export or destruction. AQIS would notify BPI immediately of action taken.

On-arrival quarantine inspection and treatment

34. The bananas and packaging materials will be inspected by AQIS.
   34.1. All shipments are subject to inspection on arrival and any treatment necessary before release.
34.2. Timber packaging, pallets or dunnage in full container load (FCL) containers will be subject to inspection and treatment on arrival, unless certified as having been treated by an approved method.

34.3. The AQIS authorised officer will select at random 600 clusters for inspection. A 600-unit inspection sample will be drawn for each lot.

34.4. A nil tolerance will apply to quarantine pests and other regulated articles.

34.5. A nil tolerance will apply to fruit that is not in mature hard green condition or is damaged.

35. All potential quarantine pests found during on-arrival inspection must be forwarded to an AQIS approved appropriate laboratory for identification. AQIS will provide the results of pest interceptions to BPI.

36. Possible treatment of rejected fruit will be considered in consultation with quarantine entomologists or pathologists.

37. Any non-compliant shipments will be treated, re-exported or destroyed at the importers expense.

38. If live stages of a quarantine arthropod pest are intercepted during on-arrival inspection, and the importer accepts the treatment option, the affected shipment will be fumigated with methyl bromide in accordance with the relevant AQIS standards. It is noted that, if methyl bromide fumigation is required, this treatment may damage the bananas.

39. The efficacy of fumigation will be verified by inspection 24 hours after completion of the treatment.

**Restricted distribution of Philippines fruit in Australia**

*These conditions apply only as an alternative if fruit is not sourced from low pest prevalence areas for Moko and freckle (see conditions 7 and 8). As noted at the beginning of this section, these conditions are in addition to the risk management practices used in the production, processing, quality control, packing, transport and shipment of fruit from the specified areas in the Philippines, as described in the Philippines Department of Agriculture responses to the IRA team questions and the Draft IRA Report regarding the proposal to import Philippine bananas (Philippines Dept. Agriculture, 2001; 2002a; 2002b). These practices are discussed in the Method for Import Risk Analysis and in the various pest risk assessments.*

40. Philippines banana fruit are restricted to distribution in those parts of Australia south of a demarcation line across Australia (Figure 13). The demarcation line starts on the Western Australian coast at the 26th parallel and continues east along the 26th parallel until it intersects with the South Australia border. The demarcation line follows the South Australian border north until it meets the Northern Territory border. At this point, the demarcation line moves east and follows South Australia’s northern border to its end at the Queensland border. The demarcation line turns south following South Australia’s border as far as the parallel equating to 32°30’S. The demarcation line follows the 32nd 30’ parallel east across New South Wales to the east coast of Australia.

41. The entry of Philippines banana fruit into Australia is limited to those ports south of the demarcation line described at condition 40. Those ports would be the ports in the States of...
South Australia, Victoria, New South Wales, Tasmania and Western Australia south of the 26th parallel, as specified in section 12 of the Proclamation.

Audits

42. AQIS may audit the pathway of imported fruit at any time.

Review of import conditions

43. AQIS may review conditions at any time and may, in consultation with BPI, suspend the importation of bananas. A suspension would be reviewed following a joint AQIS, Biosecurity Australia and BPI investigation.

44. AQIS, and Biosecurity Australia, in consultation with BPI, will review the import requirements if circumstances or information warrant such action.
The IRA process requires that the following steps be undertaken:

- Release of the revised Draft IRA Report for stakeholder comment
  - comments to be received within 60 days
- Consideration of stakeholder comment on the revised Draft IRA Report
  - stakeholders consulted further as necessary
- Preparation of the Final IRA Report
- Presentation of the Final IRA Report to the Executive Manager of Biosecurity Australia
- Release of the Final IRA Report
- Consideration of any appeals
- When the above processes are complete, the Director of Animal and Plant Quarantine makes the final policy determination.

Stakeholders will be advised of any significant variations to this process.

Biosecurity Australia is committed to a thorough risk analysis of the proposed importation of mature (hard green) fresh green Cavendish banana fruit from the Philippines. This analysis requires that technical information be gathered from a wide range of sources. The timely contribution of information would be much appreciated. Contact details for stakeholder contributions are provided in the accompanying Plant Biosecurity Policy Memorandum.

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PATHOGENS

Banana bract mosaic virus

Scientific name

*Banana bract mosaic virus* (BBrMV), [Family: Potyviridae; Genus Potyvirus]

Synonym(s)

Kokkan disease (Thomas *et al.*, 2000)

Common name(s)

Banana bract mosaic disease, bract mosaic disease (Magnaye and Espino, 1990), bract mosaic, kokkan disease (Thomas *et al.*, 2000)

Host(s)


Plant part(s) affected

All parts of the plants are probably affected. Symptoms have been noted on the leaf lamina and midrib, on the pseudostem, flower bracts and fruit (Magnaye and Espino, 1990; Magnaye and Valmayor, 1995; Thomas *et al.*, 2000). BBrMV has been detected by ELISA or PCR or ISEM in leaf and pseudostem tissue. The virus is transmitted through traditional planting material (corm pieces and suckers) and through micro propagation. It must therefore also be present in the corm (Diekmann & Putter, 1996).

Distribution

Biology

Typical symptoms of bract mosaic are distinctive. Mosaic patterns on bracts are diagnostic and distinct from symptoms caused by all other known viruses of banana. Mosaic patterns, stripes and spindle-shaped streaks may also be visible on pseudostem bases when the outer leaf sheaths are removed and can extend up the petiole bases. Infection is often associated with an increase in pseudostem pigment. Sometimes the symptoms are chlorotic on a red background and sometimes reddish, yellow or chlorotic on a green background. Symptoms can darken through red to brown and even black. Chlorotic streaks and spindle-shapes running parallel to the veins are occasionally seen on leaves. ‘Nendran’ is particularly severely affected by the disease with leaf sheaves separating from the unusually red-coloured pseudostems of young plants. Leaves also become arranged fan-like on one plane rather like the leaves of the traveller’s palm (*Ravenala madagascariensis*). Suckering is also suppressed and suckers that do emerge are distorted and deeply pigmented (Anonymous, 1995; Thomas *et al.*, 2000).

In the Philippines, greenish to brownish spindle-shaped streaks may be present on peduncles (Magnaye and Espino, 1990) and a high disease incidence is associated with increased levels of malformed fruit in commercial production. Bunches on affected plants can be compact and short. Fingers do not develop well and fruit blemishes, including streaking, can occur (Magnaye and Valmayor, 1995). Severity depends on growth stage of the fruit. Fingers three weeks old can have spindle-shaped brown streaks and be distorted on Cavendish cultivars. The bunch will not develop normally and is generally unsaleable. When infection occurs with fully developed fruit, possibly only dark green streaks and a little distortion of the fingers will occur. Commercial companies note a strong correlation between high BBrMV incidence in the plantations and high rejection rate for malformed bunches and low hand class ratings (Thomas, 1993). In India, petioles and peduncles of ‘Nendran’ become brittle and fruit is only rarely carried to maturity. If fruit does mature, it is undersized. Mosaics can be seen on the fruit of other cultivars.

Initial symptoms in aphid-inoculated plants include broad, chlorotic patches along the major leaf veins, surrounded by a rusty red border and green or reddish streaks or spindle shaped lesions on the petioles. Leaf symptoms, consisting of spindle-shaped lesions and streaks running parallel to the veins, are not always evident, but can occur on young plants that have been recently infected.

In Western Samoa, India (Tamil Nadu and Maharashtra States) and Vietnam, BBrMV has been isolated from banana plants that were showing symptoms typical of banana mosaic (caused by *Cucumber mosaic virus* — CMV) and lacking the characteristic symptoms on the bracts (Rodoni *et al.*, 1997). Some of these plants were shown to have a mixed infection of CMV and BBrMV.

BBrMV is transmitted by at least three species of aphids: *Aphis gossypii*, *Rhopalosiphum maidis* (Magnaye and Espino, 1990) and *Pentalonia nigronervosa* (Diekmann and Putter, 1996; Muñez, 1992). By analogy to other potyviruses, BBrMV potentially has many additional aphid vector species. *Pentalonia nigronervosa* transmitted BBrMV after an acquisition access period of 1 minute, indicating that transmission is of the non-persistent type (Muñez, 1992). Efficiency of transmission with the latter species was less than 10% (Caruana and Galzi, 1998).

Attempts to transmit BBrMV by sap inoculation to herbaceous indicator plants have so far been unsuccessful (Diekmann and Putter, 1996; Magnaye and Espino, 1990; Muñez, 1992). However, occasional sap transmission from banana to banana has been achieved (Thomas *et al.*, 2000). The virus can be transmitted through vegetative planting material including suckers, bits and corms and via micro propagated plantlets.
**Banana bunchy top virus**

**Scientific name**

*Banana bunchy top virus* (BBTV), [Family: Nanoviridae; Genus: Babuvirus]

**Synonym(s)**

None

**Common name(s)**

Banana bunchy top (Magnaye and Valmayor, 1995); bunchy top (Thomas and Iskra-Caruana, 2000) cabbage top, curly top, strangles (Magee, 1927).

**Host(s)**

In the Musaceae, BBTV is known to infect a range of *Musa* species and cultivars in the Eumusa and Australimusa series of edible banana, and *Ensete ventricosum*. Susceptible *Musa* include *M. balbisiana* (saba banana) (Magee, 1948; Espino *et al*., 1993), *M. acuminata* subsp. *banksii* and *M. textile* (abaca) (Magee, 1927), *M. velutina* (Thomas and Dietzgen, 1991), *M. coccinea*, *M. jackeyi*, *M. ornata* (diploid banana) and *M. acuminata* ssp. *zebrina* (Thomas and Iskra-Caruana, 2000).

There is some evidence for hosts outside the Musaceae, though reports have been conflicting. (Su *et al*., 1993) obtained positive ELISA reactions from BBTV-inoculated *Canna indica* and *Hedychium coronarium*, and recovery of the virus to banana, though not reported here, was demonstrated (Thomas and Iskra-Caruana, 2000). Ram and Summanwar (1984) reported *Colocasia esculenta* as a host of BBTV, but (Hu *et al*., 1996) were unable to demonstrate *C. esculenta* or *Alpinia purpurata* as experimental (E) or natural (N) hosts of BBTV in Hawaii. Geering and Thomas (1997) also found no evidence for the following species as hosts of BBTV in Australia: *Alocasia brisbaensis* (E,N), *Alpinia arundinelliana* (E) (taro), *Alpinia caerulea* (E,N) (blue ginger), *Alpinia zerumbat* (E), *Canna indica* (E, N), *Colocasia esculenta* (E,N) (taro), *Strelitzia* sp. (N), *C. x generalis* (N), *C. x orchiodes* (N), *Hedychium coronarium* (E) (ginger flower), *Heliconia psittacorum* (E) (“Golden Torch” heliconia). Magee (1927) was unable to infect *Strelitzia* sp. (tropical cutflower), *Ravenala* sp., *Canna* sp. (including *C. edulis*), *Solanum tuberosum* (potato) and *Zea mays* (maize).

To date, there are no confirmed reports of immunity to BBTV in any *Musa* species or cultivar. However, differences in susceptibility between cultivars subject to either experimental or field infection have frequently been noted (Espino *et al*., 1993; Jose, 1981; Magee, 1948; Muharam, 1984).

**Plant part(s) affected**

All parts of the plant are affected. Magee (1927) showed that banana bunchy top disease was systemic and that suckers produced on an infected stool generally develop symptoms before reaching maturity. He also concluded that the virus was restricted to the phloem tissue. BBTV has been detected by ELISA or PCR in most parts of the plant, including leaf lamina and midrib, pseudostem, corn, meristematic tissues, roots, fruit stalk and fruit rind (Thomas, 1991; Hafner *et al*., 1995; Wu and Su, 1992; Geering and Thomas, 1997).
Distribution

Bunchy top of banana occurs in many, though not all, countries in the south and south-east Asia/Pacific region and in various African countries. Significantly, the banana exporting countries of the Latin American-Caribbean region are free from the disease, although the aphid vector is present.

The following countries for which there are valid records of banana bunchy top disease have been extracted from Kagy *et al.* (2001) and Thomas and Iskra-Caruana (2000).

Australia, Burundi (+), Central African Republic, China (+), Congo (+), Democratic Republic of Congo, Egypt (+), Fiji (+), Gabon (+), Guam, India (+), Indonesia (+), Japan (Bonin Is., Okinawa (+)), Kiribati, Malaysia (Sarawak (+)), Malawi (+), New Caledonia (+), Pakistan (+), Philippines (+), Rwanda (+), Samoa (American), Samoa (Western)(+), Sri Lanka (+), Taiwan (+), Tonga (+), Tuvalu, USA (Hawaii)(+), Vietnam (+), Wallis Is.

(= detection of BBTV by laboratory assays)

In Australia, BBTV occurs in some areas of south-east Queensland, south of Cooloolabin, and in the Brunswick and Tweed River Valleys of northern New South Wales. It does not occur in Western Australia, the Northern Territory, north Queensland, the Bundaberg area of Queensland, or the Coff's Harbour area of New South Wales (Thomas and Iskra-Caruana (2000); New South Wales Agriculture and Queensland Department of Primary Industries bunchy top survey records).

In the Philippines, a high incidence of bunchy top was observed in the major banana growing areas i.e. northern Luzon, southern Tagalog, western Visayas, northern Mindanao and central Mindanao (Espino, 1999; Smith *et al.*, 1998)

In addition to the Philippines (Ocfemia, 1926), bunchy top of abacá has also been observed in Sri Lanka, and this is likely to be a true record as bunchy top of banana is reliably recorded in this country (Magee, 1953b). However, reports from East Malaysia (Sabah), West Malaysia and Papua New Guinea (Magee, 1953a; Wardlaw, 1961) need to be authenticated as they were associated with atypical symptoms, were not confirmed by aphid transmission tests and bunchy top of banana was not, and is still not, present.

Biology

The typical symptoms of bunchy top of banana are very distinctive, readily distinguished from those caused by other viruses of banana and have been described in detail by Magee (1927). Plants can become infected at any stage of growth and there are some initial differences between the symptoms produced in aphid-infected plants and those grown from infected planting material.

In aphid-inoculated plants, symptoms usually appear in the second leaf to emerge after inoculation and consist of a few dark green streaks or dots on the minor veins on the lower portion of the lamina. The streaks form ‘hooks’ as they enter the midrib and are best seen from the underside of the leaf in transmitted light. The ‘dot-dash’ symptoms can sometimes also be seen on the petiole. Successive leaves become smaller, both in length and in width of the lamina, and often have chlorotic, upturned margins. The leaves become harsh and brittle and stand more erect than normal giving the plant a rosetted and ‘bunchy top’ appearance.

Suckers from an infected stool can show severe symptoms in the first leaf to emerge. The leaves are rosetted and small with very chlorotic margins that tend to turn necrotic. Dark green streaks are usually evident in the leaves.
Infected plants rarely produce a bunch after infection and do not fruit in subsequent years. Plants infected late in the growing cycle may fruit once, but the bunch stalk and the fruit will often be small and distorted. On plants infected very late, the only symptoms present may be a few dark green streaks on the tips of the flower bracts (Thomas et al., 1994).

Mild strains of BBTV, which produce only limited vein clearing and dark green flecks, and symptomless strains have been reported in Cavendish plants from Taiwan (Su et al., 1993). Mild disease symptoms are expressed in some banana cultivars and Musa species (Magee, 1953b).

BBTV is transmitted by the banana aphid (Pentalonia nigronervosa) and in vegetative planting material, but not by mechanical inoculation (Magee, 1927).

**Aphid transmission**

Banana aphids have a worldwide distribution with a host range that includes Musa spp. and other species in the Musaceae. Species in several closely related plant families including the Araceae (Alocasia sp., Calladium spp., Dieffenbachia spp., Xanthosoma sp.), Cannaceae (Canna spp.), Heliconiaceae (Heliconia spp.), Strelitziaceae (Strelitzia spp.) and Zingiberaceae (Alpinia spp., Costus sp., Hedychium spp.) are also colonised (Wardlaw, 1961; Allen, 2002). However, a degree of host preference is displayed and some difficulty can be experienced transferring them between host species. On banana plants in New South Wales, aphids are found at the base of the pseudostem at soil level and for several centimetres below the soil surface, beneath the outer leaf sheaths and on newly emerging sucker. Aphid numbers decrease during periods of drought (Wardlaw, 1961).

Transmission of BBTV is of the circulative, non-propagative type. The transmission parameters reported from Hawaii (Hu et al., 1996) and Australia (Magee, 1927) respectively are: minimum acquisition access period 4 h/17 h; minimum inoculation access period 15 min/30 min-2 h; retention of infectivity after removal from virus source 13 days/20 days. No evidence was found for transmission of BBTV to the parthenogenetic offspring (Magee, 1940; Hu et al., 1996) or for multiplication of BBTV in the aphid vector (Hafner et al., 1995).

Transmission efficiency for individual aphids has been reported as ranging from 46-67% (Magee, 1927; Wu and Su, 1990; Hu et al., 1996) and the virus is more efficiently acquired by nymphs than by adults (Magee, 1940).

Colonies of P. nigronervosa from Australia (where bunchy top occurs) and from Reunion Island (where bunchy top does not occur) both transmitted each of six isolates of BBTV with similar efficiency (Thomas and Iskra-Caruana, 2000).

**Vegetative propagation**

Bunchy top is efficiently transmitted through conventional planting material including corms, bits and suckers. All suckers from an infected stool will eventually become infected (Magee, 1927).

Bunchy top is also transmitted in micro propagated banana plants (Drew et al., 1989; Ramos and Zamora, 1990; Wu and Su, 1991) though not always at rates of 100%. From time to time, apparently virus-free meristems producing apparently virus-free plants can arise from an infected clone (Thomas et al., 1995).
Epidemiology

The epidemiology of banana bunchy top in Australia is simplified by the presence of a single susceptible host and a single vector species (*P. nigronervosa*) (Magee, 1927). Spread over long distances is by infected planting material and it is by this means that new plantings in isolated areas usually become infected. Dissemination over short distances from these infection foci is by the banana aphid.

Studies of actual outbreaks of bunchy top in commercial banana plantations (Allen, 1978a; Allen, 1978b; Allen, 1987) showed that the average distance of secondary spread of the disease by aphids was only 15.5-17.2m. Nearly two-thirds of new infections were within 20m of the nearest source of infection and 99% were within 86m. Allen and Barnier (1977) showed that if a new plantation was located adjacent to a diseased plantation, the chance of spread of bunchy top into the new plantation within the first 12 months was 88%. This chance was reduced to 27% if the plantations were separated by 50-1000 m, and to less than 5% if they were 1000 m apart. On average, the interval between infection of a plant and movement of aphids from this plant to initiate new infections elsewhere (the disease latent period) was equivalent to the time taken for 3.7 new leaves to emerge. The rate of leaf emergence varied seasonally with a maximum in summer (Allen, 1987).

In the Philippines, Opina and Milloren (1996) also demonstrated that most new infections were adjacent to or in close proximity to primary sources of infection.

Moko

**Scientific name**


**Synonym(s)**

*Burkholderia solanacearum* (Smith, 1896) Yabuuchi *et al.* (1993); *Pseudomonas solanacearum* (Smith, 1896) Smith, 1914

**Common name(s)**

Moko disease; Moko; Moko disease of bananas; banana Moko; banana wilt; bacterial wilt; bacterial wilt of banana; bacterial wilt disease of banana; vascular wilt disease of banana. In the Philippines, Moko disease on the cooking bananas, Saba and Cardaba (ABB/BBB) is generally known as Bugtok disease and locally in Negros Orientale as either Tapurok (Zehrand Davide, 1969) or Tibaglon (Molina, 1996). The disease is known as Hereque in Venezuela (Buddenhagen, 1961).

**Host(s)**

*Musa* spp. (Rorer, 1911; Stover, 1972; Wardlaw, 1972; Buddenhagen, 1994) and *Heliconia* spp. (Sequeira and Averre, 1961).

*Ralstonia solanacearum* is a complex species made up of several races/ biovars differing in host range and degree of pathogenic specialisation. For the species as a whole about 300 hosts have
been described representing about 50 families of plants; they include solanaceous vegetable crops, banana, ginger, custard apple, peanut, Eucalyptus and many other crop plants and weeds (Kelman, 1953; Hayward, 1991). By contrast, *R. solanacearum* Race 2 has a narrow host range.

Under natural conditions, banana strains of *R. solanacearum* Race 2 are known to cause bacterial wilt of *Musa* spp. (bananas and plantains) and *Heliconia* (Sequeira and Averre, 1961; Buddenhagen, 1994). Berg (1971) reported the occurrence of herbaceous dicotyledonous weed hosts of the insect-transmitted SFR strain in Honduras, but the accuracy of this report has been questioned (Buddenhagen, 1986). Symptomless weed hosts are known to occur. Belalcazar et al. (1968) found 12 species of weeds in Colombia that could carry the banana strain without showing external symptoms and that four species (*Brassica campestris* (rape seed), *Datura stramonium* (jimson weed), *Solanum caripense* and *S. nigrum*) were susceptible when artificially inoculated. Granada (2002) reported that a survey of plantations in the Quindío State of Colombia showed that the bacterium may be carried by seven asymptomatic weed hosts: *Emilia sanchifolia*, *Solanum nigrum* (black nightshade), *Bidens pilosa* (cobbler’s-peg), *Browalia americana*, *Commelina* spp., *Phyllanthus corcavadensis* and *Pilea hyaline*.

Berg (1971) listed the following weed hosts of the SFR strain of *R. solanacearum* in Honduras banana farms: *Asclepias curassavica* (blood flower), *Cecropia peltate*, *Piper auritum* (tropical forest tree), *Piper peltatum* (egg plant), *Ricinus communis* (castor), *Solanum hirtum*, *Solanum nigrum* (popola), *Solanum umbellatum*, *Solanum verbascifolium*, and *Xanthosoma roseum*. He also reported that two additional species, *Physalis* sp. and *Solanum torvum*, were also susceptible in artificial inoculation experiments. Isolates from all of the species listed above were pathogenic when artificially injected into young, potted plants of banana cultivar Valery (AAA) (Berg, 1971).

While reports of weed hosts of the Moko bacterium appear in the literature, wilt symptoms have not been observed on most of these plants in the field (Buddenhagen, 1960; Buddenhagen, 1994). Buddenhagen has claimed that the hypothesis that no weed hosts exist is consistent with the observation that Moko is easily controlled if diseased banana and heliconia plants are eradicated. Buddenhagen (1960) reported that young plants of *Physalis angulata* and tomato wilted when planted in soil heavily infested artificially or following stem puncture inoculations but they were not found affected under natural conditions in the field. He thought that it is important to recognise that susceptibility to artificial inoculations is not the same as field susceptibility and that field susceptibility is more important in the biology of the pathogen (Buddenhagen, 1960). He suggested that Solanaceous weeds could not be implicated with assurance as alternate hosts of the Moko bacterium in nature (Buddenhagen, 1960). Buddenhagen thought that although Berg (1971) may undoubtedly have obtained isolates of *R. solanacearum* from these weed hosts, it is highly unlikely that they were of the SFR strain (Buddenhagen, 1986). Jeger et al. (1995) thought that while Buddenhagen queries natural infection of weed species, bacteria may survive in the rhizosphere and elimination of weed hosts is considered important in Moko control.

Sequeira (1962) concluded that under natural conditions the banana strain of the pathogen has a rather limited host range and, therefore, elimination of only the susceptible hosts (*Musa* and *Heliconia*) was the factor largely responsible for control of the disease. The results obtained from many inoculation tests support the view that the presence of wilt in plantation weeds may have little bearing on the disease liability if bananas are subsequently grown in the infected weed area (Wardlaw, 1972).

It is very doubtful whether *R. solanacearum* Race 2 occurs naturally on abaca (*Musa textilis*) in the Philippines. Abaca was shown to be susceptible on artificial inoculation with *R. solanacearum* Race 2 (Rillo, 1979). In later work, Rillo (1981) compared artificial inoculation by stem pricking
or injection on various hosts with a “natural inoculation” method where seedlings or seed were
grown on infested soil accumulated after artificial inoculation and incorporation of infested plant
material. The results of the latter method showed that *R. solanacearum* Race 2 isolates were
virulent to commercial banana, abaca and *Heliconia* whereas abaca isolates were not virulent to
any of these hosts.

Rillo (1981) concludes:

“...The failure of the abaca isolates to infect abaca under natural conditions and the
consistent recovery from initial infection of artificially inoculated abaca plants indicate
the doubtful role of *R. solanacearum* in the natural occurrence of abaca wilt. It is
suspected that some biotic or abiotic agents are associated with the disease in nature.
The abaca isolates probably belong to Race 1 because they are able to infect, although
mildly, abaca, diploid banana, tomato, eggplant, tobacco, and castor bean in artificial
inoculations”

These results were confirmed in later work (Rillo, 1982).

The aroids dieffenbachia and tannia (*Xanthosoma sagittifolium*) are reported to be susceptible to
Moko disease (Hunt, 1987) but no data is given and there is no other information that supports this
observation in other published sources.

**Plant part(s) affected**

It is important to understand the morphology and anatomy of the banana plant *inter alia* to
understand Moko infection of banana plants.

- The banana is a large herb consisting of a branched, underground stem or rhizome (commonly
  known as corm) (Figure 14) with abundant roots, several lateral buds, and erect leafy ‘trunks’
or ‘plants’, which eventually produce bunches (Wardlaw, 1972). The leafy trunk (commonly
  known as pseudostem) is made up of tightly packed leaf bases or sheaths (Jones, 2000). The
  banana plant regenerates by constant production of new suckers from an underground corm
  (Purseglove, 1972). Several plants arising from a single rhizome or corm form a mat, with the
  oldest shoot known as the mother plant (Woods, 1984). Flower development is initiated from
  the true underground stem and the inflorescence grows through the centre of the pseudostem.
  Flowers develop in clusters and spiral around the main axis. The female flowers are followed
  by a few ‘hands’ of neutral flowers that have aborted ovaries and stamens. The neutral flowers
  are followed at the terminal ends by male flowers enclosed in bracts. The male flowers have
  functional stamens but aborted ovaries. Fruit matures in about 60 - 90 days after flowers first
  appear. Each bunch of fruits consists of variable number of hands along the central stem
  (known as peduncle or fruit stalk). The fruit quality is determined by size (length and thickness
  of fingers), evenness of ripening, freedom from blemishes and defects, and the arrangement of
  the clusters. Quality standards may vary for different markets.
• Maintenance of mats is conducted by regular pruning of unwanted suckers and senescing or diseased leaves. In production areas where Moko is prevalent, the male flower bud is usually removed after the last female hand is formed that is well before the male flower bracts begin to dehisce and may be infected via insect-transmission.

• Banana is predominantly grown as a perennial crop but it is also grown as an annual crop. Perennial crops, also known as ratoon crops, are maintained for many years (sometimes up to 30 or more years). In this cropping system, a number of followers (suckers that take over after fruit is harvested from the mother plant) are selected to continue regular production while excess suckers are removed in regular desuckering operation. In annual crops fruit is harvested only once from a plant and the mats are usually destroyed within a year. Therefore, there is no need to select followers in an annual crop and it is indeed desirable to remove all suckers in order to produce a more vigorous plant with a larger bunch. After the annual crop is harvested, all banana plants are destroyed and a new crop may be planted on the same land following preparation.

All parts of the plant may be invaded by \textit{R. solanacearum} but the route of infection and the nature of the causal strain determine the type of symptoms (Thwaites et al., 2000). If insect transmission occurs, infection spreads through vascular tissue of the peduncle to pedicels, fruit and pseudostem. Fruit infection can also occur following soil-borne or rhizome-borne infection in the case of aggressive, highly systemic strains of \textit{R. solanacearum}.

For Moko, infection may occur through the roots or rhizome (corm), or by mechanical transmission (generally machetes) from a wound on an infected plant part to a wound on a healthy plant (Stover, 1972). There is also some possibility that infection may occur through insect
transmission, by carriage of inoculum from wounds or floral parts of an infected plant to wounds or floral parts of a healthy plant (Stover, 1972). The entry of Moko bacterium into banana plants occurs to a large extent through the above-ground plant parts rather than through the roots (Sequeira, 1958). The means of transmission of the bacterium and routes of infection are described in more detail in the following section on the biology of the pest.

Moko infection is generally characterised by vascular discolouration regardless of whether external symptoms of disease are evident. Rorer (1911) observed that when symptomless banana plants were cut down many of the vascular bundles in the stem, fruit stalk and fingers were discoloured and filled with bacteria. He also reported that if suckers of diseased plants were cut down, they show a discolouration of the vascular tissue varying from reddish-brown to yellow. In fruiting plants this discolouration may be traced up the stem to the stalk and into the fingers. Ashby (1926) reported that infected plants had discoloured vascular strands. Martyn (1934) reported that if suckers of diseased plants were cut down, they show a discolouration of the vascular bundles varying from reddish-brown to yellow and that in fruiting plants this discolouration may be traced up the stem to the stalk and into the fingers. Sequeira (1958) reported that the pseudostem of a banana plant affected by Moko always shows a large number of discoloured vascular bundles usually concentrated toward the inner leaf sheaths and the peduncle. Buddenhagen (1961) reported that while an infected stem may show limited external symptoms consisting of a few split or prematurely yellow fingers but the peduncle will exhibit vascular discolouration, concentrated peripherally. He reported that peduncle discolouration is a distinctive symptom of Moko. Power (1976) reported that the most prominent internal symptom of the disease was vascular discolouration of rhizome, pseudostem and fruit peduncle. Kastelein and Gangadin (1984) reported that on cutting, fruit stalks exhibit vascular discolouration. Soguilon et al. (1994a) reported that bugtok infected fruits were discoloured and vascular browning was evident in fruit stems and peduncles. Jeger et al. (1995) reported that internally, discoloured vascular bundles, which are initially cream or yellow but later become brown or black, may be seen throughout the plant. In fruit-bearing plants, these tend to be concentrated in the peduncle and the younger, central leaf bases. Soguilon (2003a) reported discoloration of vascular bundles of peduncles of symptomless infected plants.

**Distribution**

Belize (Black and Delbeke, 1991)

The following distribution list has been extracted from Lehmann-Danzinger (1987).

Brazil; Columbia; Costa Rica; Ecuador; El Salvador; Grenada; Guatemala; Guyana; Honduras; Mexico; Nicaragua; Panama; Peru; Philippines; Surinam; Trinidad; Venezuela.

The disease has been reported from southern India, but the accuracy of this report has been questioned (Buddenhagen, 1986). Reports from Jamaica and Guadeloupe are certainly incorrect, and those from Africa are very doubtful (Thwaites et al., 2000).

All of the authenticated records of Moko disease in Central and South America and the West Indies are in tropical rather than sub-tropical locations. The disease described by Wardlaw and McGuire (1933) in Santos in the Brazilian sub-tropics does not resemble Moko disease and is regarded by Buddenhagen (1961) as a very doubtful record. Moko disease in Brazil is found far to the north along the tributaries of the Amazon River adjoining Peru, Ecuador, Colombia, Guyana and Surinam. All of these countries of the Amazon basin are affected by Moko disease (Stover, 1972).
Moko disease also occurs on Cavendish bananas in Mindanao, southern Philippines and is thought to have been introduced on planting material from Honduras in 1968 (Rillo, 1979; Buddenhagen, 1994). If, as has been suggested, Bugtok disease of cooking bananas had its origin in Moko disease of dessert bananas, Moko disease must have been introduced into the Philippines before the late 1960s, contrary to several statements in the literature.

The SFR strain of R. solanacearum was detected in north Queensland near Cairns, Australia, in 1989 in legally imported Heliconia from Hawaii, and was successfully eradicated (Diatlott et al., 1992; Hyde et al., 1992; Gillings and Fahy, 1994).

Moko disease is found exclusively in the tropics; there are no confirmed instances of the entry and establishment of the disease in any sub-tropical location. In his review on the subject of distribution of Moko disease, Buddenhagen (1961) listed the several unconfirmed reports and gave cogent reasons for doubting their authenticity. There is recent information on the distribution of Moko disease in Brasil (Takatsu, 2001), a country in which banana cultivation extends from the Equator into sub-tropical regions. There is an early report of a disease resembling Moko disease in Sao Paulo (ca. 24° S; Wardlaw and McGuire, 1933) but several authorities have stated that the symptoms do not resemble Moko disease and have cast doubt on the record (Buddenhagen, 1961; Sequeira, 1958; Takatsu, 2001; Lopes, 2001). Table 32 gives data on the global distribution of Moko disease.

**Biology**

Moko bacterium infects banana plants at all growth stages and symptoms of the disease vary depending on the route of infection and the growth stage of the plant (Stover, 1972). The incubation period, i.e. time elapsed between inoculation and expression of external visible disease symptoms, could vary from less than one week to 24 weeks or more depending on the maturity of the infected plant, route of infection, method of inoculation and environmental conditions, particularly the incubation temperature and to some extent the relative humidity (Table 33). Incubation period in young actively growing plants is shorter than mature plants (Sequeira, 1958). The disease is commonly found in young actively growing suckers and produces symptoms in 2 to 4 weeks (Buddenhagen, 1961; Buddenhagen, 1994). In mature plants, the incubation period may be greater than 13 weeks (Soguilon 2003a). Incubation period in banana fruit has been reported as three weeks (Sequeira, 1958) but it is reasonable to assume that this period could be longer given that a wide range of incubation periods have been recorded in banana plants. Zehr and Davide (1969) recorded an incubation period of one month in artificially inoculated young fruit of Saba cooking banana.

Descriptions of symptoms of Moko disease in dessert and cooking banana have been documented by many authors (Rorer, 1911; Ashby, 1926; Sequeira, 1958; Buddenhagen, 1962; Stover, 1972; Wardlaw, 1972; Kastelein and Gangadin, 1984; Jeger et al., 1995; Molina, 1996; Jones, 2000) and a summary is given below.

Mature plants of dessert bananas including Cavendish cultivars, are usually infected via roots or the rhizome and show early signs of yellowing and wilting of the infected leaves, which eventually become necrotic and collapse at the junction of the lamina with the petiole. All other leaves rapidly break down in a similar manner. Eventually, all the leaves die and the plant rots down to the ground. Rapid wilting may be accompanied by bending of a plant so that it snaps off at the base close to the ground. Young suckers may wilt without showing the foliar symptoms of yellowing and necrosis. Suckers of affected mats may be blackened and deformed. Fruit development is arrested and fingers may ripen prematurely or split and eventually rot.
Table 32  Geographical distribution of Moko on bananas

<table>
<thead>
<tr>
<th>Region</th>
<th>Countries affected</th>
<th>Approximate latitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>North America, Central America, West Indies</td>
<td>Mexico (Central depression of Chiapas State)</td>
<td>18° N</td>
</tr>
<tr>
<td></td>
<td>Belize</td>
<td>16 -18° N</td>
</tr>
<tr>
<td></td>
<td>Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama</td>
<td>7° N -18° N</td>
</tr>
<tr>
<td></td>
<td>Grenada (WI)</td>
<td>13° N</td>
</tr>
<tr>
<td></td>
<td>Trinidad (WI)</td>
<td>11° N</td>
</tr>
<tr>
<td>South America</td>
<td>Brazil (Amapa, Alagoas, Amazonas, Ceara, Para, Paraiba, Rondonia and Sergipe)</td>
<td>Equator to 12° S</td>
</tr>
<tr>
<td></td>
<td>Colombia, Ecuador, Guyana, Peru, Surinam and Venezuela</td>
<td>13° N to 17° S</td>
</tr>
<tr>
<td>Southeast Asia</td>
<td>The Philippines:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mindanao</td>
<td>6° N-8° N</td>
</tr>
<tr>
<td></td>
<td>Visayan Islands**</td>
<td>8° N-12° N</td>
</tr>
<tr>
<td></td>
<td>Mindoro Island**</td>
<td>13° N</td>
</tr>
</tbody>
</table>

* Pernambuco State (8° S) and Hawaii (USA 10° N-22° N) have been excluded because Moko disease has been reported only on Heliconia but not confirmed on banana. In Pernambuco Heliconia nursery plants are affected.

** The records for the Visayan Islands and Mindoro Island are on cooking banana only as far as is known; there is doubt about Mindoro Island. (Maghirang, 1998) said that he had seen the disease on that island, whereas Molina (2002) said that the disease did not occur there.

Source: Hayward, 2002

The presence of yellow fingers in an otherwise green stem will often indicate the presence of Moko disease. Within a mat, obviously diseased and apparently normal plants may occur together but usually the whole mat is killed in due course.

Internally, the vascular tissue in all infected plant parts (including pseudostem, corm, peduncle and fruit) becomes progressively discoloured. The vascular tissue initially turns cream or yellow but later becomes brown or black and in some cases cavities may occur in pseudostem, corm and peduncle after the vascular tissue breaks down. The discolouration of vascular bundles may be seen throughout the plant but in fruit-bearing plants it is concentrated in the peduncle and younger leaf bases in the centre of the pseudostem. In fruit stalks (peduncles bearing fruit), vascular discolouration is concentrated peripherally. The discoloured vascular bundles are filled with bacteria. Creamy white drops of bacterial ooze exude from these vascular bundles when transverse sections of infected leaf petiole, stem or peduncle are cut and let stand for a short time. Also, vascular discoloration moving up into the peduncle and fruit is indicative of Moko disease. The fruit pulp is discoloured and may eventually exhibit a typical dry rot.
When infection of dessert banana occurs via insect-transmission through the male flower cushions and bract scars, the infected fingers show typical symptoms and the disease may continue to progress up the peduncle and down into the corm and then produce wilting and death of the infected plant and suckers in the mat. Due to a large underground corm and constant sucker production, a diseased mat may have some suckers free of the bacterium but as previously explained such suckers would often be killed as the disease advances.

As described by Wardlaw (1972), in the simplest case of Moko, the oldest plant is the first to succumb followed by the death of progressively younger plants as the infection spreads systemically through the mat. In such mats, the young suckers often wilt and bear discoloured leaves. In the more complicated distributions of infection within the mat, two plants may be of almost equal stature but only one is obviously diseased, the other is apparently healthy, perhaps with a good bunch. Again, youngish plant may show typical leaf discolouration whereas an older one may be symptomless. These confusing irregularities in disease manifestation are probably due to the frequently observed fact that the infection may be localised in one sector of the parent rhizome. Consequently, in the transmission of infection from parent to daughter suckers, some departure from the strict age sequence is to be expected. Direct infection of one or more plants and suckers from the soil would also account for departure from the usual parent-to-follower sequence of infection in the mat.

Moko disease in cooking banana cultivars, such as 'Bluggoe' (cf. Bugtok disease on cooking banana in the Philippines) commonly occurs through the inflorescence via transmission by insect vectors. Symptoms of insect-transmitted Moko infection are first seen in the flower buds and peduncles, which become blackened and shrivelled. The bacterium spreads to the fruit, which may ripen prematurely so that there are yellow fingers within a hand of green fruit, and initiates a rot. The infection continues towards the pseudostem, causing blackening of the vascular tissue. In the Philippines, cooking banana plants are generally not killed by inflorescence infection and the suckers in such mats usually escape infection. The visible symptoms of the disease in cooking bananas in the Philippines are largely seen on the male flower bud and the peduncle.

There is strain variation in symptoms on different hosts depending on susceptibility. For example, strains from *Heliconia* (H strains) do not affect dessert bananas, and cause localised symptoms on ‘Bluggoe’, affecting only the flower buds.

According to Rorer (1911) if the infection is not severe or if the plant does not become infected until it has formed a bunch, it may remain apparently healthy. However, many of the young fruit do not mature properly and remain small and eventually become black and rotten. In such infections, discoloured strands filled with bacteria can usually be seen in the inner leaf-sheaths, pseudostem, fruit stalk and fruit. Martyn (1934) reported that in cases where diseased plants bear bunches, the fingers are stunted and underdeveloped and tend to become blackened. If suckers of diseased plants were cut down, they show a discolouration of the vascular bundles varying from reddish-brown to yellow. In fruiting plants this discolouration may be traced up the stem to the stalk and into the fingers. Sequeira (1958) reported that in some cases, no external symptoms are seen until the fruit bunch is produced, at which time individual fingers appear distorted and the pulp exhibits a characteristic dark brown discoloration. According to Buddenhagen (1961) when Moko is present in a plantation some fruit bunches will not develop normally; the fruit bud will be small and may wither and fruit development is arrested. Internally, the fruit pulp is discoured by a firm brown rot that develops to a grey dry rot. A lightly affected stem may show limited external symptoms consisting of a few split or prematurely yellow fingers, and the fruit stalk will exhibit vascular discolouration, concentrated peripherally. Stover (1972) reported that in Honduras plantations about 15 per cent of the infected mats exhibited symptoms of fruit infection. According
to Kastelein and Gangadin (1984), the disease has been occasionally observed in bearing plants. Soguilon (2003a) reported that no symptoms developed in fruit on artificially inoculated plants for at least 13 weeks after inoculation.

**Epidemiology**

**Sources of inoculum and modes of dissemination**

The epidemiology of Moko disease in dessert bananas differs markedly from that in cooking bananas of ABB or BBB genotype. On dessert bananas, Moko disease is usually mechanically transmitted by unsanitised machetes used in pruning operations (Sequeira, 1958). Removal of excess suckers and the pseudostem of fruited plants produces numerous open wounds through which bacteria can leave diseased plants. In addition, infected insects may transmit the bacteria through such wounds (Figure 15). Insect transmission occurs from inflorescence to inflorescence, and to the exposed vascular tissue of wounds (Stover, 1972; Buddenhagen and Elsasser, 1962). Transmission from root to root also occurs (Kelman and Sequeira, 1965) through the openings in the vascular tissue where secondary roots emerge. According to Stover (1972) this mode of transmission is much more common with the B strain than with the SFR strain. The disease is transmitted from infested soil to plants. The entry of the bacteria is facilitated by mechanical injuries. Injured or decaying infected tissues release bacteria into the soil, and the bacteria are spread through soil water. According to Kelman and Sequeira (1965) evidence from field experiments indicates that extremely high populations of the bacterium are required for infection of non-wounded banana roots. They also considered it unlikely that superficial wounds in the root cortex alone will provide a pathway for infection. The negative results obtained when bacterial suspensions were placed on roots at loci where secondary roots were not emerging suggests that the pathogen cannot reach the vascular tissue by digesting its way through cortical cells (Kelman and Sequeira, 1965).

Sequeira (1958) reported that in the course of extensive investigations on the characteristics and mode of dissemination of the Moko disease organism, it became evident that its entry into banana plants occurs to a large extent through the above-ground plant parts rather than through the roots. Perhaps a more important means of dissemination is rain-carried infested soil that may splash on fresh wound surfaces, where the wilt bacterium can easily gain access to the vascular bundles of the banana plant.

Wardlaw (1972) reported that inoculation investigations have shown that if the Moko bacterium is simply poured on, or into the soil, it does not survive very long, and it does not cause wilt disease. If, however, the roots are injured, e.g. by cutting, when the bacterial culture is applied, 100 per cent, successful infection has usually been obtained. Again, when a suspension of bacteria was applied directly to intact roots, or to roots with superficial injury only, no infection occurred; but disease was usually obtained where the vascular system had been exposed (Wardlaw, 1972).

Although invasion through the root system does not appear to be responsible for the very rapid spread of bacterial wilt of banana, the organism can penetrate the rhizome tissue readily through the roots of a seed “bit” planted in heavily infested soil (Sequeira, 1958) and this happens also when suckers are cut below ground level (Lehmann-Danzinger, 1987). On the other hand, wounds produced by nematodes do not seem to have the same importance for infection (Lehmann-Danzinger 1987). Very often banana and plantain plants neighbouring Moko infected plants stay healthy in spite of the presence of nematodes (Lehmann-Danzinger, 1987). It could be that the saprophytic bacteria present in rotting roots, which accompany nematode attack, prevent the
bacterium from reaching the xylem vessels (Lehmann-Danzinger, 1987). According to Lehmann-Danzinger (1987), the low survival rate of Moko bacterium in water with organic material with the invariable presence of saprophytic bacteria, suggests that an environment with low oxygen and glucose concentration considerably diminishes the survival of the bacterium.

In the case of banana it is probable that an individual infected plant, prior to its death, may serve as a focal point for the release in the soil of large numbers of bacteria, thereby greatly increasing the inoculum potential (Kelman and Sequeira, 1965). Evidence from field experiments indicates that extremely high populations of the bacterium are required for infection of nonwounded banana roots. In the Golfito area of Costa Rica, lateral spread from infected to adjoining healthy plants occurred much more rapidly if the original infected plants were cut down and chopped into small segments rather than allowed to die in situ after weed killer application (Sequeira, unpublished data - United Fruit Co. Ann. Rep., 1959 as cited in Kelman and Sequeira, 1965). Chopping of infected pseudostems presumably resulted in the release of such high numbers of bacteria that a much higher inoculum potential resulted than in the case of natural release from infected roots. The possibility exists in this instance that increased opportunity for insect transmission was also provided (Buddenhagen and Elsasser, 1962).

It is considered unlikely, however, that superficial wounds in the root cortex alone will provide a pathway for infection. The negative results obtained when bacterial suspensions were placed on roots at loci where secondary roots were not emerging suggests that the pathogen cannot reach the vascular tissue by digesting its way through cortical cells (Kelman and Sequeira, 1965).

**Figure 15 Major pathways of transmission of *R. solanacearum* on banana plants**

Source: Stover, 1972 — Reproduced with permission from CABI Publishing, CAB International

In Moko (Bugtok) disease of cooking bananas, the principal mode of transmission is insect transmission to the inflorescence probably by thrips (Soguilon *et al.*, 1995). Bacteria have also
been isolated from thrips, bees and wasps caught on or near the flowers and fruit of infected plants. In all, 581 insects were collected between June 1996 to July 1997 in Davao, Mindanao, from which 14 isolates resembling \textit{R. solanacearum} were isolated. All were either hymenopterans or thysanopterans. Of these, 10 isolates from bees, two from wasps and one from thrips were inoculated by injection into the emerging flower bud of cv. Cardaba. All eventually gave rise to the vascular discoloration typical of Bugtok disease (Kenyon \textit{et al.}, 1997). In Bluggoe, bacteria exude from peduncle cushions and bract bases for 10 days; between about 15 to 25 days after infection by SFR strain (Buddenhagen and Elsasser, 1962). Insects frequenting banana inflorescences become contaminated on contact with bacterial ooze and transmit the disease on subsequent visits to healthy flowers. The B strain produces less ooze and is less frequently transmitted by insects (Jeger \textit{et al.}, 1995). However, Stover (1972) reported that considerable insect-transmission of SFR and B strains occurs through pruning wounds.

Detailed studies on the identity of the insect vectors involved in transmission of Moko bacterium in the Philippines have not been conducted. Kenyon \textit{et al.} (1997) isolated the Moko bacterium from insects belonging to the order Thysanoptera (thrips) and Hymenoptera (bees and wasps). Thwaites \textit{et al.} (2000) have also implicated thrips (Thysanoptera).

The pathogen moves from the inflorescence through the vascular tissue of the pedicels and peduncle into the pseudostem, but rarely penetrates to the rhizome. Transmission through the soil and mechanical transmission have been reported, but they appear to be much less important than insect transmission (Molina, 1999). That the disease in cooking bananas is only partially systemic is supported by the observation that the disease is not disseminated in suckers. Four hundred suckers harvested in a highly infested area and planted in an area where Bugtok had not been reported remained disease free through three generations (Soguilon \textit{et al.}, 1994a).

**Resistance to desiccation and survival in soil**

\textit{Ralstonia solanacearum} does not produce desiccation-resistant resting cells and survives poorly when subjected to air-drying. All of the quantitative studies have involved measurement of survival in films dried on cover slips or glass slides held under controlled humidity. Kelman (1953) quotes the work of several authors where bacteria survived for between 48 hours and 6 days. Sequeira (1958) reported survival up to 11 days of air exposure using an \textit{in vitro} technique. There is a general lack of detailed quantitative investigation of the fate of soil populations of the pathogen, but there is agreement that different strains differ in longevity in soil. According to Stover (1972), the B strain “\textit{can persist in soil for 12-18 months}”, whereas the SFR strain “\textit{...rarely survives in the soil for 6 months}”. Sequeira (1962) recorded the incidence of wilt on bananas grown in infested soil after various fallowing and rotation periods. Moko disease was effectively controlled in infested soils fallowed for 24 months. Weed fallowing was as effective as rotation with tropical kudzu.

Sequeira (1962) concluded that, because the banana strain of the pathogen has a rather limited host range, elimination of plant hosts was mainly responsible for control of the disease.

The survival of the organism in host tissue, including banana fruit is not well understood. According to Wardlaw (1972), no Moko bacteria could be isolated after eight days from infected leaf sheath tissue, maintained under humid conditions.
Other sources of inoculum

Many bacterial plant pathogens propagate and survive on floral parts, stems and leaves as epiphytic populations that play a significant role in disease epidemiology. This is true of fireblight of apple and pear caused by Erwinia amylovora and blossom blights caused by pathovars of Pseudomonas syringae. Epiphytic populations of R. solanacearum have not been described, and they are not known to play any role in the epidemiology of Moko disease. Similarly, there is no evidence of the dissemination of Moko disease in aerosols containing bacteria as described for E. amylovora, some pseudomonads and soft rot erwinias.

Dispersal by rain splash has not been investigated for Moko disease or any other form of bacterial wilt, but is an aspect requiring investigation. With some bacterial pathogens on other hosts, it is known that water droplets carrying bacterial cells can be dispersed long distances under cyclonic conditions. Goto (1990) reports that dispersal of inoculum under storm conditions, which results in subsequent infection, appears not to occur over a long distance. In the case of bacterial leaf blight of rice caused by Xanthomonas oryzae pv. oryzae the pathogen was recovered 64 m from the source of inoculum in a rainstorm with a maximum wind velocity of 28 m/sec. However, actual disease development was detected at a distance of at most only 4 m.

High wind and rain is likely to mobilise dried bacterial ooze from exposed surfaces of backyard cooking bananas growing near plantations of dessert bananas. There is no information on splash dispersal of Moko disease, but, even if it does occur, it is unlikely to be significant compared with insect transmission.

Status of insect transmission

Fruit infection occurs frequently with the SFR strain, and occurs through the male flower bract scars before the male flower is removed. According to Stover (1972), the B strain can also be insect-transmitted to fruit through the inflorescence, but this is much less common than with the SFR strain because the B strain rarely oozes from infected flower buds. Insect transmission is of variable importance in several other strains of R. solanacearum. The potential for insect transmission in a particular strain of R. solanacearum appears to be both an intrinsic property of the pathogen and a function of the host genotype.

That this is the case supported by the observation that insect transmission of the B strain to floral parts is more common on the cooking banana ‘Bluggoe’ (ABB genotype) in Costa Rica and rare on bananas (Stover, 1972). The strain affecting dessert bananas in Mindanao is not known with certainty. According to Thwaites (1999), the B strain is present in the Philippines. In the Philippines, Moko in Cavendish banana and Bugtok disease in cooking banana are caused by the same organism (Molina, 1996; Raymundo and Ilagan, 1999). Moko and Bugtok strains of R. solanacearum from the Philippines have been identified as MLG 24, and those few authentic B strains from Central America, which have been examined are also MLG 24 (Fegan, 2002). Insect transmission of Moko disease on dessert bananas in the Philippines appears to be uncommon, whereas the same pathogen on the cooking bananas “Cardaba” and “Saba” has very high potential for insect transmission. The behaviour of B strains on “Bluggoe” cooking bananas in Costa Rica as reported by Stover (1972) is similar to that observed on cooking bananas of the same genotype in the Philippines.

Soguilon et al. (1994b) carried out inoculation tests with Bugtok isolates in tissue-cultured banana cv. Cardaba and field-collected suckers of Cavendish banana. Ten millilitres of a turbid suspension was injected into the bases of 80 cm tall banana plantlets, and 10 ml of sterile distilled water was
injected into control plants. Six selected Bugtok isolates caused a wilt in Cardaba 6–12 days after inoculation. Two selected isolates inoculated into Cavendish suckers caused wilting 6 days after stem injection. Control plants did not wilt. Although these pathogenicity tests were limited in extent, and no tests were made to establish whether Moko isolates could produce symptoms typical of Bugtok disease via infection of the inflorescence, they are consistent with other evidence on the identity of the Moko and Bugtok agents.

These conclusions are supported by Molina (1999), who states that Bugtok disease ‘… is caused by a bacterium Ralstonia solanacearum race 2 …’ and that ‘… recent DNA analysis using RFLP and PCR techniques has confirmed that the same strain of the bacterium causes both Moko and Bugtok diseases …’. About transmission of the disease, Molina states that ‘… the bacterium is known to be transmitted by insects as a result of feeding from infected flowers. While mechanical and soil transmission have also been reported, insect transmission remains the major mode of spread of Bugtok/Tibaglon on cooking bananas…’

Detailed studies on the identity of the insect vectors involved in transmission of Bugtok disease in the Philippines have not been done. Thwaites et al. (2000) implicated thrips (Thysanoptera). According to Buddenhagen and Kelman (1964) native bees (Trigona spp.), wasps (Polybia spp.), fruit flies (Drosophila spp.) and many other genera of flies visit banana flowers.

Buddenhagen and Elsasser (1962) found that, of 700 bees (Trigona corvina Cockerell) and wasps collected in a diseased patch of bananas during a 20-day period, 5% were carrying the pathogen as ascertained by direct isolation techniques. Stover (1972) states that ‘...from frequency counts of insects reaching infectible sites on banana plants it was calculated that fewer than one carrier in 100,000 can account for the scattered disease incidence in Honduras plantations’. Stover (1993) reports an epidemic of the SFR strain in a banana variety collection because of failure to promptly remove the male flower buds and destroy large nests of ‘Morocco’ bees (Trigona corvina) within 200 m of the collection. These bees are the most frequent insect visitors to emerging banana flowers.

Long-range movement on fruit, rhizomes, and ornamental and other plants

There appears to be no published information on the survival of R. solanacearum on the surface of green, unripened or ripened fruit under natural conditions. However, under experimental conditions, Soguilon (2003b) reported that under moist conditions the bacterium could survive on the fruit surface for up to two weeks. The surface of fruit could become contaminated by insects or rain splash of bacterial ooze. Internal infection of fruit occurs through the vascular system from the rhizome upwards through the pseudostem or, in the case of insect transmission to the inflorescence, downwards through the pedicels and peduncles into the pseudostem.

The pathogen can be readily isolated from the vascular system of the fruit stalk and the pseudostem. In the case of Bugtok disease (Soguilon et al., 1994b) the authors state that ‘...pure cultures were obtained only when infected male axis and detached male inflorescences were incubated for 3 – 14 days or until exudates from the cut ends were visible. Later, it was found that bacterial isolation was possible by directly streaking on agar medium the milky substance oozing from detached bracts of the male inflorescence.’

No published records of the introduction and establishment of Moko disease locally or internationally as the result of marketing of infected fruit have been found. There is ample evidence of short- as well as long-distance spread of Moko through movement of infected or contaminated propagation material. Propagation material may be contaminated by infested soil,
cutting tools used for pruning rhizomes or for pruning suckers and, in some cases, by insects. In Grenada, West Indies, an eradication program for Moko disease on banana has been in progress since the disease was discovered in 1978. The following comments by Hunt (1987) are based on several years of involvement in this program, but unfortunately no supporting data are given.

‘At present among the Windward and Leeward Islands, Moko is confined to Grenada and Carriacou. If Moko is ever introduced to other islands, it will almost certainly have been carried there by man, most likely on infected planting material or in diseased fruit; there is a smaller but still important risk of introduction through importation of other plants susceptible to Moko infection, e.g., Heliconia, Dieffenbachia, tannia.’

Moko was reportedly introduced to the Philippines in 1969 (Rillo, 1979; Buddenhagen, 1986) from planting material originating in Central America. However, according to Soguilon et al. (1994b) ‘...backyard growers from Mindanao have been bothered by a disease known locally as Bugtok...since early 1950’s...’. The causative agents of the two disease conditions have been shown to be indistinguishable in phenotypic properties and in genotype using sensitive and discriminatory DNA-based methods (Soguilon, et al., 1995; Raymundo et al., 1997; Raymundo and Ilagan, 1999; Soguilon, 2003a).

The origin of Moko in the Philippines is unclear but it is possible that it was introduced from Central America earlier than 1969, and this is a more likely explanation than that two identical agents evolved independently in Central America and the Philippines. The same MLG group, MLG 24, as that found in the Philippines is also found in Honduras and Guatemala where planting material sent to the Philippines had originated. A plausible hypothesis is that R. solanacearum MLG 24 was introduced from Central America and then became established on cooking bananas (Saba and Cardaba, ABB/BBB genotype) before the large-scale cultivation of dessert bananas in Mindanao in the late 1960s and 1970s.

The key question is whether Bugtok-infected plants provide a source of inoculum for dessert bananas. Because isolates from cooking and dessert bananas are indistinguishable in culture, experimental epidemiology is needed to resolve the matter. Molina (1996) demonstrated that infection by insects through the inflorescence in the commercial plantations is insignificant because the pest management measures being used are effective in controlling such infections. According to BPI (2002), the standard field operations in Philippines commercial banana plantations have proven to minimize the probability of Moko infection by insect transmission to negligible levels.
Table 33  Incubation period of *Ralstonia solanacearum* in Musa

<table>
<thead>
<tr>
<th>Incubation period</th>
<th>Plant type and growth stage/comment</th>
<th>Banana cultivar</th>
<th>Strain of Moko</th>
<th>Method of inoculation</th>
<th>Comment</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 month</td>
<td>Half grown plants</td>
<td>Moko (Bluggoe) plantain</td>
<td>B****</td>
<td>Injecting bacterial suspension into one of the upper leaves</td>
<td>The injected plant was dead within 7 weeks and also suckers died within about four and half months</td>
<td>Rorer, 1911</td>
</tr>
<tr>
<td>2 weeks to 19 days</td>
<td>Red banana</td>
<td>B****</td>
<td>Smearing bacterial growth on a young leaf and pricking 6 to 8 times into the petiole</td>
<td>The inoculated leaves broke down and within the next 2 weeks the whole plant was dead</td>
<td>Rorer, 1911</td>
<td></td>
</tr>
<tr>
<td>17 to 24 days</td>
<td>Red banana</td>
<td>B****</td>
<td>Smearing bacterial growth on a young leaf and pricking 6 to 8 times into the petiole</td>
<td>The inoculated plants were dead within 7 weeks</td>
<td>Rorer, 1911</td>
<td></td>
</tr>
<tr>
<td>7 weeks</td>
<td>Dwarf banana</td>
<td>B****</td>
<td>Smearing bacterial growth on a young leaf and pricking 6 to 8 times into the petiole</td>
<td>Inoculated plants died in 13 weeks, in addition, many suckers were diseased or even dead (also see below*)</td>
<td>Rorer, 1911</td>
<td></td>
</tr>
<tr>
<td>7 Weeks</td>
<td>Banana</td>
<td>B****</td>
<td>De-suckering with a machete, which was infested by piercing</td>
<td>The bacterium moved rapidly through the plant when a young leaf was</td>
<td>Sequeira, 1958</td>
<td></td>
</tr>
<tr>
<td>Incubation period</td>
<td>Plant type and growth stage/comment</td>
<td>Banana cultivar</td>
<td>Strain of Moko</td>
<td>Method of inoculation</td>
<td>Comment</td>
<td>Reference</td>
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</tr>
<tr>
<td>3 weeks</td>
<td>Mature plants, peduncles</td>
<td>Banana</td>
<td>B****</td>
<td>De-budding with an infested knife</td>
<td>100 % of the treated plants developed symptoms</td>
<td>Sequeira, 1958</td>
</tr>
<tr>
<td>7 weeks</td>
<td>Mature plants, peduncles</td>
<td>Banana</td>
<td>B****</td>
<td>De-leafing a young and actively growing leaf with an infested knife</td>
<td>100 % of the treated plants developed symptoms (also see below“)</td>
<td>Sequeira, 1958</td>
</tr>
<tr>
<td>30 days or more</td>
<td>Young and mature plants</td>
<td>Banana</td>
<td>B****</td>
<td>Pruning young suckers and smearing the pruning wounds with soil from a heavily Moko infected area</td>
<td>32.6 % treated plants developed symptoms in 30 days and 6.6 % of the suckers belonging to these plants developed symptoms within this time</td>
<td>Sequeira, 1958</td>
</tr>
<tr>
<td>7 to 45 days</td>
<td>3 ft tall young plants</td>
<td>Gros Michel</td>
<td>B****</td>
<td>Injecting bacterial suspension into the pseudostem about 15 cm above the soil level.</td>
<td>Most of the “normal” isolates produced rapid wilting symptoms in 7 days - plants inoculated with a “distortion” strain showed symptoms within 45 days</td>
<td>Buddenhagen, 1960</td>
</tr>
<tr>
<td>Incubation period</td>
<td>Plant type and growth stage/comment</td>
<td>Banana cultivar</td>
<td>Strain of Moko</td>
<td>Method of inoculation</td>
<td>Comment</td>
<td>Reference</td>
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<tr>
<td>2-4 weeks</td>
<td>Young regrowth suckers</td>
<td>Banana cultivar</td>
<td>Strain of Moko</td>
<td>Method of inoculation</td>
<td>Comment</td>
<td>Reference</td>
</tr>
<tr>
<td>2-4 weeks</td>
<td>Young regrowth suckers</td>
<td>Banana</td>
<td>Moko</td>
<td>De-suckering with contaminated knife</td>
<td>Symptoms progressed rapidly on young, actively growing plants; most leaves collapses within a few days to a weeks after initial wilting symptoms appeared</td>
<td>Buddenhagen, 1961</td>
</tr>
<tr>
<td>8 to 29 days</td>
<td>1-month old plants</td>
<td>Gros Michel</td>
<td>B (ex-banana), B (ex-Heliconia)</td>
<td>Injecting bacterial suspension into the pseudostem base</td>
<td>The isolates from banana caused a dramatic quick wilt as compared with slow wilt caused by isolates from Heliconia</td>
<td>Sequeira and Averre, 1961</td>
</tr>
<tr>
<td>1 month</td>
<td>Immature fruit</td>
<td>Saba</td>
<td>B</td>
<td>Injecting bacterial suspension into the fruit</td>
<td></td>
<td>Zehr and Davide, 1969</td>
</tr>
<tr>
<td>4-8 days</td>
<td>15 cm tall plants</td>
<td>Musa balbisiana</td>
<td>B, D, SFR, T</td>
<td>Piercing pseudostem 2-3 cm above the soil line</td>
<td>Incubation temperature ranged from 30-33°C at night to 30-40°C in the day time</td>
<td>French and Sequeira, 1970</td>
</tr>
<tr>
<td>6 weeks to 3</td>
<td>Mature plants</td>
<td>Banana</td>
<td></td>
<td>Pruning suckers with contaminated machete</td>
<td>40 % of the mats showed symptoms after 70 days and 60 % after 90 days (also see below)</td>
<td>Stover, 1972</td>
</tr>
<tr>
<td>months or more</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 weeks</td>
<td>Young plants</td>
<td></td>
<td></td>
<td>Injecting bacterial suspension in the pseudostem or the rhizome or placing extract</td>
<td></td>
<td>Power, 1976</td>
</tr>
<tr>
<td>Incubation period</td>
<td>Plant type and growth stage/comment</td>
<td>Banana cultivar</td>
<td>Strain of Moko</td>
<td>Method of inoculation</td>
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<tr>
<td>7 to 10 days</td>
<td>Young plants with 4 or more expanded leaves</td>
<td>Giant Cavendish</td>
<td></td>
<td>from infected peduncle on damaged parts of rhizomes</td>
<td></td>
<td>Rillo, 1979</td>
</tr>
<tr>
<td>8 to 24 weeks or more</td>
<td>Young, 1 m high plants</td>
<td>B, SFR</td>
<td>Pouring bacterial suspension into the exposed and injured lateral roots 5-10 cm from either the base or corm</td>
<td></td>
<td>Woods, 1984</td>
<td></td>
</tr>
<tr>
<td>2 weeks</td>
<td>Young plants, 3 month old</td>
<td>Bluggoe SFR</td>
<td>Cutting roots 1 cm below the root neck and then dipping them in bacterial suspension or injecting bacterial suspension into the pseudostem</td>
<td></td>
<td>Lehmann-Danzinger, 1987</td>
<td></td>
</tr>
<tr>
<td>Up to 3 months</td>
<td>Mature plants</td>
<td>B</td>
<td></td>
<td></td>
<td>Lehmann-Danziger, 1987</td>
<td></td>
</tr>
<tr>
<td>4 months</td>
<td>Mature plants</td>
<td>Abuhon B***</td>
<td>Injecting pseudostem with bacterial suspension</td>
<td>Symptoms were seen in the fruit four months after inoculation</td>
<td>Soguilon et al., 1994a</td>
<td></td>
</tr>
<tr>
<td>Incubation period</td>
<td>Plant type and growth stage/comment</td>
<td>Banana cultivar</td>
<td>Strain of Moko</td>
<td>Method of inoculation</td>
<td>Comment</td>
<td>Reference</td>
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<tr>
<td>6 to 12 days</td>
<td>Young tissue cultured plants</td>
<td>Cardaba</td>
<td>B***</td>
<td>Injecting pseudostem with bacterial suspension</td>
<td></td>
<td>Soguilon et al., 1994b</td>
</tr>
<tr>
<td>6 days</td>
<td>Young plants, suckers about 80 cm tall</td>
<td>Cavendish</td>
<td>B***</td>
<td>Injecting bacterial suspension into the base</td>
<td></td>
<td>Soguilon et al., 1994b</td>
</tr>
<tr>
<td>Not recorded</td>
<td>Mature plants</td>
<td>Abuhon</td>
<td>B***</td>
<td>Injecting bacterial suspension into newly emerged, punctured inflorescence</td>
<td>Typical Bugtok symptoms appeared in fruit and bracts covering the male flowers</td>
<td>Soguilon et al., 1994b</td>
</tr>
<tr>
<td>More than 13 weeks</td>
<td>Mature plants</td>
<td>Cavendish</td>
<td>B</td>
<td>Sprayed bacterial suspension on to fresh peduncle wounds immediately after debelling. Sprayed surface covered with plastic film for 48hrs</td>
<td>None of the inoculated plants expressed external symptoms at the end of the observation period of 13 weeks. All test plants manifested varying degrees of vascular discoulouration in peduncle</td>
<td>Soguilon, 2003a</td>
</tr>
</tbody>
</table>

* In two mats suckers were symptomless until they came to maturity; they produced very poor bunches, some of the fingers being black and rotten. Internally, the vascular bundles in the stem, fruit stalk and fingers of these plants were discoloured and filled with bacteria.
** When fully mature leaves were pruned, bacteria moved down the petiole very slowly.
*** When a chisel type tool was used to remove unwanted suckers and mother plants close to or below the ground level, some rhizomes were infected but infection remained localised. The fact that some infections remain latent or do not become systemic for long periods complicates detection and control.
**** Presumably B strain was used in these experiments.
**Freckle**

**Scientific name**

*Guignardia musae* Racib (Anamorph - *Phyllosticta musarum* (Cooke) van der Aa, 1973) [Order: Dothideales; Family: Mycosphaerellaceae]

**Synonym(s)**

*Phyllostictina musarum* (Cooke, Petr.) (Van der Aa, 1973); *Phoma musae* (Cke.) Sacc.; *Phoma musarum* Cke.; *Sphaeropsis musarum* Cke.; *Macrophoma musae* (Cooke) Berl. and Volg.; *Phyllachora musarum* (Kleb) Sacc.; *Dothidea musae* Kleb (Wardlaw, 1961)

**Common name(s)**

Black spot; Freckle (Pref.); Phyllosticta leaf spot.

**Host(s)**

*Musa textiles* (Abaca) (Anunciado et al., 1977); *Musa* spp.

**Plant part(s) affected**

Leaves and fruit (Carpenter, 1919; Meredith, 1968).

**Distribution**

American Samoa (Dingley et al., 1981), Australia (Jones and Alcorn, 1982), Bangladesh (Jones, 2000), Burma (Wardlaw, 1961), Bhutan (Jones, 2000), Brunei (Jones, 2000), Congo (Wardlaw, 1961), China (Zhou and Xie, 1992), Cook Islands (Dingley et al., 1981), Fiji (Campbell, 1926), Hawaii (Carpenter, 1918), Hong Kong (Lee, 1922), India (Wardlaw, 1961), Indonesia (Jones, 2000), Malaysia (Jones, 2000), Nepal (Jones, 2000), New Caledonia (Johnston, 1965), New Zealand (Jones, 2000), Niue (Dingley et al., 1981), Pakistan (Jones, 2000), Papua New Guinea (Shaw, 1963), Philippines (Lee, 1922), Solomon Islands (Jones, 2000), Sri Lanka (Wardlaw, 1961 Taiwan (Wang, 1959), Thailand (Wardlaw, 1961; Johnston, 1965), Tonga (Dingley et al., 1981), USA (Wardlaw, 1961), Vietnam (Jones and Daniells, 1988) and Western Samoa (Dingley et al., 1981).

Records from Africa (Congo, Zambia) and the Caribbean (Dominican Republic, Jamaica and St Lucia) need confirmation because of confusion in the taxonomy of the fungus and lack of typical symptoms in these regions (Jones, 2000).

In the Philippines, Lee (1922) noted that black spot disease (freckle) was widespread through the Sulu Archipelago and the island of Mindanao, and concluded that as these regions are sparsely populated and no fruit is imported, black-spot disease is either indigenous or of very long standing.

In Australia, there are three records of freckle in New South Wales including, two on cultivar Goldfinger and one on *Musa* x cult (Priest, 2002). In Queensland there are 32 records of freckle with all but three from the Torres Strait are from Bluggoe or *Musa* spp. The other three records are
from north Queensland from the ABB cultivars Bluggoe and Blue Java (Shivas, 2001). Freckle was recorded on Cavendish bananas at Kalumbaru near Kununurra in Western Australia in early 2001 (identification was confirmed by Dr Roger Shivas). A successful eradication campaign was conducted - all bananas at the original detection site at Kulumburu and on all neighbouring properties were destroyed. In 2001, an extensive survey in the Northern Territory recorded freckle from a number of locations but it was not detected on any Cavendish bananas (Conde, 2001).

Biology

Description of organism

The pycnidial stage of the fungus (P. musarum) is usually present on the host. Van der Aa (1973) found the pycnidia in herbarium specimens from India, Indonesia and the Philippines were 60-170µm (usually 135µm) in diameter, globose, brown to black and occur singly or in groups. Meredith (1968) reported less than five pycnidia in small spots and up to 70 in large spots. Conidia are one celled, obovoidal, ellipsoidal or short cylindrical with a truncated base, broadly rounded, apically and conspicuously indented. A distinctive apical appendage (6-8µm) is sometimes present (Jones, 2000). Conidia are usually 15-18µm × 9-10µm but can be 10-20µm × 7-13µm (Van der Aa, 1973). Conidia are surrounded by a 1-3µm thick gelatinous envelope and germinate after 12 hours to form lobed appressoria (15µm diameter) (Stover, 1972). Conidiogenous cells are cylindrical or conical and 4-11µm × 2.5-5µm in size (Van der Aa, 1973).

Perithecia are globose or somewhat depressed, 70-220µm in diameter and distinctly papillate. The walls consist of dark brown cells and are 1-2µm thick. Asci have eight ascospores, are clavate or cylindrical, usually with a short stalk and measure 35-85µm × 20-25µm. Ascospores are single celled, ovoid or oblong ovoid and 17-22 x 8-10µm in size. Spermatia have similar dimensions to pycnidia with a 20µm wide pore. Spermatia are aseptate, cylindrical or dumb-bell shaped and 6-10µm × 0.5-2µm in size (Van der Aa, 1973). The fungus grows very slowly on V8 juice agar, attaining a blackish coloured colony only 5mm in size after 2 months (Chuang, 1981).

Disease symptoms

Leaf symptoms

Two types of leaf spot symptoms have been described (Meredith, 1968). One consists of very small (<1mm) dark brown to black spots, mainly on the upper surface of the leaves, which give the leaf a sooty appearance. Numerous pycnidia develop and protrude slightly through the cuticle, which gives a rough/sand paper feel to the leaf surface. Spots can cluster in lines/streaks that may run diagonally or horizontally across the leaf. In other cases, the streaks run along the veins from midrib to the edge of the leaf. Yellowing of the leaf occurs where freckling is severe.

The second type of spotting as described by Meredith (1968) is characterised by relatively large, individual dark brown to black spots up to 4mm in diameter. The spots may have grey centres and can aggregate to form large blackened areas or streaks with yellowish/green haloes. Pycnidia are very prominent and raise the epidermis to give the diseased leaves a rough sandpaper feel. Severely affected leaves yellow, wither and die prematurely (Meredith, 1968). Spots also form on petioles and midribs usually on the concave, adaxial surface. The transition/spade leaf and bracts can also be affected frequently with abundant pycnidia. Larger spots mainly occur in vigorous plants, whereas the small ones occur on less vigorous plants (Meredith, 1968).
Meredith (1968) indicated that although freckle is restricted to the older leaves it might hasten death and collapse of these leaves. In Taiwan the longevity of freckle affected leaves is reported to be half that of healthy leaves (Chuang, 1984).

**Fruit symptoms**

Fruit are susceptible to infection by *Guignardia musae* from emergence (Meredith, 1968) but Chaung (1984) claims susceptibility of both leaves and fruit increases with age. A few widely scattered spots or occasionally dense aggregates can occur as early as 2-4 weeks after bunch emergence. On green fruit, individual spots first appear as minute, reddish-brown flecks, surrounded by a halo of dark green water-soaked tissue up to 2mm in size. Secondary infections occur resulting in large areas of the peduncle and fruit surface becomes black from the dense aggregation of spots. The severity of the disease increases as the fruit matures. Freckle is particularly severe where the fruit is in contact with or adjacent to diseased leaves. During ripening, the individual spots are surrounded by a halo of green tissue up to 3mm in diameter. Although this discoloration detracts from the appearance of the fruit, eating qualities are not affected (Meredith, 1968).

Fruit spots are mainly a concentration of pycnidia. Consumers in Asia and the Pacific tolerate these blemishes in the local markets. However, disconcerting buyers in Japan and other areas do not tolerate the blemishes and therefore the disease is a problem for the export industries in Taiwan and the Philippines (Jones, 2000).

**Epidemiology**

Ascospores are discharged from the perithecia, but the significance of these spores in the disease cycle is unclear. Conidia are exuded from the pycnidia en masse as white gelatinous tendrils during wet conditions, including heavy dews. Conidia are the major cause of infection (Jones, 2000).

In the tendrils, the conidia adhere to each other as a mucilaginous sheath surrounds each conidium. However, in water the mucilaginous sheath disintegrates and the conidia readily separate. Water is essential in the dispersal of the conidia, which collect in the droplets of water (up to $10^6$ conidia/ml). The conidia are disseminated with the water droplets, which frequently run across the leaf or fruit surface resulting in the streaks of infection (pycnidia). The main source of inoculum is diseased leaves and fruit. Water (rain/dew) picks up the spores on the diseased tissues and deposits them on the younger leaves or fruit. Secondary infection is common near pycnidia leading to an increase in disease intensity. On leaves, continuous day-to-day infection results in an overlap of lesions, resulting in extensive dead areas of tissue (Meredith, 1968).

No study on the temperature or moisture requirements of the organism was located. However water is essential for the dissemination of conidia and moisture is needed for germination and infection (Chuang, 1984). No data on temperature requirements were located, but Meredith (1968) used 24°C during his studies on infection suggesting it was or was close to the optimum temperature.

**Infection**

Meredith (1968) showed that the infection process at 24°C on immature dwarf Cavendish fruit (AAA, Cavendish subgroup) was:

- Spore germination commences after 2 to 3 hours.
- After 12 hours a lateral swelling forms on the side of the spore and the cell contents move into the swelling to form an irregular, hyaline appressorium.
• After 18 to 30 hours, the appressorium is distinct, being light to dark grey in colour, variously lobed with a thickened wall and separated from the spore by a septum.
• Most appressoria are formed in depressions between adjacent epidermal cells.
• Penetration is thought to occur after 24 to 72 hours when single epidermal cells become reddish brown in colour. There is no evidence of infection via stomatal cells.
• After 96 hours more than 60% of appressoria are associated with discoloured host cells. This response is more rapid when the density of appressoria is high.
• A fine penetration hyphae from the under side of the appressoria enters the epidermal cell and swells to 3 to 5µm.
• The surrounding tissue is subsequently invaded by cell-to-cell penetration and by inter-cellular hyphae.
• Lesions are relatively superficial and necrosis rarely extends beyond the fifth layer of cells below the epidermis.
• Pycnidia can develop as early as 3 weeks after inoculation.
• In Taiwan, Chaung (1984) showed:
  - The incubation period varies from 20 days (warm, wet conditions) to 60 days (cool, dry conditions).
  - Susceptibility of fruit and leaves increases with age.
  - Pycnidia develop in lesions of all sizes, some as small as five dead cells.
  - A film of water on the surface is required for 12 to 48 hours for infection to occur.

**Strains of Organism**

Ability to attack various banana lines, in particular the AAA, Cavendish subgroup and the ABB line Bluggoe, suggest more than one type/strain of the banana pathogen recorded as *Guignardia musae* may exist. Jones (2000) indicated that two strains of *P. musarum* might exist. One that attacks Bluggoe but not Cavendish (Australia and South Pacific) and the other that attacks Cavendish and not Bluggoe (Hawaii). However, there appears to be a third strain in the South and South-East Asia region that attacks all lines as reported by Jones and Daniells (1988), Jones (1993) and Jones (1994a).

Research is needed to clarify if the various strains can be distinguished taxonomically on morphological or molecular grounds. This would determine if there are more than one species involved or if there are two different races of the same pathogen. Also, it would indicate if the two types of symptoms are also linked to taxonomic differences (Jones, 2000).

An examination is also needed on the disease found in Africa and the Caribbean to determine if the pathogens in that area fit van der Aa’s description of *G. musae*.

**Spread of freckle**

The risk of long distance aerial spread by conidia is low as water is necessary to disperse the conidia from the tendrils and spread would largely be limited to the spread of the water droplets. Little is known about the dispersal of ascospores and the role of these spores in the epidemiology of the disease. However, it is assumed that the ascospores would be aerially spread (Jones, 2000).
No documentation on the role of infected fruit in the long distance spread was located. However, movement of infected fruit with symptoms or with latent infections maybe an ideal means for the spread of the organism.

**Host reaction**

Table 34 provides an indication of the recorded reaction of host banana strains to freckle disease.

### Table 34  Recorded reaction of banana cultivars to freckle

<table>
<thead>
<tr>
<th>Banana Line</th>
<th>Reaction to freckle</th>
<th>Hawaii*</th>
<th>Australia and South Pacific#</th>
<th>South and South-East Asia¤</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wild species</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Musa acuminata</em> ssp. <em>banksii</em></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Musa schizocarpa</em></td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hybrids of these species</strong></td>
<td>S (severe)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Musa balbisiana</em></td>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sucrier</td>
<td>R*</td>
<td></td>
<td>S (less)</td>
<td></td>
</tr>
<tr>
<td>Pisang Lilum</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Inarnibal</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>Pisang Jari Buaya</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td><strong>AAA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dwarf Cavendish</td>
<td>S</td>
<td>R</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Giant Cavendish</td>
<td>S</td>
<td>R</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Robusta</td>
<td>S</td>
<td></td>
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<td></td>
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<tr>
<td>Pisang Masak Hijau</td>
<td>S</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Gros Michel</td>
<td>R</td>
<td></td>
<td>S (less)</td>
<td></td>
</tr>
<tr>
<td>Cocos</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red and Green Dacca</td>
<td>R</td>
<td></td>
<td>S (less)</td>
<td></td>
</tr>
<tr>
<td>Banana Line</td>
<td>Hawaii*</td>
<td>Australia and South Pacific#</td>
<td>South and South-East Asia¤</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Iholena</td>
<td>R</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lakatan</td>
<td>S</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisang Nangka</td>
<td>S (less)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**AAB**

<table>
<thead>
<tr>
<th>Banana Line</th>
<th>Hawaii*</th>
<th>Australia and South Pacific#</th>
<th>South and South-East Asia¤</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horn Plantain</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>French Plantains</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pome</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Silk</td>
<td>S</td>
<td>S</td>
<td></td>
</tr>
<tr>
<td>Rajapuri</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Walha</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maia Maoli</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Popoulu</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iho-u</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eslesno</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Father Leonore</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Huamoa</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mysore</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pisang Raja</td>
<td>S (less)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ABB**

<table>
<thead>
<tr>
<th>Banana Line</th>
<th>Hawaii*</th>
<th>Australia and South Pacific#</th>
<th>South and South-East Asia¤</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bluggoe</td>
<td>R</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Monthan</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ice Cream</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blue Java (Ney Mannan)</td>
<td>R?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saba</td>
<td></td>
<td></td>
<td>S</td>
</tr>
<tr>
<td>Pisang Awak (Ducasse)</td>
<td></td>
<td></td>
<td>S</td>
</tr>
<tr>
<td>Pelipita</td>
<td></td>
<td></td>
<td>S</td>
</tr>
</tbody>
</table>
**Reaction to freckle**

<table>
<thead>
<tr>
<th>Banana Line</th>
<th>Hawaii*</th>
<th>Australia and South Pacific#</th>
<th>South and South-East Asia¤</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kluai Teparot</td>
<td></td>
<td>R</td>
<td>S</td>
</tr>
</tbody>
</table>

* Meredith (1968)
# Jones (2000)
¤ Jones and Daniells (1988); Jones (1993) and Jones (1994a)
R Resistant
S Susceptible

**Black Sigatoka**

**Scientific name**


**Synonym(s)**


**Common name(s)**

Black Leaf Streak (BLS) (Rhodes, 1964); Black Sigatoka (Pref, BS) (Stover, 1974),

[Black leaf streak has priority but black Sigatoka is the commonly used name in most banana areas.]

**Host(s)**

Banana (Rhodes, 1964; Meredith and Lawrence, 1969).

Advanced symptoms of black Sigatoka caused by *Mycosphaerella fijiensis* have been recorded on cultivars in the *Eumusa* series of edible banana and the wild banana species, *Musa balbisiana* (saba banana) and *Musa acuminata* (banana) (subsp. *banksii* and subsp. *zebrina*). The disease does not affect *Musa textiles* (abaca) or *Ensete ventricosum* (ornamental banana) (enset) (Gauhl, 1994). Banana cultivars differ in their reaction to the pathogen. Many cultivars are susceptible, but some show varying degrees of resistance from slow lesion development to a hypersensitive-like response.
to infection. Most wild species that have been tested are infected, but invasion is usually halted at a very early stage in a hypersensitive-like response (Carlier et al., 2000).

**Plant part(s) affected**
Leaves.

**Distribution**
The following distribution has been extracted from CABI (2002):

American Samoa; Australia [restricted distribution in Queensland]; Belize; Benin; Bhutan; Bolivia; Brazil; Burundi; Cameroon; Central African Republic; China; Colombia; Comoros; Congo Democratic Republic; Congo; Cook Islands; Costa Rica; Côte d'Ivoire; Cuba; Dominican Republic; Ecuador; El Salvador; Florida; Fujian; Gabon; Ghana; Guangdong; Guatemala; Guinea-Bissau; Guyana; Haiti; Honduras; Hainan; Hawaii; Jamaica; Java; Kalimantan; Kenya; Malawi; Mexico; Federated states of Micronesia; Moluccas; Netherlands Antilles; New Caledonia; Nicaragua; Niger; Nigeria; Norfolk Island; Northern Mariana Islands; Panama; Papua New Guinea; Peninsular Malaysia; Peru; Philippines; Rwanda; Samoa; Sarawak; Singapore [absent, reported but not confirmed]; Solomon Islands; Sumatra; Taiwan; Tanzania; Thailand; Togo; Tonga; Uganda; Vanuatu; Venezuela; Vietnam; Wallis and Futuna Islands; Yunnan (IMI, 1997; EPPO, 1999); Zambia (IMI, 1997); Zanzibar.

Black Sigatoka was recorded on the Philippine Island of Luzon in 1964 (Hapitan and Reyes, 1970) and Mindanao in 1965 (Timm, 1965). It is now widespread in most areas (Anonymous, 1994a; Jones and Daniells, 1988).

In Australia black Sigatoka is endemic in the Torres Strait area between the Australian mainland and Papua New Guinea. The organism has been detected in the Cape York area on eight occasions over the last 20 years and each finding has been eradicated. Black Sigatoka was found in the production area at Tully in April 2001 and an eradication program commenced in August 2001. Black Sigatoka has not been detected in any commercial plantation in the Tully Banana Production Area since despite a very intensive surveillance program (every second row on every plantation at 4-6 week intervals). All commercial properties in the adjoining banana areas of Innisfail and Kennedy were surveyed and no black Sigatoka was detected outside the Tully banana production area. It was found on four unmanaged banana plants in the Tully banana production area in November 2001. All land parcels in the area have since been visited and all unmanaged plants destroyed. Black Sigatoka has not been detected since.

**Biology**

**Description of organism**

*Mycosphaerella fijiensis* and *M. musicola* are morphologically very similar, especially the sexual stages (Meredith and Lawrence, 1969; Meredith and Lawrence, 1970; Mulder and Stover, 1976; Meredith and Lawrence, 1969) and separation into two fungi has been questioned (Graham, 1968; Meredith, 1970). However studies using restriction fragment length polymorphism (RFLP) techniques (Carlier et al., 2000) and sequence analysis of the internal transcribed spacer (ITS) region of nuclear ribosomal DNA (Johanson and Jeger, 1993) support the classification of the two pathogens as separate species.
**Conidiophores**

Conidiophores first develop in the initial flecks or streaks but most are produced from the early spot stage on the lower surface of the leaf and continue to be produced until spots mature. They emerge singly or in diverging fascicles of 2-8 from stroma on the lower surface of the leaf within the boundary of the lesion; few arise on the upper surface. Conidiophores are pale to medium olivaceous-brown, becoming slightly paler towards the tip. They are straight or bent, often with geniculations and sometimes with a basal swelling up to 8 µm in diameter, 0- to 5-septate, 16.5-62.5 x 4-7 µm, usually slightly narrower, but occasionally wider, at the tip. One or more scars are present near the tip of the conidiophore, either flat against the apex or on the side, or on a slightly sloping shoulder.

**Conidia**

Conidia are formed singly at the apex of the conidiophore, later becoming lateral as the conidiophore develops. Up to four mature conidia may be attached to a single conidiophore. Conidia are not quite colourless, being pale-green or olivaceous. They are obclavate to cylindro-obclavate, 1- to 10-septate (commonly 5- to 7-septate), straight or curved, obtuse at the apex, truncate or rounded at the base with a visible and slightly thickened hilum, 30-132 x 2.5-5 µm, the broadest point being near the base.

**Spermogonia**

Spermogonia develop at the stage when streaks develop into spots and are more abundant on the lower surface of the leaf, being consistently associated with conidiophores. Spermogonia are hourglass shaped, oval or almost globose and measure 55-88 x 35-50 µm. The ostiole is slightly prominent and protrudes through the stoma pore. Many hyaline, rod-shaped spermatia, 2.5-5.0 x 1.0-2.5 µm, are found in mature spermogonia.

**Ascomata and Asci**

Ascomata are perithecial, globose, 47-85 µm in diameter. They are immersed in the leaf tissue with protruding ostioles and are found on both leaf surfaces, although more abundant on the upper. Asci are numerous, obclavate, bitunicate and 8-spored; paraphyses are lacking. Ascospores are unequally 1-septate and slightly constricted at the septum, the longer cell being uppermost in the ascus. They are hyaline, biserrate, fusiform, 11.5-16.5 x 2.5-5.0 µm.

**Colony Morphology**

Colonies on potato dextrose agar are slow growing, compact but with a velvety surface, prominently raised, grey to pale-buff or olive-green, black in reverse (Mulder and Halliday, 1974). On Mycophyl agar, colonies are dark-grey or grey-brown with a crenate edge or pale-grey to pink (Stover, 1976). Conidia can be produced in culture for use in inoculation experiments. Mourichon et al. (1987) used colonies growing on modified V8 juice agar at 25°C under continuous light as a source of conidia.

**Disease symptoms**

The first visible symptoms of black Sigatoka are faint, minute, reddish-brown specks on the lower surface of the leaf. Specks elongate, becoming slightly wider, to form a characteristic narrow,
reddish-brown streak with dimensions of 20 x 2 mm with the long axis parallel to leaf veins. Streaks frequently overlap to form compound streaks. The colour of streaks, which are now clearly visible on the upper leaf surface, changes to dark brown, almost black. The entire leaf can blacken at this stage if streaks are numerous. If less densely congregated, streaks broaden and become fusiform or elliptical spots. Water-soaked borders appear around spots and surrounding leaf tissue yellows slightly. The centres of spots become slightly depressed and dry out, becoming light grey or buff. Each spot has a well-defined, narrow dark brown or black border and surrounding tissue is often yellow. Whole sections of leaves can become necrotic as spots coalesce. After the leaf has withered, spots remain visible because of their light-coloured centres. Different stages of disease development have been identified (Meredith and Lawrence, 1969; Fouré, 1987). Often, all stages of disease development can be seen on one leaf.

If inoculum pressure is high, leaves are rapidly destroyed. Often, fewer than six living leaves may be seen on a susceptible plant that is growing vegetatively. On resistant cultivars, symptoms are only usually seen on the older, lower leaves. The disease is more severe on plants with bunches because new leaves are no longer being produced to replace those lost due to disease. If disease pressure is great, it is not uncommon for a susceptible cultivar to have no viable leaves before the bunch has matured.

**Epidemiology**

The period between infection and the formation of mature spots depends on the resistance or susceptibility of the cultivar, intensity of infection and environmental conditions. Infection is believed to occur as a new leaf emerges from the pseudostem and unfurls. If the cultivar is susceptible, initial specks may appear on the second and third open leaves of a growing plant, streaks on the third and fourth leaves and both spots and streaks on older leaves. If a cultivar has resistance, streaks and spots may only be seen on the very oldest leaves. In some highly resistant cultivars, specks develop quite rapidly in response to infection, but there is no further disease development. Some authors believe that in these cases, the speck may represent a hypersensitive-like reaction (Carlier et al., 2000).

Conidia are formed in lesions and spread the infection to other leaves on the same plant or to adjacent plants. They are dislodged from conidiophores by water and to a lesser degree by wind (Stover, 1980). Germination occurs in water and the leaf is penetrated through stomata. Ascospores contribute to most of the inoculum and can spread the disease further distances than conidia. They are forcibly discharged when the leaf is wet and can be carried many kilometres in air currents (Stover, 1980). However, recent studies suggest that ascospores are susceptible to UV radiation that may prevent spread over very long distances (Parnell et al., 1998). Ascospores also germinate in moisture and infect leaves through stomata. Both conidia and ascospores can germinate within 2-3 hours, but stomata are not usually penetrated until after 48-72 hours of humidity at or near saturation, and at temperatures above 26°C. The process is slower at lower temperatures. After infection, hyphae emerge from the stomata and grow across the surface and infect adjacent stomata. Streaks usually appear first near the leaf apex and along the leaf margin which is indicative of infection by ascospores (Meredith, 1970). Spotting can develop on the third or fourth fully opened leaf of a susceptible, vegetatively growing plant (Stover, 1980).

Populations of *M. fijiensis* maintain a high level of genetic diversity and it is speculated that pathogenic variability is, therefore, also likely to exist (Carlier et al., 2000). Isolates of the pathogen from different locations in Papua New Guinea and elsewhere have in fact been found to vary in their pathogenicity in glasshouse screening tests using differential *Musa* genotypes.
Isolates have also been shown to vary in aggressiveness (Jacome and Schuh, 1993; Romero and Sutton, 1997).

The black Sigatoka pathogen is well suited for the environmental conditions prevailing in wet tropical coastal regions and can replace *M. musicola*, the pathogen that causes Sigatoka or yellow Sigatoka. This occurred within 2-3 years in Honduras and in less than 5 years in Costa Rica. Lesion expansion and ascospore production is greater for *M. fijiensis* and this has probably given it a competitive advantage over *M. musicola*. However, the situation is different at higher altitudes, as *M. musicola* seems more suited to cooler environments. Records showing that black Sigatoka is gradually becoming dominant at higher and higher altitudes suggest that *M. fijiensis* may be slowly adapting to cooler temperatures (Carlier *et al.*, 2000).

In South-East Asia, *M. fijiensis* was recorded as present in Indonesia, West Malaysia and Thailand in the 1960s, but it has not become the dominant leaf spot pathogen. Other diseases such as Septoria leaf spot appear to be common and widespread in West Malaysia and Thailand and in these countries the causal agents may be out competing *M. fijiensis*. In Java, its lack of dominance over *M. musicola* is harder to explain, but may be related to environmental factors and the great genetic diversity of banana cultivars which are mainly grown in mixed plantings.

**Spread of Black Sigatoka**

Black Sigatoka can be disseminated by dispersed conidia and ascospores as well as by non-dispersed spores in/on leaf material. Spread via conidia is limited to other leaves on same plant or to adjacent plants (Stover, 1980). Ascospores can spread the disease further in air currents than conidia but spread over long distances may be limited due to the susceptibility of the ascospores to UV radiation (Parnell *et al.*, 1998).

Ascospores have been detected on the surface of mature fruit (10000/fruit) in Brazil (Gasparotto *et al.*, 2000) and Costa Rica (Gauhl, 1994). The survival of these spores however is unknown. Ascospores germinate at >95% RH and conidia above 92% RH. Ascospores can survive exposure to sunlight for up to 5 hours (Fulton 1961, unpublished, cited by Campbell, 1926) and temperatures of 40ºC for 24 hours (Frossard, 1962). It would therefore be expected that some ascospores would survive for extended periods on any surface at moderate levels of humidity (70-90%) and temperatures (13-30ºC) as would occur on the surface of fruit in cartons during transport. Dispersal potential of these spores on the fruit surface to banana leaves is unknown.

Ascospores can survive for periods up to 20 weeks in necrotic leaf material (Stover, 1980, Peterson *et al.*, 1998) and therefore can be dispersed in leaf trash with fruit, on suckers or as contaminants over very long distances. Spread of black Sigatoka into Jamaica is considered to have occurred on/with cartons of fruit from Costa Rica (J Cowie Jamaica, in Peterson, 2001).

**Panama disease**

**Scientific name**

*Fusarium oxysporum* f. sp. *cubense* (E.F. Smith) Snyder and Hansen [anamorph] (Foc).

[Order: Hypocreales; Family: Hypocreaceae]
Synonym(s)
None of recent significance.

Common name(s)
Fusarium wilt of banana (Pref.); Panama; Panama disease of banana.

Hosts
Bananas (*Musa* spp.) are the only known hosts of *F. oxysporum* f. sp. *cubense* in which a disease occurs and on which large populations develop (Allen, 1999). *Heliconia* spp. are also affected (Ploetz and Pegg, 2000). The fungus can also inhabit the root surface of several plant species without causing disease; the populations on alternative hosts are very low and not easy to detect, but persist almost indefinitely (Allen, 1999).

Three species of grass (*Paspalum fasciculatum* (grass), *Panicum purpurascens* (*Brachiaria mutica*) (para grass) and *Ixophorus unisetus* (pitiillo grass) and *Commelina diffusa* (spreading day flower) (Commelinaceae) may serve as alternative hosts (Waite and Dunlap, 1953). The wild banana *Musa balbisiana* has shown susceptibility in the seedling stage, but mature plants are resistant (Vakili, 1965).

Plant part(s) affected
Roots, rhizome and pseudostem. Leaf, bell (flower bud) and peduncle (stalk) tissue can be systemically infected with *F. oxysporum* f sp. *cubense* when the disease is in an advanced stage; the edible part of the fruit tissue does not become infected with *F. oxysporum* f sp. *cubense* but it is possible that remnants of bunch stem (cushion) left on hands of fruit maybe infested.

Distribution
The disease is found in virtually all areas where banana is grown except in some islands of the South Pacific, parts of Melanesia, countries around the Mediterranean Sea and Somalia (Ploetz, 1998; Ploetz and Pegg, 2000). Fusarium wilt is thought to have originated in South-East Asia but the first description was in Australia in 1876, followed soon after by reports from tropical America (Costa Rica and Panama) in 1890. There was a dramatic increase in the number of new records in the early 1900s, most of which described damage in export plantations.

Four vegetative compatibility groups (VCG; refer section on Physiologic Races and Vegetative Compatibility Groups) have been recognised in Queensland, namely, VCG's 0124 and 0125 (Race 1) and VCG's 0120 and 0129 (Sub-tropical Race 4). Outbreaks in Cavendish banana caused by ‘Sub-tropical Race 4’ have been successfully contained to an area in south-eastern Queensland known as the “Special quarantine area”.

Tropical Race 4 has been found at three properties within 100 km of Darwin in the Northern Territory. Race 1 has also been confirmed in the Carnarvon district of Western Australia but has not been detected for over 10 years (McKirdy, 2002).
The characteristic internal symptom of Fusarium wilt is reddish to dark brown discolouration of the host's vascular system. These internal symptoms appear first in the feeder roots, the initial sites of infection, and progress to the rhizome where they are most pronounced where the stele joins the cortex. Eventually the pseudostem is colonized, in which symptoms are often evident as faint brown streaks or flecks in outer portions of older leaf sheaths.

The first external symptoms of Fusarium wilt in banana are a yellowing of the oldest leaves or a longitudinal splitting of the lower portion of the outer leaf sheaths on the pseudostem. This is followed by a wilt and collapse of leaves at the petiole base; in some cases these leaves remain green. As the disease progresses, younger and younger leaves collapse until the entire canopy consists of dead or dying leaves; by which time, a pronounced, red-brown discolouration of the vascular tissues is usually seen if the pseudostem is cut.

The expression of disease is affected by environmental stress on plant growth or by poor water relations. Symptoms may appear when host growth resumes after winter chilling or as soil dries out after prolonged saturation. The pathogen can develop insidiously and spread undetected in apparently healthy plantations until these stress factors occur, causing external symptoms to manifest.

The yellowing symptoms of Fusarium wilt are easy to distinguish in the field. Very early symptoms are more difficult for the untrained eye to detect. Proof of Fusarium wilt is vascular discoloration in the lower pseudostem or in the rhizome. Where both Fusarium wilt and Moko disease caused by Ralstonia solanacearum Race 2 occur in the same plantation it is possible to confuse the two diseases. External symptoms of F. oxysporum f. sp. cubense infection do not usually develop on plants and suckers that are less than about 4 months old, whereas plants that are affected by Moko disease will wilt and become chlorotic at a very early stage of development. The first symptoms of Moko on rapidly growing plants are the chlorosis, yellowing and collapse of the three youngest leaves, not the older leaves as with Fusarium wilt. Also, the vascular discoloration is concentrated near the centre of the pseudostem with Moko and is not found peripherally, which is common with Fusarium wilt. The two can be distinguished if the plant has fruit. Fusarium wilt does not affect fruit, but Moko causes a premature ripening of infected fingers and an internal dry rot symptom clearly visible if the fruit is cut (CABI, 2002).

F. oxysporum f. sp. cubense is a soil-inhabiting fungal organism characterised by a filamentous mycelium from which macroconidia, microconidia and chlamydospores are produced by vegetative processes. No sexually produced spore stages are known for this species. Mycelium is typically associated with a suitable substrate such as a plant root or decomposing organic matter. However, the three spore types can be spread and survive independently of the fungal mycelium. Chlamydospores are produced typically in host tissue and have potential for long-term survival for years in the absence of host or substrate. Conidial forms are produced in or on host tissue and have potential for local spread, but do not survive for more than a few weeks except when stored under specialised conditions. The fungus is also able to colonize and persist in the roots of alternative hosts, including close relatives of the banana and several species of grasses and a weed (Commelina diffusa), even though these plants remain symptomless under field conditions.

Infection of plants occurs by mycelial invasion of root systems, particularly at points of injury. The mycelium penetrates to the xylem vessels where it advances by producing microconidia and spreading systemically. A wilting disease is induced both as a result of occlusion of xylem vessels and a host reaction to fungal metabolites. Microconidial concentrations in xylem tissue may be in
the order of one billion/kg; in soil associated with infested banana plants the concentration of spores may be in the order of ten thousand/kg (Allen, 1999).

*F. oxysporum* f. sp. *cubense* is most frequently spread locally, nationally and internationally in infected rhizomes or suckers and attached soil. Since these propagation materials are usually symptomless when infected, producers often unknowingly move the pathogen within and among plantations. The pathogen also moves within root systems of interconnected matts, running water, and on infested tools and machinery (Ploetz, 1998). Work in the early export plantations indicated that susceptible clones could not be successfully replanted in an infested site for up to 30 years, because of the long-term survival of *F. oxysporum* f. sp. *cubense* in soil and as a parasite of non-host weed species (Ploetz and Pegg, 2000). Spread of conidia in air, aerosols and dust clouds may be possible but has not been demonstrated under natural conditions for bananas. From an isolated point of introduction in a disease-free plantation, the fungus will spread slowly from plant to plant. However, if spores are carried in surface run-off water or contaminate an irrigation reservoir, the disease can spread rapidly, decimating a plantation within months if conditions are favourable.

Physiologic Races and Vegetative Compatibility Groups: Four Races of *F. oxysporum* f. sp. *cubense* are recognised, distinguished by differences in host preference and pathogenicity as shown in susceptibility of various species and clones to different Races of the fungus (Ploetz and Pegg, 2000).

<table>
<thead>
<tr>
<th>Race</th>
<th>Susceptible species and clones</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Musa textilis</em> (abaca), 'Gros Michel' (AAA), Maqueno (AAB, Maia Maoli-Popoulu subgroup), 'Silk' (AAB), Pome subgroup (AAB), 'Pisang Awak' (ABB), '1.C.2' (bred AAAAA)</td>
</tr>
<tr>
<td>2</td>
<td>'Bluggoe' (ABB), bred AAAAs</td>
</tr>
<tr>
<td>3</td>
<td><em>Heliconia caribe</em>, <em>H. chartacea</em>, <em>H. crassa</em>, <em>H. collinsiana</em>, <em>H. latispatha</em>, <em>H. mariae</em>, <em>H. rostrata</em>, <em>H. vellerigera</em>, <em>M. balbisiana</em> (seedlings), <em>'Gros Michel'</em> (AAA)</td>
</tr>
<tr>
<td>4</td>
<td>Cultivars in the AAA Cavendish subgroup (except 'Dwarf Parfitt') in the subtropics, plus cultivars susceptible to Race 1 and Race 2. Race 4 in the tropics (T4) also attacks 'Sucrerie' (AA) and 'Lakatan' (AAA)</td>
</tr>
</tbody>
</table>

* Waite (1963), indicated that seedlings of *M. balbisiana* and “Gros Michel” were slightly susceptible to Race 3

Race 1 was responsible for the epidemics on “Gros Michel” and other species and clones; Race 2 affects ABB cooking bananas such as “Bluggoe” (ABB) and some bred AAAA tetraploids. Race 3 was reported to affect *Heliconia* spp. and was weakly pathogenic on “Gros Michel” and seedlings of *M. balbisiana* (Waite, 1963).

However, Fusarium wilt on Heliconia has not been reported since Waite's work more than 30 years ago, and the disease has not been found again in recent surveys of parts of Central America where Waite reported finding the disease. Race 4 affects Race 1- and Race 2- susceptible clones in addition to the Cavendish cultivars. Before recent outbreaks in South-East Asia, Cavendish clones had only been affected in the subtropical production areas in the Canary Islands, South Africa, Taiwan and Australia, where cold winter temperatures are presumed to predispose Cavendish to damage that would not normally develop.
A unique population of the pathogen, VCG 01213/16, is responsible for the affected Cavendish monocultures in tropical South-East Asia (Pegg et al., 1994; Ploetz, 1994; Bentley et al., 1998). More work is needed to clarify the Race structure in *F. oxysporum* f. sp. *cubense*; in addition to Tropical Race 4 there are other situations which suggest that more than the current four races exist (Ploetz, 1994).

Outbreaks of Panama disease have been managed in Queensland for more than 100 years and much has been learned particularly in the past 20 years about the strains of the fungus occurring in Australia and their management. Four VCG's have been recognised in Queensland, VCG's 0124 and 0125 (Race 1) that attack Lady Finger but not Cavendish, and VCG's 0120 and 0129 (Sub-tropical Race 4) which attack Cavendish as well as Lady Finger.

Outbreaks in Cavendish bananas discovered in 1978 have been successfully managed by controls on the movement of planting material and encouragement of growers to limit the transfer of soil between banana farms. Panama disease caused by *F. oxysporum* f. sp. *cubense* VCG 01213/16 (Tropical Race 4) was recognised in Indonesia and Malaysia in 1996, where it was associated with devastating losses in Cavendish banana plantations. The same disease has now been found on a small number of properties within 100 km of Darwin in the Northern Territory, where it also had a severe impact on Cavendish bananas. The origin of the disease around Darwin is not known. This strain of the pathogen is not known to occur elsewhere in Australia. Spread of this disease to other production areas would prevent commercial production of Cavendish and perhaps most other banana cultivars until a suitable disease resistant cultivar, which does not exist at present, is found as a replacement. The use of resistant genotypes is the best way to combat this disease. Resistant cultivars exist for several different kinds of banana (Buddenhagen, 1990) and these should be used when they are available. In other situations, new hybrids could be used to replace susceptible clones. Jones (1994b) has reviewed recent progress in breeding disease-resistant banana hybrids.

**ARTHROPODS**

**Fruit flies**

**Scientific name**

*Bactrocera dorsalis* (Hendel) species complex

Note: *Bactrocera occipitalis* (Bezzi) and *B. philippinensis* Drew & Hancock both belong to the oriental fruit fly *Bactrocera dorsalis* (Hendel) species complex, which was revised by Drew and Hancock (1994) who provided a key to all 52 Oriental Region species

*Bactrocera occipitalis* (Bezzi) [Order: Diptera; Family: Tephritidae]

*Bactrocera philippinensis* Drew & Hancock [Order: Diptera; Family: Tephritidae]

**Synonym(s)**

*Bactrocera occipitalis*: *Chaetodacus ferrugineus* var. *occipitalis* Bezzi, *Dacus (strumeta) dorsalis* var. *occipitalis* (Bezzi), *Dacus (strumeta) occipitalis* (Bezzi), *Bactrocera (Bactrocera) occipitalis* (Bezzi)
**Bactrocera philippinensis**: none.

**Common name(s)**

*Bactrocera occipitalis*: fruit fly

*Bactrocera philippinensis*: Philippine fruit fly

**Host(s)**

*Bactrocera occipitalis*: *Averrhoa carambola* (carambola), *Citrus reticulata* (mandarin), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Psidium guajava* (guava) and *Spondias purpurea* (Spanish prune) (Drew and Hancock, 1994; CABI, 2002). There is no published record of this species on banana. However, there has been no host plant survey of fruit fly in the Philippines (Drew, 2002).


There is no published record of *B. philippinensis* on banana. However, the Philippines have not been the focus of a major fruit fly survey in the same manner as Malaysia and Thailand, and so the extent to which other fruit crops are attacked is uncertain (CABI, 2002). *B. philippinensis* is closely related to *B. papayae* Drew and Hancock which is a serious pest of banana in Malaysia (Drew, 2002).

**Plant part(s) affected**

Fruit (Drew and Hancock, 1994).

**Distribution**

Both species are found in the Philippines and *B. occipitalis* also occurs in Borneo (Drew and Hancock, 1994).

*B. philippinensis* was detected on mainland Australia near Darwin on 21 November 1997, but was eradicated in 1999 (CSIRO-AFFA, 2001).

**Biology**

These two species are typical dacine fruit fly of the Oriental fruit fly complex: adult body length about 7-8 mm, wing length about 6 mm; body colour reddish-brown (fulvous) with darker markings; wings clear with dark bands on parts of wing. Drew and Hancock (1994) provided a detailed description of their diagnostic characteristics.

Specific biological details are not available for *B. occipitalis* and *B. philippinensis*. CABI (2002) provides the following information for both species.

Eggs of related species are laid below the skin of the host fruit. These hatch within a day (although delayed up to 20 days in cool conditions) and the larvae feed for another 6–35 days, depending on
season. Pupariation is in the soil under the host plant for 10–12 days but may be delayed for up to 90 days in cool conditions. Adults occur throughout the year and begin mating after about 8–12 days, and may live 1–3 months, depending on temperature (up to 12 months in cool conditions). (Note: the shortest periods quoted above are likely to apply to the tropical species of *B. occipitalis* and *B. philippinensis* because *B. dorsalis* is the most temperate species of this complex.) Adult flight (50–100 km) and the transport of infected fruit are the major means of movement and dispersal to previously uninfested areas.

**Hard scales**

**Scientific name**

*Aspidiotus coryphae* Cockerell & Robinson [Order: Hemiptera; Family: Diaspididae]

*Aspidiotus excisus* Green [Order: Hemiptera; Family: Diaspididae]

**Synonym(s)**

*A. coryphae*: apparently none

*A. excisus*: Temnaspidiotus excisus (Green)

**Common name(s)**

Hard scales, armoured scales

**Host(s)**

*Aspidiotus coryphae* has been reported on *Corypha elata* (buri palm) and *Cocos nucifera* (coconut) (Munting, 1971). *A. excisus* has been reported on *Carica papaya* (paw paw), *Citrus aurantifolia* (acid lime), *Citrus* sp. and *Euphorbia* sp. (Williams and Watson, 1988). Both species were intercepted on the Philippine banana exported to Japan (Sugimoto, 1984) and *A. excisus* has been routinely intercepted on Philippines bananas exported to New Zealand.

**Plant part(s) affected:**

*A. destructor* affects leaves, stems, growing points, and fruits (CABI, 2002) and *A. coryphae* and *A. excisus* would have similar affect.

**Distribution:**

Both species are found in the Philippines (Sugimoto, 1994). *A. excisus* is also found in Sri Lanka, Papua New Guinea (Williams and Watson, 1988).

**Biology**

No published information on the biology of these species on banana could be identified. However, the biology of *A. coryphae* and *A. excisus* is probably similar to that of *A. destructor*. The
biological information presented below is for *A. destructor* on coconut and has been taken from CABI (2002) and information provided by Philippines Dept. Agriculture (2001).

The life cycle (egg to egg) of *A. destructor* typically lasts for 32–34 days, although it may extend to 44 days. In one study the life cycle was found to be 32 days for females and 27 days for males. The larvae and the adult males are the only mobile stages during the life cycle.

The scale cover of the adult female is oval to circular, 1.5-2.0 mm across, fairly flat, very thin and translucent. The pale yellow exuviae are more or less central on the scale. The yellow adult female under the scale is 0.6-1.1 mm long. The eggs of *A. destructor* are laid under the scale of the adult female. The female deposits 20–50 eggs under her scale over a few days. The eggs are white when first laid and turn yellow after a few days. The eggs are incubated for 7–8 days. In the Philippines, on coconuts, the egg stage lasts for 8 days in both sexes. After hatching, the nymphs crawl under the scale edge out into the open and colonise the undersurface of the leaf.

The females have two nymphal stages. The males have four immature stages, first-instar nymph, second-instar nymph, pre-pupa and pupa.

The first-instar nymph (crawler) leaves the maternal scale and begins feeding on the leaves of the host. It is mobile in both sexes. Crawlers are found on the undersides of leaves and tender shoots and on leaf tips. They drop off the leaves easily and may be dispersed by the wind. Damage is reduced during the rainy season.

**Scientific name**

*Pinnaspis musae* Takagi [Hemiptera: Diaspididae]

**Synonym(s)**

Apparently none.

**Common name(s)**

Hard scales, armoured scales

**Host(s)**

Banana (Takagi, 1963; Sugimoto, 1994). No other published information could be obtained for this species. However, some other species of *Pinnaspis*, such as *P. strachani* (Cooley) are polyphagous and it is probable that *P. musae* would feed on plants other than banana.

**Plant part(s) affected**

The cogeneric species *P. strachani* is found on fruits, leaves, and stems of its host plants (CABI, 2002). *P. musae* would be similar.

**Distribution**

Philippines (Sugimoto, 1994).
Biology

Apparently, no published information on the biology of *P. musae* is available. The biology of a cogeneric species *P. buxi* (Bouche) on banana in Hawaii prepared by Tenbrink (2002) is presented below as a guide. This general information can apply to most species in the family Diaspididae.

Eggs of the armoured scales are laid under the armour of the female where they develop and hatch. The first stage after hatching is the only nymphal stage with legs, so the insects are called crawlers. Crawlers may stay under the maternal armour for several hours until outside conditions, especially temperature and humidity, are good. After they leave the cover, they wander for a period ranging from minutes to days, but usually a few hours. At the end of the wandering period they flatten against the leaf or stem and begin to secrete their armour. Newly settled nymphs insert their piercing, sucking mouthparts into plant tissue and start feeding on plant juices. Nymphs shed their exoskeletons twice as they grow and develop. The cast exoskeletons, called exuviae, are incorporated into the armour at the narrow end, forming a dot. The armour is non-living and is made of cast skins, threads, and liquid, all produced by the insect. Females remain under the armour in one place throughout their lives to feed and reproduce.

Since female armoured scales are not capable of wandering after they have settled and started feeding, long–range dispersal happens by passive transport of infested plant material. Short-range dispersal happens as crawlers search out places to settle and feed. It is the crawler stage that can be carried directly from place to place by people, animals, birds, ants, and wind currents. Wind is an agent of dispersal and also one of mortality, since crawlers dislodged by wind may not land on suitable host plants.

Mealybugs

Scientific name

*Dysmicoccus neobrevipes* Beardsley [Hemiptera: Pseudococcidae]

Synonym(s)

Not available.

Common name(s)

Annona mealybug, grey pineapple mealybug

Host(s)

The following host list was extracted from Beardsley (1959), Williams and Watson (1988), Ben-Dov (1994) and Ben-Dov et al. (2002).

*Acacia farnesiana* (huisache); *Acacia koa*; *Agave sisalana* (sisal); *Aglaonema treubii*; *Alpinia purpurata* (red ginger); *Ananas comosus* (pineapple); *Ananas sativus*; *Anonan muricate* (sour sop); *Anonan reticulata* (bullock’s heart); *Arachis hypogaea* (ground nut); *Artocarpus altilis* (bread fruit); *Barringtonia speciosa*; *Brassavola cordata* (orchid species); *Cajanus cajan* (pigeon pea); *Citrus aurantifolia*; *Citrus limon* (lemon); *Citrus sinensis* (sweet orange); *Clerodendrum*; *Coccoloba*; *Coccoloba uvifera* (sea grape); *Cocos nucifera* (coconut); *Codiaeum*; *Coffea arabica*
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(coffee); Coffea canephora (robusta coffee); Cordia alliodora (laurel); Crescentia alata (calabash tree); Cucurbita maxima (squash); Garcinia mangostana (mangosteen); Gossypium (cotton); Guettarda speciosa; Heliconia latispatha (“Golden Torch” heliconia); Lycopersicon esculentum (tomato); Machaerium robinifolium; Manilkara zapota (sapodilla); Messerschmidia argentea; Musa; Musa paradisiaca (banana); Nothopanax; Opuntia megacantha (cactus); Pandanus; Phaseolus (bean); Philodendron; Pipturus argentea; Piscidia piscipula; Polianthes tuberosa (tuberose); Punica granatum (pomegranate); Samanea saman (saman); Solanum melongena (egg plant); Tectona grandis (teak); Theobroma cacao (cocoa); Thespesia propulnea; Tournefortia argentea; Vigna sesquipedalis (asparagus bean); Yucca elephantipes; Zea mays (maize).

Plant part(s) affected

Developing fruit (pineapple) (Beardsley, 1993)

Aerial roots, flower, fruit, leaf and stem (Kessing and Mau, 1992).

Distribution

The following list on distribution was taken from Ben-Dov et al. (2002).

American Samoa; Antigua and Barbuda; Bahamas; Brazil; Colombia; Cook Islands; Costa Rica; Dominican Republic; Ecuador; El Salvador; Fiji; Guam; Guatemala; Haiti; Hawaiian Islands; Honduras; Jamaica; Kiribati; Marshall Islands; Mexico; Northern Mariana Islands; Panama; Peru; Philippines; Puerto Rico & Vieques Island (Puerto Rico); Sicily; Suriname; Trinidad and Tobago (Trinidad); U.S.; Vietnam; Virgin Islands; Western Samoa.

Note that Philippines Dept. Agriculture (2001) lists D. neobrevipes as occurring in Australia and cites Woodward et al. (1970) as evidence. However, D. neobrevipes is actually not listed anywhere in the book but D. brevipes (Cockerell) is listed as a pest of pineapple on page 430 of Woodward et al. (1970). In Hawaii, both D. brevipes and D. neobrevipes are reported to transmit pineapple wilt disease but only D. neobrevipes causes green spot on pineapple (Beardsley, 1965). Because green spotting was reported by Carter (1942) in Queensland, presumably, this is the basis on which Williams (1985), based on available specimens, reported only D. brevipes in his book on Australian mealybugs, the remarks under that species hint at a possible occurrence of D. neobrevipes in Australia”. This is actually not totally correct. Williams’ (1985: 118) exact statement reads “No specimens [of D. neobrevipes] have been found so far in Australia, despite the record by Carter, 1942 that green spotting occurs on pineapples in Queensland.” Williams (1985) then tried to explain why this may be the case using Beardsley’s (1965) work and the explanations are as follow. There are two forms of D. brevipes: one is a parthenogenetic form that transmits only pineapple wilt in Hawaii; the other is a bisexual (biparental) form that apparently causes green spotting in Brazil. Although all the specimens examined by Williams (1985) are female but the record of green spotting in Queensland leads him to suggest that the bisexual form may be there. It is clear that Williams’s (1985) explanation of the record of the presence of green spotting on pineapple in Queensland is due to the possible presence of the bisexual form of D. brevipes not the presence of the species D. neobrevipes. This explanation is enhanced by the fact that he examined numerous specimens of D. brevipes from Queensland, New South Wales, Western Australia and Northern Territory (see his material examined for details) and found no specimens of D. neobrevipes. In addition, Ben-Dov and German (2002) does not include Australia in the known
distribution of *D. neobrevipes*. These two species do co-exist in many instances in some countries but *D. brevipes* appears to be much more widespread (see lists of distribution for these two species in Ben-Dov and German, 2002) and many countries still do not have records of *D. neobrevipes* although *D. brevipes* has been reported there. Therefore, there is no evidence to support the contention that *D. neobrevipes* is present in Australia.

**Biology**

Philippines Dept. Agriculture (2001) states that *D. neobrevipes* is a common pest of banana but most work on its biology has been done on pineapple and there appear to be no studies of its biology specifically on banana.

*Dysmicoccus neobrevipes* reproduces sexually, and mating must occur for young to be produced (Beardsley, 1965; Ito, 1938; Rohrbach *et al*., 1988). No eggs are laid; the young emerge from the female as fully developed first instar larvae called crawlers. The crawler stage is the primary dispersal stage (Rohrbach *et al*., 1988). Crawlers move about actively for a short period of time, no more than a day, and may be dispersed on to other plants up to several hundred yards by wind (Rohrbach *et al*., 1988).

Females undergo three nymphal stages (moults) before reaching maturity; each nymphal stage lasts for 11-23 days, 6-20 days and 7-28 days, respectively (Kessing and Mau, 1992), or an average of 8-14 days (Ito, 1938). The total nymphal period varies from 26-52 days, averaging about 35 days (Kessing and Mau, 1992). When the adult female emerges, there is a period of about 25 days before it produces its first larvae (Kessing and Mau, 1992). During this period the female is mated by males. Further mating can take place at any time after the maturation of the female. The female then produces nymphs for a period of about 30 days (Kessing and Mau, 1992). Females die about four days after they cease to produce young (Ito, 1938; Kessing and Mau, 1992). Each female can produce up to 350 nymphs (Ito, 1938), but there are some that produce up to 1000 young (Kessing and Mau, 1992). Unmated females live for an average length of 148 days, while mated females an average of 95 days (Ito, 1938). Duration of female adult life varies from 48-72 days, averaging about 61 days (Kessing and Mau, 1992). The lifespan from first instar to adult death varies from 59-117 days, averaging 90 days (Kessing and Mau, 1992).

Males moult four times before reaching the winged adult stage; first nymphal stage lasts for 11-19 days, second 7-19 days, third 2-7 days and fourth 2-8 days (Kessing and Mau, 1992), or an average of 3-13 days (Ito, 1938). The total nymphal period varies from 22-53 days (Kessing and Mau, 1992). Feeding is limited to the first and second stages, which together last for about 20 days. The second, third and fourth moults of the male take place inside a waxy cocoon, during a period of about 12 days. When the adult male emerges from this cocoon, it is a fragile insect about 1 mm long, with a pair of membranous wings. It has no mouthparts, and lives for only 2–7 days (Ito, 1938; Kessing and Mau, 1992).

Adult females appear predominantly grey in colour as their common name implies. In actuality their bodies are brown to greyish-orange, but take on a greyish appearance in combination with the waxy exudation that covers them (Kessing and Mau, 1992). The body is broadly oval and measures about 1/17 inch long by 1/25 inch wide. The back is heavily coated with tiny tufts of white mealy wax. Short filaments of wax extend from around the margin of the entire body. Lateral wax filaments are usually less than one fourth as long as the breadth of the body and those towards the back of the insect are one-half as long as the body.
In pineapple fields in Hawaii, mealybug populations were mostly confined to the actively growing portions of the plant, such as young leaves and developing fruit (Beardsley et al., 1982). They are normally found on the aerial parts of its hosts such as leaves, stems, aerial roots, and flowers and fruit clusters (Kessing and Mau, 1992). However, mealybug populations declined rapidly as the fruits and foliage approached maturity (Beardsley et al., 1982). Following the harvest of the first fruit crop, new shoot growth could again support large mealybug populations, and mealybug populations increased (Beardsley et al., 1982). Sustained heavy rain may also cause a decline in mealybug populations, but pest populations can recover after the return of dry weather (Beardsley et al., 1982).

**Relationship to ants**

*D. neobrevipes* is tended by *Pheidole megacephala* (big-headed ant) in pineapple fields in Hawaii. This ant greatly encourages the mealybug by interfering with their natural enemies, and maintaining the health of the mealybug colony by removing excess honeydew (Beardsley et al., 1982). Ants move mealybugs from one plant to another, and control of mealybugs depends on control of the ants (Beardsley et al., 1982; Carter, 1973; McEwen et al., 1979). The ant that attends and encourages this mealybug, *P. megacephala*, is common in eastern and northern Australia (Shattuck, 1998). However, in the absence of natural enemies and inclement weather, the ants do not move mealybugs from one plant to another and do not cause an increase in mealybug populations (Jahn and Beardsley, 1996). Attempts to use natural enemies to control mealybugs have been unsuccessful unless the ants were also controlled (Rohrbach et al., 1988). Infestations of mealybugs and their attendant ants originate along field margins and gradually move inwards. Mealybug wilt spreads from single infested plants to adjacent plants. Cultivation destroys ant populations, and newly prepared fields are re-invaded slowly from adjacent infested fields. Pesticide treatment around the margins of new plantings would prevent the establishment of new ant populations, and hence prevent the establishment of mealybug populations (Beardsley et al., 1982).

**Vector potential**

*D. neobrevipes* is the principal vector of pineapple wilt disease (Beardsley, 1965; McEwen et al., 1979; Rohrbach et al., 1988), which appears to be caused by a virus (Carter, 1963). Pineapple wilt, or mealybug wilt, is the most serious type of damage and is the principal cause of crop failure in Hawaii (Kessing and Mau, 1992). It can cause complete loss of pineapple crops if not controlled (Beardsley, 1993). There are two types of wilt, “quick wilt” and “slow wilt”. Both types cause the collapse of roots by the invasion of saprophytic organisms or by drying up (Kessing and Mau, 1992). “Quick wilt” is produced by a short period of feeding by a large colony of mealybugs and is characterized by discoloration of leaves to yellows or reds and the loss of rigidity in leaves (Kessing and Mau, 1992). “Slow wilt” occurs after the development of a large colony of mealybugs and shows fewer colour changes (Kessing and Mau, 1992). Leaves will be covered with mealybug feeding sites, leaf tips are browned, outer leaves droop, and the leaf will be flaccid to the touch (Kessing and Mau, 1992). Pineapple wilt has also been called “edge wilt” because the margins of the field would be affected first and the infection would move inward as the mealybug infestation dispersed. Fortunately, this disease has been controlled for the last three decades by routine ant control (Kessing and Mau, 1992). However, it may once again become prevalent if mealybugs are not continually suppressed by limiting ant populations (Kessing and Mau, 1992).

*D. neobrevipes* is also implicated as causing a physiological reaction known as “green spot” on pineapples (Beardsley, 1965).
Scientific name

*Pseudococcus jackbeardsleyi* Gimpel & Miller [Order: Hemiptera; Family: Pseudococcidae]

**Synonym(s)**

*Pseudococcus jackbeardsleyi* was previously known in the Philippines as *P. elisae* (e.g. in Lit and Calilung, 1994). However, Gimpel and Miller, (1996) discovered that the species previously identified as *P. elisae* actually included two cryptic species, and described *P. jackbeardsleyi*. Ben-Dov et al. (2002) provides a complete list of synonyms.

**Common name(s)**

Jack Beardsley mealybug

**Host(s)**

The following host list was taken from Ben-Dov et al. (2002).

*Acacia; Acalypha wilkesiana; Acanthocereus; Aeschynomene americana* (forage legume); *Agave* (sisa); *Aglaoema commutatum; Aglaonema simplex; Aglaonema; Alpinia purpurata* (red ginger); *Alpinia; Ananas comosus* (pineapple); *Annona cherimola* (custard apple); *Annona muricata* (sour sop); *Annona squamosa* (sweet sop); *Annona; Anthurium* (tropical flower); *Apis graveolens* (celery); *Aralia; Begonia; Bidens bipinnata; Blighia sapida* (akee apple); *Cajanus cajan* (pigeon pea); *Cajanus indicus* (pigeon pea); *Capsicum frutescens* (sweet pepper); *Capsicum*; *Carica papaya* (paw paw); *Cattleya* (orchid); *Cereus peruvianus* (cactus); *Cereus; Chamaesyce*; *Chrysophyllum cainito*; *Citrus aurantiifolia* (Mexican lime); *Citrus paradisi* (grapefruit); *Citrus; Coccinia grandis* (scarlet gourd); *Cocos; Codiaeum; Coffea arabica* (coffee); *Coleus, Mentha; Cordia curassavica; Coryphanta cubensis; Croton; Cucumis melon* (oriental melon); *Cucurbita pepo* (zucchini); *Cucurbita; Cycnoches; Cymbopogon citratus* (lemon grass); *Dendrobium tortile* (orchid); *Dendrobium* (orchid); *Dieffenbachia; Dracaena* (Caiman lizard); *Eugenia; Fernaldia; Ficus decora* (rubber plant); *Ficus tricolor; Ficus; Gardenia jasminoides* (cape jasmine); *Gossypium barbadense* (cotton); *Gossypium; Haematoxyllum campechianum; Heliconia* (cut flower); *Hibiscus cannabinus* (kenaf); *Hibiscus esculentus* (okra); *Hibiscus; Hoya carnosa* (ornamental flower plant); *Hura crepitans* (sandbox tree); *Ipomoea batatas* (sweet potato); *Ipomoea; Iris; Jatropha curcas; Jatropha; Lantana camara* (lantana); *Litchi chinesis* (litchi); *Lycopersicon esculentum* (tomato); *Macadamia; Mangifera indica* (mango); *Manihot esculenta* (manioc); *Melocactus cactus*; *Melochia tomentose; Moringa oleifera* (drumstick); *Mormolyca balsamina*; *Morus; Musa; Musa paradisiaca* (banana); *Musa sapientum* (banana); *Musa; Nephelium lappaceum* (rambutan); *Nephelium; Nerium oleander* (Mediterranean shrub); *Ocimum; Salvia; Paphiopedilum* (orchid); *Pelargonium; Persea; Phaeomeria; Phaseolus limensis* (lima bean); *Physalis peruviana* (cape gooseberry); *Physalis pubescens* (ground cherry); *Piper nigrum* (pepper); *Plumeria; Psidium guava* (guava); *Psidium; Pueraria javanica; Punica granatum* (pomegranate); *Rhapis mesembrianthemoiides; Rumex; Sechium edule* (chayote); *Solanum melongena* (eggplant); *Solanum tuberosum* (potato); *Solanum; Spondias; Tamarindus indica* (tamarind); *Tamarindus; Theobroma cacao* (cocoa); *Vitis; Yucca; Zea mays* (maize); *Zingiber* (ginger)
Plant part(s) affected
Leaves and fruits (CABI, 2002; Gimpel and Miller, 1996).

Distribution
The following list on distribution was taken from Ben-Dov et al. (2002).
Aruba; Bahamas; Barbados; Belize; Brazil; Canada; Colombia; Costa Rica; Cuba; Dominican Republic; El Salvador; Federated States of Micronesia (Caroline Islands); Galapagos Islands; Guatemala; Haiti; Hawaiian Islands (Hawaii); Honduras; Jamaica; Martinique; Mexico; Panama Canal Zone; Panama; Philippines; Puerto Rico & Vieques Island (Puerto Rico); Singapore; Taiwan; Thailand; Trinidad and Tobago; U.S. Virgin Islands; United States of America (Florida, Texas); Venezuela.

Biology
No information on the biology of *P. jackbeardsleyi* on banana could be identified. However, the following information is from CABI (2002) under *P. elisae*.

Mealybugs in general have four female and five male instars (including the adults). The first instar is usually more mobile than the rest. The adult female lays her eggs in a waxy sac called an ovisac attached to the host-plant. The eggs usually hatch in a few hours to a few days and the first instars escape from the ovisac and crawl on the host searching for a suitable feeding site. First-instar larvae are sometimes transported by wind. Male first instars are similar to female first instars, but male second instars form a waxy sac and pass through two more non-feeding instars (the pre-pupa and pupa) before becoming winged adults. Females do not form an ovisac until they are adults. Adult males cannot feed and usually survive for no more than a day. It is assumed that most mealybug males locate females by a pheromone. Males can often be seen in flight early in the morning or late in the day when winds are generally calm. Mealybugs have from one to nine generations a year depending on the weather conditions and species of mealybug.

Scientific name
*Rastrococcus invadens* Williams [Hemiptera: Pseudococcidae]

Synonym(s)
*R. invadens* is very close to *R. spinosus* Robinson, and the identities of the two species have somewhat confused (CABI, 2002).

Common name(s)
Mango mealybug

Hosts
The following host list was taken from Ben-Dov et al. (2002).
Acacia; Acalypha hispida (acalypha); Acanthus mollis; Ailanthus excelsa (ardu); Annona muricata (sour sop); Annona reticulata (bullock’s heart); Anthocephala vogelli; Aphelandra; Artocarpus altilis (breadfruit); Artocarpus alephrene; Artocarpus incisa (breadfruit); Artocarpus integrifolia (kathal); Barleria involucrata; Borreria verticillata, Ixora; Caladium; Calophyllum inophyllum (takamaka); Canna indica (Indian shot); Citrus aurantifolia (acid lime); Citrus grandis (pummelo); Citrus limon (lemon); Citrus paradisi (grape fruit); Citrus reticulata (mandarin orange); Citrus sinensis (sweet orange); Codiaeum variegatum (croton); Colocasia antiquorum (taro); Costus lucanusianus; Dacryodes edulis (African pear); Dieffenbachia maculata (ornamental); Dieffenbachia; Dioscorea alata (alabio manior); Echites; Ficus elastica (rubber plant); Ficus exasperata; Ficus mucuso; Ficus percisifolia; Ficus thomconii; Ficus; Heliconia humilis; Hydrangea macrophylla (hortensia); Khaya ivorensis (African mahogany); Lindernia crustacea; Mallotus; Mangifera indica (mango); Momordica foetida; Monstera deliciosa (ornamental); Musa paradisiaca (basrai banana); Musa sapientum (dwarf cavendish); Nerium oleander (oleander); Persea americana (avocado); Philodendron (tropical ornamental); Plumeria alba (white frangipani); Plumeria rubra (temple tree); Plumeria; Premna tomentose; Pseuderanthemum (ornamental); Psidium guava (guava); Sanchezia nobilis; Sida acuta (spinyhead sida); Spondias dulcis; Strongylodon; Strophantus; Thevetia peruviana (yellow oleander); Trema guineensis (pioneer tree); Xanthosoma (cocoyam).

**Plant part(s) affected**

Whole plant, leaves, stems, inflorescence, and fruits (CABI, 2002)

**Distribution**

The following list on distribution was taken from Ben-Dov et al. (2002).

Bangladesh; Benin; Bhutan; Congo; Gabon; Ghana; Hong Kong; India; Indonesia (Bali, Java); Malaysia (Sarawak); Pakistan; Philippines; Singapore; Sri Lanka; Thailand; Togo; Vietnam.

**Biology**

Adult female pale greenish white, covered with white wax except for a bare area on midline. Length 3.5-4 mm, width 2-2.5 mm. Filaments conspicuous and long, anterior 3.5-6 mm long, posterior 5-8 mm long, lateral 1.5-2.5 mm long (Williams, 1986). Males have not been described in detail, but have a single pair of wings and no mouthparts.

The following information on the biology of *R. invadens* is extracted from CABI, 2002. The data are mainly for the species on mango in Africa where the species was accidentally introduced. There has apparently been no detailed biological study of this species on banana in the Philippines.

The females of the mango mealybug produce first-instar larvae, which, under field conditions in tropical Africa, moult within 10–12 days into second instars. The second instar lasts 7–8.5 days, and slight differences can be observed between the sexes. Third-instar males form a cocoon and go through to a fourth instar over 8–11 days; third-instar females take 6.5-8.5 days before moulting to adults. Overall, males take 28–31 days from hatching to last moult. The short-lived adult males are capable of mating upon emergence. Females take 25–27 days from hatching to adult emergence. The pre–reproductive period of the females lasts for 17–18 days. Females survive up to 225 days and lay eggs up to about day 200.
Willink and Moore (1988) found that *R. invadens* requires longer development times and a shorter reproductive period in the laboratory or the glasshouse. Up to almost 200 first instars are produced on average during the lifetime of one female.

**Spread**

In West Africa, *R. invadens* has been shown to disperse very well, most likely as a result of people transporting seedlings from nurseries. Population densities were usually higher on young than on old leaves and differed markedly between individual mango trees. On highly infested mango trees, the pre-reproductive period was shorter and the total offspring production higher than on less-infested trees, indicating the importance of plant genotype on mealybug size and survival. Similarly, there are also reports of large differences in mealybug population levels between different mango trees.

Population peaks occurred irregularly, but mainly in the wet season, though they often seemed to be more influenced by the plant host than by weather. The proportion of male mealybugs showed large and unexplained fluctuations, which were independent of population density.

In three studies in Africa, namely in Togo, Congo and Benin, population dynamics were heavily influenced by classical biological control. Pest populations crashed within 1–2 years, and local extinction was sometimes observed.

In India *R. invadens* does not seem to be of great economic importance. In fact, the species had not been recognised and was mistaken for *R. spinosus*, before it was accidentally introduced into Africa (Williams, 1986). Wherever this mealybug appeared in Africa it became a pest of prime importance on mango, sometimes on citrus, and on many horticultural crops and shade trees.

**Spider mites**

**Scientific name**

*Oligonychus orthius* Rimando (Bolland et al., 1998).

*Oligonychus velascoi* Rimando (Bolland et al., 1998).

**Synonym(s)**

None for both species

**Common name(s)**

Both species can be called ‘spider mites’ and *O. velascoi* is also known as coconut spider mite.

**Host(s)**

The following host list was taken from Cayme and Gapasin (1987), Corpuz-Raros (1989) and Bolland et al. (1998).

*Adonidia merrilli; Brachuaria mutica* (para grass); *Caryota cumingii; Cocos nucifera* (coconut); *Corchorus* sp. (jute); *Corypha elata* (buri palm); *Digitaria sp.* (cooch grass); *Imperata cylindrica* (alang-alang); *Miscanthus sinensis* (Japanese pampas grass); *Musa sapientum* (dwarf cavendish); *Musa* sp.; *Musa x paradisiaca; Oligonychus orthius; Oligonychus velascoi; Pandanus*
odoratissimus; Pennisetum purpureum (napier grass); Ptychosperma macarthurii (ornamental palm); Saccharum officinarum (sugar cane); Saccharum spontaneum (tigergrass); Sorghum sp.; Wedelia biflora; Zea mays (maize).

Plant part(s) affected
Mainly on leaves, and likely to be found on fruit.

Distribution
The following distribution lists were taken from Bolland et al. (1998).
Oligonychus orthius: China, Japan, Korea, Philippines, Taiwan and Thailand.
Oligonychus velascoi: Philippines and Thailand.

Biology
Mites of the family Teranychidae develop through eggs, larvae, protonymphs, deutonymphs and adults. The time required to complete a life cycle from egg to adult varies between genera or species.

Apparently, no published information is available on the biology of these mites on banana in the Philippines. Cayme and Gapasin (1987) studied the biology, host range and natural enemies of O. velascoi on coconut in the Philippines. They found that the duration of development of the mite in the laboratory averaged 6.3 days on detached coconut leaflets and 6.9 days on undetached ones. This mite causes discolouration of leaves and dieback of plant tissues.

Although spider mites are usually found on leaves, they are able to move to other parts of the plants including fruit, especially when populations are high.

Scientific name
Tetranychus piercei McGregor (Bolland et al., 1998)

Synonym(s)
Tetranychus manihotis Flechmann

Common name(s)
Spider mite

Host(s)
The following distribution list was taken from Bolland et al. (1998), Corpuz-Raros (1989) and CABI (2002).

Ageratum conyzoides (bill goat weed); Ageratum esculenta; Ageratum sp.; Arachis hypogaea (ground nut); Asarum blumei; Canavalia martima; Carica papaya (paw paw); Cassia obtusifolia (sickle pod); Cassia tora (sickle senna); Clitoria ternatea (butterfly pea); Codiaeum variegatum
The Importation of Philippines bananas: Draft IRA Report

(croton); Colocasia esculenta (taro); Curculigo orchioides; Dolichos lablab (kidney bean); Elaeis guineensis; Houttuynia cordata; Ipomoea batatas (sweet potato); Lablab purpureus (field bean); Manihot esculenta (manioc); Manihot sp.; Morus alba (mulberry); Musa sp.; Musa sapientum (= x paradisiaca) (dwarf cavendish); Musa textilis (abaca); Palmae (plants of the palm family); Passiflora foetida; Phaseolus vulgaris (kidney bean); Polygala paniculata; Prunus persica (peach); Psophocarpus tetragonolobus (winged bean); Pueraria montana (kudzu); Rhamnus crenata; Ricinus communis (castor) and Solanum melongena (egg plant).

Plant part(s) affected

Mainly on leaves, but likely to be found on fruit.

Distribution

The following distribution list was taken from Bolland et al. (1998) and CABI (2002).

China; Cambodia; Indonesia; Japan; Malaysia; Papua New Guinea; Philippines; Surinam; Taiwan; Thailand and Vietnam.

Biology

Liu and Liu (1986) studied the biology of T. piercei on Carica papaya in Guangdong, China. They found that the egg, larval, nymphal and preoviposition stages last 3.3–3.8, 1.3–1.6, 2.9–3.0 and 1.1–2.0 days, respectively, at 28–32°C and 74-85% relative humidity. Mobile stages suck the juice of tender leaves and stems. Unmated females produce only male progeny. T. piercei often feeds on the undersides of the leaves. Nymphs and adults spin webs on leaves and stems, infestation usually beginning at the lower parts of the plant and then spreading upwards. Gutierrez et al. (1979) studied of a strain of T. piercei from Indonesia, which includes redescription, karyotype, and reproduction. Fecundity is about 155 eggs per female (CABI, 2002).

Although spider mites usually are found on leaves, they are able to move to other parts of the plants including fruit, especially when populations are high.

Weevils

Scientific name

Philicoptus demissus (Heller) [Order: Coleoptera; Family: Curculionidae]

Philicoptus iliganus (Heller) [Order: Coleoptera; Family: Curculionidae]

Philicoptus sp.1 [Order: Coleoptera; Family: Curculionidae]

Philicoptus sp.2 [Order: Coleoptera; Family: Curculionidae]

Philicoptus stringifrons (Heller) [Order: Coleoptera; Family: Curculionidae]

Synonym(s)

Philicoptus demissus, P. iliganus and P. stringifrons were originally described in the genus Coptorrhynchus by Heller (1929).
Common name(s)
Peel-scarring weevil

Host(s)
The following host lists on *Philicopus demissus* and *Philicopus iliganus* were taken from Stephens (1984) and Philippines Dept. Agriculture (2001).

*Philicopus demissus*: *Coffea arabica* (coffee), *Dureo zibethinus* (durian), *Musa* spp. (banana), *Nephelium lappaceus* (rambutan), *Persea americana* (avocado), and *Theobroma cacao* (cacao)


*Philicopus* sp.1: *Musa sapientum* (banana) and many other plants (Stephens, 1984).

*Philicopus* sp.2: Coffee plants. Adults are able to feed on banana fingers *in vitro* (Stephens, 1984).

*Philicopus stringifrons*: Stephens (1984) states that ‘… the insect is not a proven banana peel-feeding weevil in the field but is suspect since it feeds on banana followers and feed voraciously on young banana fingers in a 1500ml beaker …’

Plant part(s) affected
In banana, leaves and fruit peel (Stephens, 1984)

Distribution
Philippines (Stephens, 1984)

Biology
Among these five species, *P. iliganus* is the most severe pest (Stephens, 1984). Therefore, there is more information on its biology than on the other four species. The following biological data are mainly for *P. iliganus* but probably apply to the other species.

The eggs are laid singly or in mass in the soil and hatch in 10 days (PBGEA, 2001). The total nymphal period ranges from 102 to 174 days on banana suckers. Larvae pupate in the soil. Pupae last 10-23 days. The life cycle from eggs to adults takes 111-176 days. Adults have no hind wings and elytra (first pair of wings) are firmly united at the suture. Adults are slow moving and cannot fly.

In laboratory studies, the egg stage of *P*. sp.1 lasted 6-10 days, the larva 104-165 days, the pupa 42-58 days, and the adult 33-128 days (Stephens, 1984).

In banana, adults hide in leaf axils, between touching leaves, and concealed among fruit (Stephens, 1984). During the day, there are periods of inactivity interspersed with periods of active crawling. Adults feed near the base of the youngest leaf of non-fruited banana plants. Pronounced feeding can occur on leaf veins. Feeding occurs on lower bracts before young banana fingers are exposed. When the bracts open, adults enter the flower bud and scar the young fingers. Scarring occurs up to
harvest time. Adults tend to feed along fruit ridges. Fruit scars crack with age. Damage appears as deep scars on the fruit peel.
Survey of households for banana plants in Australia

A survey was conducted on 11, 12 and 14 March 2002 to determine the percentage of household (‘backyards’) in residential and semi-rural areas of Australia.

Methodology

Personal communication with the following regulatory and horticultural staff of Queensland Department of Primary Industries (QDPI), New South Wales Agriculture (NSW Agriculture) and Western Australia Department of Agriculture (AGWest).

- QDPI Extension horticulturist – Nth Qld – wet tropics
- QDPI Plant Health Inspectors covering the Brisbane and Sth East Qld banana growing areas
- NSW Agriculture Inspectors based in Murwillumbah (Tweed district) and Mullumbimby (Brunswick district)
- NSW Agriculture Inquiry Officers at Murwillumbah and Coffs Harbour (located in the two major banana growing districts)
- NSW Agriculture District Horticulturist, Coffs Harbour
- AGWest Section Manager – horticulture, Carnarvon

Field regulatory staff were selected because of their active involvement in the Bunchy Top eradication campaign (if undertaken in their State/Territory). Major house to house campaigns to eradicate Bunchy Top from backyard bananas were conducted from 1993 to 1998 and follow up campaigns are conducted on an annual or biennial basis (Peasley, 1996; Peasley et al., 1998). Agricultural inquiry staff receive inquiries and organise details for banana planting permits. Staff were asked to estimate the percentage or proportion of backyards in which bananas are grown in the major towns and surrounds in their geographical area of responsibility.

Results

**Wet tropics:** (Nth Qld – Stewart Lindsay, Program Extension Horticulturist QDPI).

- Tully – negligible – effectively zero as a result of the black Sigatoka eradication campaign.
- Innisfail – 20% (unmanaged – Ducasse).
- Mosman – 20% (Dwarf Cavendish)
- Cairns – 10% - overall – new areas negligible, established areas 20-25%.

**South East Queensland:** QDPI District Inspectors, Plant Health, Paul McArdy and Trevor Lanham independently estimated the percentage in two major towns in the banana growing area (Nambour and Caboolture) at 25% (1 in 4).

Brisbane: QDPI District Inspector, Plant Health, Don Gordon estimated the percentage at 15% (1 in 6.66).
Northern NSW: NSW Agriculture Inspectors, Greg Wassell (Murwillumbah, Tweed Valley) and Terry Grant (Mullumbimby, Brunswick Heads), estimated the percentage at 10% (1 in 10) for the new residential areas and 25% (1 in 4), for the older established areas. In the 1996 census (Anonymous, 1999a), there were 137,657 households in the local government areas and urban centres in the banana growing areas of northern NSW.

- NSW Banana Industry Development Officer, Bob Campbell, also actively engaged in administering the Bunchy Top control program, estimated the percentage at 25% (1 in 4).
- NSW Agriculture Inquiry Officer, Jim Aston (Murwillumbah) estimated the figure at 15% (1 in 6.6).
- NSW Agriculture Inquiry Officer, Jenny Denison (Coffs Harbour) estimated the figure at 10% (1 in 10), for Coffs Harbour.
- NSW Agriculture District Horticulturist, Greig Ireland (Coffs Harbour) estimated a figure of 10% (1 in 10), for Coffs Harbour.

All respondents commented that the percentage of backyards with banana plants was significantly higher in the established residential areas, (some areas up to 50 percent) while in the new residential areas, the figure was as low as nil in some areas but typically around 5 percent.

- AGWest Section Manager Kesi Kesavan, Carnarvon, reported that most backyard plants had been eradicated to protect the local industry. Less than 1% of backyards in both Carnarvon and Kununurra had banana plants.

Outside Production Areas: Sydney, Melbourne and Perth while not in the commercial growing districts of Australia, have banana plants growing in residential and semi-rural and rural properties predominantly for ornamental purposes.

The number of plants is not as high as in the growing areas because of the cooler climatic conditions, and there is a higher proportion of the AAB types (Lady Finger, Sugar) with a high tolerance than the Cavendish variety of cooler conditions. These are planted predominantly for ornamental purposes.

The proportion of backyards with banana plants in Sydney is estimated at 1-5% depending on the suburbs, and Melbourne < 1%. Perth has very low percentage – certainly less than 1% (Kesavan, 2002).

Semirural - rural residential areas – South East Queensland and Northern NSW: A brief visual survey by vehicle was conducted on 12 March 2002 through semi-rural and rural residential areas of the far north coast of NSW to determine if the banana plant population in rural areas varied from those in the residential areas. It was noted that the percentage of properties in semi-rural areas with banana plants was higher than in residential/urban areas – and varied with the aspect and microclimate and slope – approx. 1 in 4 (25%).

The number of plants per property varied from less than 5 plants to a few clumps of 50-100 plants.

Most appeared to be planted for ornamental purposes and appeared healthy (also good growing conditions – temp and rainfall).

As most plantings appear to be for ornamental purposes and only 1 or 2 plants on average, the impact on consumption in the local area is negligible.
Stakeholder submissions on the June 2002 Draft IRA Report

1. The South Australian Country Women’s Association Incorporated
2. The Carnarvon Banana Industry Protection Committee
3. Australian Banana Wholesalers
4. Carnarvon Growers Association Inc. (CGA)
5. Mr Jeff Daniells
6. Ag. –White Pty Ltd
7. Mackay Estates/Scientific Advisory Services Pty Ltd
8. Queensland Department of Primary Industries (QDPI)
9. Western Australia Department of Agriculture (WADA)
10. Mr Alan Zappala
11. Philippine Government/banana industry stakeholders
12. Cardwell Shire Council
13. Bananas NSW
14. Pilipino Banana Growers & Exporters Association, Inc. (PBGEA) and Banana Export Industry Foundation, Inc. (BEIF)
15. Australian Banana Growers’ Council Inc (ABGC)
16. Johnstone Shire Council
17. Victorian Department of Natural Resources and Environment (DNRE))
18. Bonlac Foods/Murray Goulburn Cooperative/Tatura Milk Industries/Warrnambool Cheese and Butter Factory
19. New South Wales Agriculture
20. Queensland fruit and vegetable growers

Non-confidential stakeholder submissions are held at Biosecurity Australia’s office in Canberra and documents may be accessed during business hours, by prior appointment, for perusal and copying.
Comparison of banana industry in Australia and the Philippines

<table>
<thead>
<tr>
<th>Feature</th>
<th>Australia</th>
<th>The Philippines</th>
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<tr>
<td>Domestic consumption</td>
<td>From bananas grown in Australian commercial plantations. These are approximately 85–90% Cavendish (Daniells, 2001a)</td>
<td>Native (non-Cavendish) varieties grown in backyard plots as staple food (PCARRD, 1988)</td>
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<tr>
<td>Markets</td>
<td>Production for the Australian domestic market only</td>
<td>Focussed largely on exports of Cavendish (Armstrong, 2001)</td>
</tr>
<tr>
<td>Location</td>
<td>Regionalised, and generally at distance from major population centres</td>
<td>Grown throughout and in close proximity to household bananas (PCARRD, 1988)</td>
</tr>
<tr>
<td>Alternative enterprise options</td>
<td>Limited to forestry and parkland, in some cases because of dieldrin residue (Anonymous, 1994b). Sugarcane or beef production on floodplains subject to pesticide residue limitations (Peasley, 2001a)</td>
<td>Tropical horticulture, field crop and livestock enterprises</td>
</tr>
<tr>
<td>Climate</td>
<td>Wide climatic diversity, although production focussed in the tropics and subtropics (Figure 2)</td>
<td>Tropical throughout (Figure 2)</td>
</tr>
<tr>
<td>Topography</td>
<td>Variable, including flood plains slopes, steep hillsides</td>
<td>Mainly flat, lowlands, although some recent plantations on undulating, highland areas</td>
</tr>
<tr>
<td>Flood risk</td>
<td>Variable, including high in north Queensland and relatively low in other areas</td>
<td>High flooding risk in lowland flood plain areas</td>
</tr>
<tr>
<td>Rows, drains, design and layout</td>
<td>In the tropics, long mounded rows to facilitate drainage and mechanisation. In other areas, layout influenced by gradient</td>
<td>Drains located according to water table depth, and not designed for machinery access (Peasley, 2001a)</td>
</tr>
<tr>
<td>Soil movement</td>
<td>On flood plains or on steep country, limited ability to control soil movement with heavy rainfall</td>
<td>Extensive drainage systems and no vehicles within plantations restrict soil movement (Peasley, 2001a)</td>
</tr>
<tr>
<td>Feature</td>
<td>Australia</td>
<td>The Philippines</td>
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</tr>
<tr>
<td>Vehicle use within plantation</td>
<td>Variable use and frequency of wheeled vehicles. In north Queensland high frequency (2-3 times per week), but in steep country or on small holdings, mechanisation limited</td>
<td>No wheeled vehicles used, except on access roads (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Transport of bunches — field to packing station</td>
<td>Wheeled vehicles with or without a padded A-frame trailer (Peasley, 2001a)</td>
<td>Mostly cableways (average length 400 m), with some use of trailer transport on roads. In-field de-handing with padded stretcher used for the specialised Japanese organic market (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Transport — packing station to market</td>
<td>Refrigerated vans, road and rail transport. Concession rates because of back-loading opportunities</td>
<td>Vertical integration of road and sea transport through corporate ownership. Refrigerated containers or covered trucks (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>In-transit monitoring</td>
<td>Relative humidity, temperature and carbon dioxide levels monitored</td>
<td>Relative humidity, temperature and carbon dioxide levels monitored</td>
</tr>
<tr>
<td>Handling time</td>
<td>Maximum 24 hours from harvest to loading on refrigerated truck or train. 1–3 days in transit to market</td>
<td>Maximum 24 hours from harvest to loading wharf. Estimated 10–14 days sea voyage to Sydney (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Packing and shipping</td>
<td>13kg cartons, variable cartons/pallet. Generally consigned in refrigerated vans as break bulk. Some containerisation</td>
<td>13kg cartons, with 54 cartons/pallet. Break bulk and containerised shipments (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Environmental awareness</td>
<td>Some innovative environmental programs, for example, frog relocation in north Queensland; biological control; integrated pest management; crop hygiene, etc (Armstrong, 2001; Peasley, 2001a; Peasley, 2001b)</td>
<td>Compulsory compliance with ISO 14001. Environmental Compliance Certificate (ECC) for all new plantations (Philippines Scientific Delegation, 2002). Environment management plan submitted to government agency before ECC issued</td>
</tr>
<tr>
<td>Community standards for environment issues</td>
<td>High community expectations for environmental management, particularly spraying of pesticides in areas with high populations. Any increase in spray programs or use of pesticides is unacceptable to the community</td>
<td>Environmental management regulated by Government agencies and plantation owners, through the use of quality assurance systems and testing programs. Pesticide programs comply with Fertiliser and Pesticide Authority guidelines (Anonymous, 1999b)</td>
</tr>
<tr>
<td>Feature</td>
<td>Australia</td>
<td>The Philippines</td>
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<tr>
<td>Environmental risks</td>
<td>New diseases may be a risk to native bananas and to other aspects of the natural environment. Sediments and nutrients may be a risk to the sustainability of the Barrier Reef (Guymer, 2002)</td>
<td>Chlorpyrifos impregnated bunch covers are not permitted in environmentally sensitive areas (Peasley, 2001b)</td>
</tr>
<tr>
<td>Risks to native bananas</td>
<td>Three native banana species present in areas adjacent to commercial plantations in north Qld. These are relatively uncommon, and two are protected under environmental legislation. Native species rarely infested with pests or diseases (Guymer, 2002)</td>
<td>Native bananas very common, and heavily infested with pests and disease if growing near commercial plantations (Peasley, 2001b)</td>
</tr>
<tr>
<td>Ownership</td>
<td>Family or private ownership and management</td>
<td>Production dominated by large multi-national corporate plantations and cooperatives</td>
</tr>
<tr>
<td>Plantation size</td>
<td>Between 0.5–500 hectares (Lake, 1998)</td>
<td>Between 70 and more than 6,000 hectares (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Capital investment</td>
<td>Low in the subtropics, but high in north Queensland, Western Australia and Northern Territory</td>
<td>Highly capital intensive (PBGEA, 2001)</td>
</tr>
<tr>
<td>Production/ha</td>
<td>30–40 tonnes per hectare in north Queensland, Western Australia and the Northern Territory (Lindsay, 2002a; Kesavan, 2001a; Richards, 2001). 20–26 tonnes per hectare in New South Wales and southeast Queensland (Peasley, 2001a)</td>
<td>50-75 tonnes per hectare, which generally yields more than 35 tonnes per hectare of export quality fruit (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Bunch maturation time</td>
<td>11–18 weeks in north Queensland and the Northern Territory, and more than 20 weeks in the subtropics (Lindsay, 1998)</td>
<td>9–13 weeks in coastal lowlands, and 18–20 weeks in highlands (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Cropping system</td>
<td>Annual cropping not practised in Australia, as slower growing conditions and higher structural costs</td>
<td>Based on ratoon (continuous) cropping. Annual cropping increasing — for example, 50% of the Dole plantation is</td>
</tr>
<tr>
<td>Feature</td>
<td>Australia</td>
<td>The Philippines</td>
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<tr>
<td>Planting material</td>
<td>Predominantly conventional material (bits &amp; suckers), although use of tissue culture increasing (Lindsay, 1998)</td>
<td>New plantings are 90% tissue culture, with some virus indexed. Balance selected from superior mother plants (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Mechanisation versus labour</td>
<td>Generally low availability of labour. In tropical north Queensland, approximately 0.33 worker per hectare. In subtropics approximately 0.25 worker per hectare (Peasley, 2001a). Degree of mechanisation used is generally dependent on plantation size and topography</td>
<td>High availability of labour using about uses 0.8–1 worker per hectare (Philippines Scientific Delegation, 2002). No use of vehicles, although cableways for transporting bunches and fertilizer (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Staff training</td>
<td>Variable levels of training available and utilised for monitoring, pesticide application, machinery use, quality management etc</td>
<td>High level of training in the monitoring of diseases and pests, the application of chemicals, the use of disinfection, packing to specification, and standard operation procedures (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Specialisation of labour</td>
<td>Larger plantations have specialist crews for particular operations. Smaller plantations have generalist workers and tend to be operated by families</td>
<td>Specialist labour crews for individual tasks, e.g. monitoring, harvesting, disease control, packing (Peasley, 2001b)</td>
</tr>
<tr>
<td>Plantation security</td>
<td>Plantations are in popular tourist areas, particularly on the east coast. Variable security levels – plantations generally accessible</td>
<td>Production areas are not in tourist areas. Entry to plantations is strictly supervised (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Access for plantation operations</td>
<td>North Queensland, Western Australia and the Northern Territory is mainly by wheeled vehicle. New South Wales and southeast Queensland is on foot or by 4-wheel-drive</td>
<td>Plantation operations conducted on foot (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Quality assurance systems (QA)</td>
<td>Variable, but QA systems increasingly adopted. Packing stations operate under ISO 9002 and/or SQF 2000. Some growers operating under approved supplier schemes (Peasley and Baker, 2001)</td>
<td>All exporters operate under ISO 9002 or equivalent. Some are qualifying for SQF 2000 accreditation (Philippines Dept. Agriculture, 2001)</td>
</tr>
<tr>
<td>Feature</td>
<td>Australia</td>
<td>The Philippines</td>
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<tr>
<td>R&amp;D access</td>
<td>R&amp;D information publicly accessible but adoption rate variable according to area, relevance and financial capacity</td>
<td>Public R&amp;D information available but increasingly private and confidential intellectual property held by plantation/company owners</td>
</tr>
<tr>
<td>Technology</td>
<td>Variable technology support adoption. Increasing use of private pest and disease monitoring services as basis for managing pests and diseases</td>
<td>High degree of technology support and implementation</td>
</tr>
<tr>
<td>Packing</td>
<td>North Queensland a trend towards larger (central) packing station servicing several plantations (Lake, 1998). Southeast Queensland, New South Wales, Western Australia and the Northern Territory, most small plantations pack their own fruit</td>
<td>Large-scale cooperative and private packing stations. Fruit partially vacuum-packed in polyethylene bags (70–80% of air removed) in cartons for export (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Pest status</td>
<td>Yellow Sigatoka and <em>Mycosphaerella</em> leaf speckle ubiquitous. Black Sigatoka and banana bunchy top restricted and under official control. Strict quarantine on movement of planting material and fruit (Allen and Priestly, 1999)</td>
<td>Black Sigatoka, banana bunchy top and Moko under intensive management. Freckle present on Cavendish but managed under black Sigatoka program (Peasley, 2001b; Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td>Pest pressure</td>
<td>Varies with location and season. High pressure in wet tropics — North Queensland; Minimal in dry tropics — Queensland; and Minimal in subtropics — Western Australia, New South Wales</td>
<td>High pest pressure all year</td>
</tr>
<tr>
<td>Leaf disease</td>
<td>Highly variable according to area (Peasley, 2001a). Carnarvon, Western Australia — no sprays; New South Wales and southeast Queensland — 4–6 sprays/year; and North Queensland — 20–22 sprays/year Mancozeb, triazoles and oil — monitoring for resistance — green de-leafing.</td>
<td>More than 45 applications/year in coastal lowlands (Peasley, 2001b; Philippines Scientific Delegation, 2002); 26 applications/year in highlands. Alternating fungicide groups as anti-resistance strategy. Monitoring for resistance and green de-leafing</td>
</tr>
<tr>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pesticide use</td>
<td>Active programs to minimise pesticide use. ‘Clean Green’ image goal for Australian bananas — substantial reductions in pesticide use achieved, particularly insecticides (Daniells, 2001b).</td>
<td>Generally high pesticide use. Testing only when demanded by importing country (Philippines Scientific Delegation, 2002). Some measures to reduce pesticides use — e.g., annual</td>
</tr>
<tr>
<td>Feature</td>
<td>Australia</td>
<td>The Philippines</td>
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</tr>
<tr>
<td><strong>Training of pesticide applicators</strong></td>
<td>Evaluating new plant varieties (Daniells and Bryde, 2001). Crop hygiene, monitoring, integrated pest management (Daniells, 2001b)</td>
<td>cropping, exclusion bunch covers, higher altitude (cooler, drier climate). Fruit within acceptable levels for pesticide residues — Codex International Standard (Philippines Scientific Delegation, 2002)</td>
</tr>
<tr>
<td><strong>Vectors of diseases/pests</strong></td>
<td>Most pesticide applicators certificated (Chemical Users Certification) under quality assurance</td>
<td>Compulsory certification for pesticide applicators (PBGEA, 2001)</td>
</tr>
<tr>
<td></td>
<td>High native animal population (fruit bats, possums, birds), as well as wild pigs and insects</td>
<td>Bees, wasps, thrips and other insects are common (Buddenhagen and Elsasser, 1962)</td>
</tr>
</tbody>
</table>
Environmental issues considered in the risk analysis of quarantine pests of Philippines banana fruit.

<table>
<thead>
<tr>
<th>Quarantine pest concern</th>
<th>Entry, Establishment or Spread</th>
<th>Consequences</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana bract mosaic virus</td>
<td>Exposure of native bananas was considered in the risk assessment</td>
<td>There are no known direct impacts of BBrMV on the natural or built environment such as the physical and biological environment. Although additional pesticide applications may be required to control aphid vectors of BBrMV in commercial banana plantations, this is unlikely to impact on the environment, as it was not considered to be distinguishable from normal day-to-day variation of pesticide in the environment.</td>
<td>The pest is highly host specific.</td>
</tr>
<tr>
<td>Banana bunchy top virus</td>
<td>Exposure of native bananas was considered in the risk assessment</td>
<td>It is not likely that BBTV would impact on the environment.</td>
<td>The pest is highly host specific. It is already present in some areas of Australia.</td>
</tr>
<tr>
<td>Moko</td>
<td>Exposure of weeds, native bananas and heliconias was considered in the risk assessment</td>
<td>The direct impact of the disease on other susceptible cultivated plants (e.g. <em>Heliconia</em> spp.) is difficult to estimate, although unlikely to be discernible except for commercial growers who are directly affected. There are no obvious direct impacts of the disease on the environment, although there is some potential for the Moko Race of <em>R. solanacearum</em>, Race 2, to impact on native banana plants. The level of impact that could occur is unknown, however, native <em>Musa</em> species in Australia have already been exposed to Race 1 of <em>R. solanacearum</em> with no reported impact (Akiew, 1991). Further, as native bananas are not grown in monocultures, they are relatively much less likely to experience epidemics of pest and diseases that may occur in monocultures of commercial bananas. This is supported by the</td>
<td>The pest is host specific. Another Race of this bacterium pathogenic to native bananas is already present in Australia.</td>
</tr>
</tbody>
</table>
fact that no disease threats have been identified for the survival of native bananas. It appears that native bananas in Australia are generally disease free either due to their low density and isolation from commercial plantations or some level of inherent tolerance to disease.

<table>
<thead>
<tr>
<th>Disease</th>
<th>Exposure of native bananas was considered in the risk assessment</th>
<th>The severity of freckle infection on native Australian <em>Musa</em> spp. is unknown. <em>Musa acuminata</em> subsp. <em>banksii</em> is reported to be susceptible to freckle (Jones, 2000) but the susceptibilities of the other two native bananas in Australia (<em>M. jackeyi</em> and <em>M. fitzalanii</em>) have not been assessed. In any event, freckle does not kill infected plants. Rather, as explained above, <em>G. musae</em> reduces the photosynthetic area of the plant generally on the older leaves. It is expected that fungicide sprays could control freckle and de-leafing programs similar to that already used for yellow Sigatoka in Australia. If this is the case, there are unlikely to be any additional indirect effects on the environment.</th>
<th>The pest is highly host specific. Some forms of freckle are already present in Australia.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freckle</td>
<td>Exposure of native bananas was considered in the risk assessment</td>
<td>Local government and health authorities often raise concerns over the application of chemical sprays near urban areas. While the chemical residues would be the same as those currently used in the environment, a potential increase would be unwelcome in high profile protected areas. Local restrictions on additional chemical sprays may be imposed that would further impact on farm viability. The severity of black Sigatoka on native Australian <em>Musa</em> species (<em>M. acuminata</em> subsp. <em>banksii</em>, <em>M. jackeyi</em>, <em>M. fitzalanii</em>) is unknown. However, given their limited distribution in Australia and their isolation from other native and commercial bananas, it is very unlikely that they would be infected.</td>
<td>The pest is highly host specific. It is endemic in some non-commercial banana growing areas of far north Queensland and Torres Strait. Occasional outbreaks of the disease have occurred in banana production areas, including the Tully district where the disease has been eradicated.</td>
</tr>
<tr>
<td>Black Sigatoka</td>
<td>Exposure of native bananas was considered in the risk assessment</td>
<td><em>F. oxysporum</em> f. sp. <em>Cubense</em> (Panama) is pathogenic only to banana species. It is not known to impact on other aspects of the natural or built environment, such as the physical environment or micro-organisms.</td>
<td>The pest is host specific. Some forms of Panama disease are already present in Australia.</td>
</tr>
<tr>
<td>Panama</td>
<td>Exposure of weeds and native bananas was considered in the risk assessment</td>
<td></td>
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</tbody>
</table>
While it is known that the native *M. acuminata* subsp. *banksii* is susceptible to the organism, the susceptibility of the other two native bananas in Australia, *M. jackeyi* and *M. fitzalanii*, is unknown. However, given the limited distribution of native bananas in Australia and their isolation from other native and commercial bananas, it is extremely unlikely that they would be infected.

Fruitflies

<table>
<thead>
<tr>
<th>Exposure of hosts including native plants was considered</th>
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<tbody>
<tr>
<td>There are no known direct impacts on the physical environment or other micro-organisms. Further, fruit flies are unlikely to lead to indirect impacts on the environment.</td>
</tr>
<tr>
<td>Fruitflies are polyphagous – affect a number of host plants including, breadfruit, carambola, papaw, mandarin, mango, sapodilla, guava and malay-apple. Some fruit fly species occur in Australia.</td>
</tr>
</tbody>
</table>

Hard scales

- *Aspidiotus coryphae*
- *Aspidiotus excisus*
- *Pinnaspis musae*

<table>
<thead>
<tr>
<th>Exposure of hosts including native plants was considered</th>
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</thead>
<tbody>
<tr>
<td>Although additional pre-harvest pesticide applications would be required to control scales on marketable fruit, this is unlikely to impact on the environment, as it was not considered to be distinguishable from normal day-to-day variation of pesticide in the environment</td>
</tr>
<tr>
<td>The three hard scale species are known to attack musa species, <em>Cocos nucifera</em>, <em>Corypha elata</em>, <em>Carica papaya</em>, <em>Citrus aurantifolia</em>, <em>Citrus</em> sp. and <em>Euphorbia</em> sp.</td>
</tr>
</tbody>
</table>

Mealybugs

- *Dysmicoccus neobrevipes*
- *Pseudococcus jackbeardsleyi*
- *Rastrococcus*

<table>
<thead>
<tr>
<th>Exposure of hosts including native plants was considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Because the complete host range of these mealybugs is not known, their direct impact on the Australian environment was difficult to estimate. It is known, however, that many tropical and subtropical native species would be susceptible including native <em>Musa</em> species, and that environmental conditions where these plants grow would favour the establishment and spread of mealybugs. Although additional pre-harvest pesticide application may be required to control mealybugs on susceptible crops, this is unlikely to impact on the environment any</td>
</tr>
<tr>
<td>These three mealybug species are considered polyphagous including <em>Musa</em> species, many fruit and vegetables as well as weeds.</td>
</tr>
<tr>
<td>Mites</td>
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</tr>
<tr>
<td><em>Oligonychus orthius</em></td>
</tr>
<tr>
<td><em>Oligonychus velascoi</em></td>
</tr>
<tr>
<td><em>Tetranychus piercei</em></td>
</tr>
<tr>
<td>Weevils</td>
</tr>
<tr>
<td><em>Philicoptus demissus</em></td>
</tr>
<tr>
<td><em>Philicoptus iliganus</em></td>
</tr>
<tr>
<td><em>Philicoptus sp.1</em></td>
</tr>
<tr>
<td><em>Philicoptus sp.2</em></td>
</tr>
<tr>
<td><em>Philicoptus stringifrons</em></td>
</tr>
<tr>
<td>Weed contaminants of shipments</td>
</tr>
</tbody>
</table>
Non-weed contaminants of shipments (mammals e.g. rats, mice and bats; amphibians e.g. frogs and toads; reptiles e.g. snakes and lizards; Molluscs, e.g. snails) arthropods (e.g. spiders and ants)

<table>
<thead>
<tr>
<th>acceptable level</th>
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</thead>
<tbody>
<tr>
<td>Some of the contaminants could cause significant environmental impacts such as competition with existing native species. However, because these groups of contaminants are macroscopic it was considered very likely that they would be detected at on-arrival inspection. No frogs or toads have been detected in shipments of Philippines bananas to New Zealand and Japan.</td>
</tr>
</tbody>
</table>