Australian Government

Biosecurity Australia

Draft

Non-regulated Analysis:

Extension of Existing Fresh Mango Fruit Import Policy to Pakistan

April 2011

Cite this report as:
Biosecurity Australia (2011) Draft Non-regulated analysis: Extension of existing fresh mango fruit import policy to Pakistan. Biosecurity Australia, Canberra.

www.biosecurityaustralia.gov.au

Cover image: Fresh mango fruit (Courtesy: [http://thoughtworksuk.files.wordpress.com/2008/08/mangoes_from_pakistan.jpg])

Submissions

This draft extension of existing policy report has been issued to give all interested parties an opportunity to comment and draw attention to any scientific, technical, or other gaps in the data, misinterpretations and errors. Any comments should be submitted to Biosecurity Australia within the comment period stated in the related Biosecurity Australia Advice on the Biosecurity Australia website. The draft extension of existing policy report will then be revised as necessary to take account of the comments received and a final extension of existing policy report will be released at a later date.

Comments on the draft IRA report should be submitted to:

Office of the Chief Executive
Biosecurity Australia
GPO Box 858
CANBERRA ACT 2601
AUSTRALIA

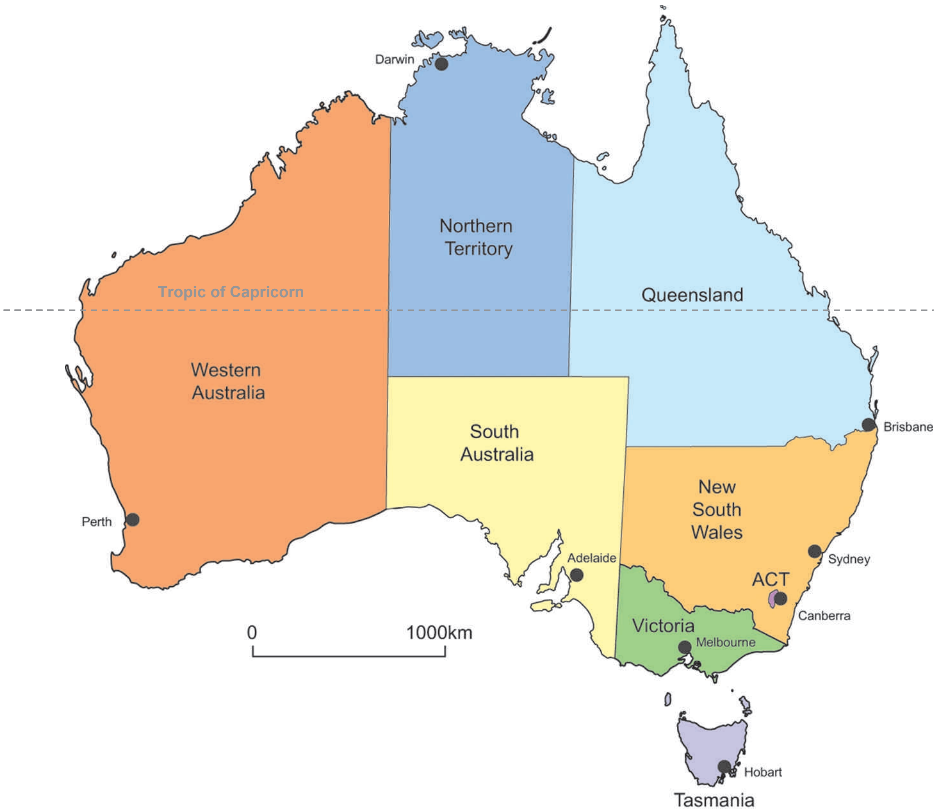
Telephone: +61 2 6272 4004
Facsimile: +61 2 6272 5245
Email: plant@biosecurity.gov.au
Internet: www.biosecurityaustralia.gov.au

Contents

Tables

Figures

Figure 1 Map of Australia



Acronyms and abbreviations

Term or abbreviation	**Definition**
ALOP	Appropriate level of protection
APPD	Australian Plant Pest Database (Plant Health Australia)
AQIS	Australian Quarantine and Inspection Service
BA	Biosecurity Australia
BAA	Biosecurity Australia Advice
BSG	Biosecurity Services Group
CABI	CAB International, Wallingford, UK
CMI	Commonwealth Mycological Institute
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
DAFWA	Department of Agriculture and Food, Western Australia (formerly DAWA)
DAWA	Department of Agriculture, Western Australia
EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization of the United Nations
FSANZ	Food Standards Australia and New Zealand
HWT	Hot water treatment
ICON	AQIS Import Conditions database
IPC	International Phytosanitary Certificate
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IRA	Import Risk Analysis
ISPM	International Standard for Phytosanitary Measures
MINFA	Ministry of Food and Agriculture, Government of Pakistan
MSDS	Mango sudden death syndrome
NPPO	National Plant Protection Organization
NSW	New South Wales
NT	Northern Territory
PHDEB	Pakistan Horticulture Development and Export Board
PRA	Pest Risk Analysis
SA	South Australia
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures (WTO 1995)
Qld	Queensland
Tas.	Tasmania
VHT	Vapour Heat Treatment
Vic.	Victoria
WA	Western Australia
WTO	World Trade Organisation

Summary

Australia initiated a qualitative, pathway-initiated pest risk assessment for the importation of fresh mangoes from Pakistan, following a request for market access from the Department of Plant Protection, Ministry of Food and Agriculture (MINFA), Government of Pakistan.

Australia has existing quarantine policy that allows the importation of mangoes from Haiti, India, Mexico, the Philippines and Taiwan, subject to specific quarantine conditions.

This non-regulated analysis: extension of existing fresh mango fruit import policy to Pakistan has identified the following pests of quarantine concern which require quarantine measures in order to achieve Australia's appropriate level of protection (ALOP): fruit flies (*Bactrocera correcta*, *Bactrocera dorsalis* and *Bactrocera zonata*), mealybugs (*Ferrisia virgata*, *Rastrococcus invadens* and *Rastrococcus spinosus*); and the mango bark beetle (*Hypocryphalus mangiferae*) potentially carrying propagules of the pathogen complex associated with mango sudden death syndrome (MSDS).

Fruitflies and mealybugs have previously undergone risk assessments in the policies to import mango fruit from India and Taiwan. Australia has a well-established policy to mitigate the risks posed by fruit flies and mealybugs associated with mango fruit from India, the Philippines and Taiwan. Consistent with the existing policy, fresh mango fruit from Pakistan would be subject to existing measures to meet Australia's ALOP for these pests. Biosecurity Australia has evaluated the existing policy and proposed additional measures where required. However, the mango bark beetle potentially carrying propagules of the MSDS pathogen complex, has not been considered in previous policies. Therefore, Biosecurity Australia has proposed additional measures to mitigate the risk of MSDS pathogens entering Australia on mango bark beetle.

The draft report proposes a combination of risk management measures and operational systems that will reduce the risk associated with the importation of fresh mango fruit from Pakistan into Australia to achieve Australia's ALOP, specifically:

- Orchard management for mango bark beetle and MSDS; and
- Pre-export disinfestation of fruit
  - Mandatory pre-export irradiation treatment at 250 Gy for fruit flies and mealybugs at DAFF accredited facilities; or
  - Mandatory hot water dipping treatment using continuous flow system for fruit flies at 48 °C for 60 minutes, at DAFF accredited facilities; or
  - Mandatory vapour heat treatment for fruit flies at 46.5 °C for 30 minutes, at DAFF accredited facilities
- On arrival inspection and remedial action if required;
- Supporting operational systems to maintain and verify phytosanitary status

DAFF officers will observe the application of the treatments and the phytosanitary inspection by MINFA officers in Pakistan at the commencement of the initial export season and at other times as necessary. This requirement will be reviewed annually.

Biosecurity Australia invites comments on the technical aspects of the proposed risk management measures. In particular, comments are sought on their appropriateness and any other measures stakeholders consider would provide equivalent risk management outcomes.

1 Introduction

1.1 Australia's biosecurity policy framework

Australia's biosecurity policies aim to protect Australia against the risks that may arise from exotic pests[1] entering, establishing and spreading in Australia, thereby threatening Australia's unique flora and fauna, as well as those agricultural industries that are relatively free from serious pests.

The pest risk analysis (PRA) process is an important part of Australia's biosecurity policies. It enables the Australian Government to formally consider the risks that could be associated with proposals to import new products into Australia. If the risks are found to exceed Australia's appropriate level of protection (ALOP), risk management measures are proposed to reduce the risks to an acceptable level. But, if it is not possible to reduce the risks to an acceptable level, then no trade will be allowed.

Successive Australian Governments have maintained a conservative, but not a zero-risk, approach to the management of biosecurity risks. This approach is expressed in terms of Australia's ALOP, which reflects community expectations through government policy and is currently described as providing a high level of protection aimed at reducing risk to a very low level, but not to zero.

Australia's PRAs are undertaken by Biosecurity Australia using teams of technical and scientific experts in relevant fields, and involves consultation with stakeholders at various stages during the process. Biosecurity Australia provides recommendations for animal and plant quarantine policy to Australia's Director of Animal and Plant Quarantine (the Secretary of the Australian Department of Agriculture, Fisheries and Forestry). The Director, or delegate, is responsible for determining whether or not an importation can be permitted under the *Quarantine Act 1908*, and if so, under what conditions. The Australian Quarantine and Inspection Service (AQIS) is responsible for implementing appropriate risk management measures.

More information about Australia's biosecurity framework is provided in Appendix C of this report and in the *Import Risk Analyis Handbook 2007 (update 2009)* located on the Biosecurity Australia website www.biosecurityaustralia.gov.au.

[1] A pest is any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2009).

1.2 This pest risk analysis

1.2.1 Background

The Department of Plant Protection, Ministry of Food and Agriculture (MINFA), Government of Pakistan requested access for fresh mango fruit (*Mangifera indica* L.) to Australia and provided pest information to facilitate a pest risk analysis.

In early 2007, Biosecurity Australia suggested that irradiation would be the preferred management option for arthropod pests of concern. Pakistan acknowledged this position and informed Biosecurity Australia in August 2007 that an irradiation treatment facility for the treatment of mango fruits for export was nearing completion. In November 2009, Pakistan formally advised Australia that it has operational facilities able to treat fresh mango fruit for export to Australia to mitigate the risk of fruit flies.

Quarantine policy currently exists for the import of fresh mango fruit for consumption from Haiti, India, Mexico, the Philippines and Taiwan. Relevant risk management measures were established for these countries through the import risk analysis process, which included stakeholder consultation. The likelihood and/or consequences of entry, establishment or spread of pests and diseases do not differ from those previously assessed.

Table 1.1: Quarantine pests of mangoes from Pakistan addressed in previous policy for India and/or Taiwan

Pest Type	Countries	
	India	Taiwan
Bactrocera correcta (Bezzi, 1916) [Diptera: Tephritidae]	✓	
Bactrocera dorsalis (Hendel, 1912) [Diptera: Tephritidae]	✓	✓
Bactrocera zonata (Saunders, 1814) [Diptera: Tephritidae]	✓	✓
Ferrisia virgata (Cockerell, 1893) [Hemiptera: Pseudococcidae] WA	✓	
Parlatoria crypta (McKenzie, 1943) [Hemiptera: Diaspididae]	✓	
Parlatoria pseudaspidiotus (Lindinger, 1905) [Hemiptera: Diaspididae] WA		✓
Rastrococcus invadens (Williams, 1986) [Hemiptera: Pseudococcidae]	✓	
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	✓	✓
Rhipiphorothrips cruentatus (Hood, 1919) [Thysanoptera: Thripidae]	✓	✓
Fusarium mangiferae (Britz, M.J., Wingf. and Marasas 2002)	✓	

In the above table, WA = regional pest for Western Australia

Pest categorisation tables may differ for these countries. However, most of the pests of concern in Pakistan are also found in India and Taiwan. Differences in pest categorisation tables may be due to a number of factors including changes in pest and disease status, new scientific information becoming available and constant review of the pest categorisation tables by Biosecurity Australia.

Due to the commonalities between pests found in Pakistan, India and Taiwan, and the mitigation measures required to manage these pests, a non-regulated analysis of existing policy was considered to be the best option for assessing the market access request from Pakistan. Accordingly, Biosecurity Australia advised stakeholders on 17 March 2010 (BAA 2010/06) that the access request would be considered as a non-regulated analysis of existing policy for mango from India and Taiwan.

During the course of undertaking the risk analysis it became clear that the causal agents of mango sudden death syndrome (MSDS) and their insect vector, the mango bark beetle, would need to be considered through a formal risk assessment. The causal agents of MSDS are not known to be associated with the fruit import pathway; however, they may be associated with their insect vector which may contaminate fruit consignments. These species have not been considered in previous policy and so, have been assessed in detail here.

1.2.2 Scope

The scope of this non-regulated analysis is limited to:

- identification of biosecurity risks associated with mangoes from Pakistan
- evaluation of existing risk management measures for the identified risk and propose additional phytosanitary measures, where appropriate, to manage the risks.

Previous risk analyses for the importation of mangoes from India and Taiwan have been taken into account in this PRA.

1.2.3 Existing policy

International policy

Australia has existing policies for fresh mango fruit from a number of countries including Haiti, India, Mexico, the Philippines and Taiwan. The pest risk analysis for fresh mango fruit from India was completed in July 2008. Pests considered in this policy and other previous policies were taken into consideration and included in this report, where appropriate.

The import requirements for these commodities can be found at the AQIS Import Conditions Database (ICON): http://www.aqis.gov.au/icon. The general requirements (Condition C6000) include an AQIS import permit, a quarantine entry, a Phytosanitary Certificate, freedom from regulated articles and on-arrival inspection and remedial action, when required, by AQIS. In addition to such general measures, specific quarantine/biosecurity measures for each of these countries have also been developed (Table 1.2).

Table 1.2: Specific quarantine/biosecurity measures for fresh mango fruit

Country	ICON Condition	Condition title
Haiti	C6036	Mango fruit from Haiti
India[2]	To be finalised	
Mexico	C6040	Mango fruit from Mexico
Philippines	C9212	Mango fruit from the Philippines
Taiwan	**C10583**	**Mango fruit from Taiwan**

This extension of existing policy for mango from Pakistan is based on current mango quarantine policy for India, the Philippines and Taiwan. Current policy for the import of mango fruit for consumption from these countries requires:

[2] The Final Import Risk Analysis Report for Fresh Mango Fruit from India has been released, however, to date import conditions have not been finalised.

- operational systems for the maintenance and verification of the phytosanitary status of imported mango fruit
- vapour-heat treatment (the Philippines, Taiwan) or irradiation (India) for fruit flies
- visual inspection (the Philippines, Taiwan) or irradiation (India) for mealybugs
- area freedom (the Philippines) or irradiation (India) for mango pulp weevil and mango seed weevil
- area freedom (the Philippines) or irradiation (India) for red-banded mango caterpillar
- phytosanitary inspection and certification by the National Plant Protection Organisation (NPPO)
- on-arrival phytosanitary inspection by AQIS and remedial action for live quarantine pests, if required, and regulated articles.

The import conditions for mango fruit for consumption from India, the Philippines and Taiwan are summarised below.

India

The general requirements (Condition C6000) include an AQIS import permit, a quarantine entry, a Phytosanitary Certificate, freedom from regulated articles and on-arrival inspection and remedial action, if required, by AQIS.

Fresh mango fruit for consumption imported from India must undergo a pre-export irradiation treatment at a minimum absorbed dose rate of 400 Gy for mango pulp weevil, mango seed weevil, fruit flies, red-banded mango caterpillar and mealybugs.

A Phytosanitary Certificate issued by India's NPPO must accompany every consignment of fresh mango fruit from India.

The Philippines

Australia has an agreement with the Philippines Bureau of Plant Industry (BPI) that sets out the plant quarantine conditions governing the import of commercial mango fruit from the growing regions of Guimaras Island in the Philippines into Australia.

The following ICON conditions apply:

Condition C6000 – General requirements for all fresh fruits and vegetables.

Condition C9212 – Fresh mango fruits from the Philippines (Guimaras Island).

The general requirements (Condition C6000) include an AQIS import permit, a quarantine entry, a Phytosanitary Certificate, freedom from regulated articles and on-arrival inspection and remedial action by AQIS.

Fresh mango fruit for consumption imported from the Philippines (Guimaras Island) must undergo a vapour heat disinfestation treatment for fruit flies (*Bactrocera cucurbitae*, *Bactrocera occipitalis* and *Bactrocera philippinensis*).

A Phytosanitary Certificate issued by BPI must accompany every consignment of fresh mango fruit from the Philippines and bear the following additional declaration:

> "Mangoes have been produced in Guimaras Island which has been subject to annual

> surveys and found to be free of mango pulp weevil (MPW; *Sternochetus frigidus*) and mango seed weevils (MSW; including *S. mangiferae*)"

Vapour heat treatment must be endorsed on the Phytosanitary Certificate.

The extension of existing policy for the importation of fresh mango fruit from the additional growing area of Davao Del Sur, Mindanao Island was released on 28 September 2010 (BAA 2010/27). Import conditions are yet to be finalised for this additional growing area.

Taiwan

Australia has an agreement with the Taiwan Bureau of Animal Plant Health Inspection and Quarantine (BAPHIQ) that sets out the plant quarantine conditions governing the import of commercial mango fruit into Australia.

The following ICON conditions apply:

Condition C6000 – General requirements for all fresh fruits and vegetables.

Condition C10583 – Fresh mango fruits from Taiwan.

The general requirements (Condition C6000) include an AQIS import permit, a quarantine entry, a Phytosanitary Certificate, freedom from regulated articles and on-arrival inspection and remedial action by AQIS.

Fresh mango fruit for consumption imported from Taiwan must undergo a vapour heat disinfestation treatment for fruit flies (*Bactrocera cucurbitae*, *Bactrocera dorsalis* and *Bactrocera zonata*).

A Phytosanitary Certificate issued by BAPHIQ must accompany every consignment of fresh mango fruit from Taiwan and bear the following additional declaration:

> "The mangoes in this consignment have been produced in Taiwan in accordance with the conditions governing entry of fresh mangoes to Australia and inspected and found to be free of quarantine pests"

Vapour heat treatment must be endorsed on the Phytosanitary Certificate.

Domestic arrangements

The Federal Government is responsible for regulating the movement of plants and plant products in and out of Australia. However, state and territory governments are responsible for plant health controls within Australia. Legislation relating to resource management or plant health may be used by state or territory government agencies to control interstate movement of plants or their products

1.2.4 Contaminating pests

In addition to the pests of mangoes from Pakistan that are identified in this draft extension of existing policy, there are other organisms that may arrive with mango fruit. These organisms could include pests of other crops or predators and parasitoids of other arthropods. Biosecurity Australia considers these organisms to be contaminating pests that could pose sanitary and phytosanitary risks. These risks are addressed by existing operational procedures.

In this risk analysis mango bark beetle (*Hypocryphalus mangiferae*) is considered in detail, despite being considered a contaminating pest. Its role as a vector for MSDS, its association with mango trees in the country of origin and potential association with mango fruit consignments warrants a detailed investigation of the risk of entry, establishment and spread and potential for economic consequences.

2 Method for pest risk analysis

Biosecurity Australia has conducted this PRA in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for Pest Risk Analysis* (FAO 2007) and ISPM 11: *Pest Risk Analysis for Quarantine Pests, including analysis of environmental risks and living modified organisms* (FAO 2004a).

A PRA is 'the process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it'(FAO 2009). A pest is 'any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products'(FAO 2009).

Quarantine risk consists of two major components: the probability of a pest entering, establishing and spreading in Australia from imports; and the consequences should this happen. These two components are combined to give an overall estimate of the risk.

When estimating the unrestricted risk, Biosecurity Australia considered the existing commercial production practices of the exporting country and took into account the on-arrival quarantine procedures, conducted by AQIS, that include verifying the consignment received is as described on the commercial documents and that the consignment's integrity has been maintained. Restricted risk is estimated with phytosanitary measure(s) applied. A phytosanitary measure is 'any legislation, regulation or official procedure having the purpose to prevent the introduction and spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests'(FAO 2009).

A glossary of the terms used is provided at the back of this PRA report.

PRAs are conducted in three consecutive stages.

2.1 Stage 1: Initiation

Initiation identifies the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

The initiation point for this PRA was the receipt of a technical submission from the National Plant Protection Organisation (NPPO) for access to the Australian market for the commodity. This submission included information on the pests associated with the production of the commodity, including the plant part affected, and the existing commercial production practices for the commodity.

The pests associated with the crop and the exported commodity were tabulated from information provided by the NPPO of the exporting country and literature and database searches. This information is set out in Appendix A.

For this PRA, the 'PRA area' is defined as Australia for pests that are absent, or of limited distribution and under official control. For areas with regional freedom from a pest, the 'PRA area' may be defined on the basis of a state or territory of Australia or may be defined as a region of Australia consisting of parts of a state or territory or several states or territories.

For pests that had been considered by Biosecurity Australia in other risk assessments and for which import policies already exist, a judgement was made on the likelihood of entry of pests on the commodity and whether existing policy is adequate to manage the risks associated with its import. Where appropriate, the previous policy has been adopted.

2.2 Stage 2: Pest risk assessment

A pest risk assessment (for quarantine pests) is: 'the evaluation of the probability of the introduction and spread of a pest and of the likelihood of associated potential economic consequences'(FAO 2009).

In this PRA, pest risk assessment was divided into the following interrelated processes:

2.2.1 Pest categorisation

Pest categorisation identifies which of the pests identified in Stage 1 require a pest risk assessment. The categorisation process examines, for each pest, whether the criteria in the definition for a quarantine pest are satisfied. 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, as defined in ISPM 5: *Glossary of phytosanitary terms* (FAO 2009).

The pests identified in Stage 1 were categorised using the following primary elements to identify the quarantine pests for the commodity being assessed:

- identity of the pest
- presence or absence in the PRA area
- regulatory status
- potential for establishment and spread in the PRA area
- potential for economic consequences (including environmental consequences) in the PRA area.

The results of pest categorisation are set out in Appendix A. The quarantine pests identified during pest categorisation were carried forward for pest risk assessment and are listed in Table 4.1.

2.2.2 Assessment of the probability of entry, establishment and spread

Details of how to assess the 'probability of entry', 'probability of establishment' and 'probability of spread' of a pest are given in ISPM 11 (FAO 2004a). A summary of this process is given below, followed by a description of the qualitative methodology used in this IRA.

Probability of entry

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 in the PRA area and subsequently be transferred to a host. It is based on pathway scenarios depicting necessary steps in the sourcing of the commodity for export, its processing, transport and storage, its use in Australia and the generation and disposal of waste. In particular, the ability of the pest to survive is considered for each of these various stages.

The probability of entry estimates for the quarantine pests for a commodity are based on the use of the existing commercial production, packaging and shipping practices of the exporting country. Details of the existing commercial production practices for the commodity are set out in Section 3. These practices are taken into consideration by Biosecurity Australia when estimating the probability of entry.

For the purpose of considering the probability of entry, Biosecurity Australia divides this step of this stage of the PRA into two components:

Probability of importation: the probability that a pest will arrive in Australia when a given commodity is imported

Probability of distribution: the probability that the pest will be distributed, as a result of the processing, sale or disposal of the commodity, in the PRA area and subsequently transfer to a susceptible part of a host.

Factors considered in the probability of importation include:

- distribution and incidence of the pest in the source area
- occurrence of the pest in a life-stage that would be associated with the commodity
- volume and frequency of movement of the commodity along each pathway
- seasonal timing of imports
- pest management, cultural and commercial procedures applied at the place of origin
- speed of transport and conditions of storage compared with the duration of the lifecycle of the pest
- vulnerability of the life-stages of the pest during transport or storage
- incidence of the pest likely to be associated with a consignment
- commercial procedures (e.g. refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia.

Factors considered in the probability of distribution include:

- commercial procedures (e.g. refrigeration) applied to consignments during distribution in Australia
- dispersal mechanisms of the pest, including vectors, to allow movement from the pathway to a host
- whether the imported commodity is to be sent to a few or many destination points in the PRA area
- proximity of entry, transit and destination points to hosts
- time of year at which import takes place
- intended use of the commodity (e.g. for planting, processing or consumption)
- risks from by-products and waste.

Probability of establishment

Establishment is defined as the ‘perpetuation for the foreseeable future, of a pest within an area after entry’ (FAO 2004a). In order to estimate the probability of establishment of a pest, reliable biological information (lifecycle, host range, epidemiology, survival, etc.) is obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment.

Factors considered in the probability of establishment in the PRA area include:

- availability of hosts, alternative hosts and vectors
- suitability of the environment

- reproductive strategy and potential for adaptation
- minimum population needed for establishment
- cultural practices and control measures.

Probability of spread

Spread is defined as 'the expansion of the geographical distribution of a pest within an area' (FAO 2004a). The probability of spread considers the factors relevant to the movement of the pest, after establishment on a host plant or plants, to other susceptible host plants of the same or different species in other areas. In order to estimate the probability of spread of the pest, reliable biological information is obtained from areas where the pest currently occurs. The situation in the PRA area is then carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the probability of spread.

Factors considered in the probability of spread include:

- suitability of the natural and/or managed environment for natural spread of the pest
- presence of natural barriers
- potential for movement with commodities, conveyances or by vectors
- intended use of the commodity
- potential vectors of the pest in the PRA area
- potential natural enemies of the pest in the PRA area.

Assigning qualitative likelihoods for the probability of entry, establishment and spread

In its qualitative PRAs, Biosecurity Australia uses the term 'likelihood' for the descriptors it uses for its estimates of probability of entry, establishment and spread. Qualitative likelihoods are assigned to each step of entry, establishment and spread. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible (Table 2.1). Descriptive definitions for these descriptors and their indicative probability ranges are given in Table 2.1. The indicative probability ranges are only provided to illustrate the boundaries of the descriptors. These indicative probability ranges are not used beyond this purpose in qualitative PRAs. The standardised likelihood descriptors and the associated indicative probability ranges provide guidance to the risk analyst and promote consistency between different risk analyses.

Table 2.1 Nomenclature for qualitative likelihoods

Likelihood	Descriptive definition	Indicative probability (P) range
High	The event would be very likely to occur	$0.7 < P \leq 1$
Moderate	The event would occur with an even probability	$0.3 < P \leq 0.7$
Low	The event would be unlikely to occur	$0.05 < P \leq 0.3$
Very low	The event would be very unlikely to occur	$0.001 < P \leq 0.05$
Extremely low	The event would be extremely unlikely to occur	$0.000001 < P \leq 0.001$
Negligible	The event would almost certainly not occur	$0 \leq P \leq 0.000001$

The likelihood of entry is determined by combining the likelihood that the pest will be imported into the PRA area and the likelihood that the pest will be distributed within the PRA area, using a matrix of rules (Table 2.2). This matrix is then used to combine the likelihood of entry and the likelihood of establishment, and the likelihood of entry and establishment is then combined with the likelihood of spread to determine the overall likelihood of entry, establishment and spread.

For example, if the probability of importation is assigned a likelihood of ‘low’ and the probability of distribution is assigned a likelihood of ‘moderate’, then they are combined to give a likelihood of ‘low’ for the probability of entry. The likelihood for the probability of entry is then combined with the likelihood assigned to the probability of establishment (e.g. ‘high’) to give a likelihood for the probability of entry and establishment of ‘low’. The likelihood for the probability of entry and establishment is then combined with the likelihood assigned to the probability of spread (e.g. ‘very low’) to give the overall likelihood for the probability of entry, establishment and spread of ‘very low’.

Table 2.2 Matrix of rules for combining qualitative likelihoods

	High	Moderate	Low	Very low	Extremely low	Negligible
High	High	Moderate	Low	Very low	Extremely low	Negligible
Moderate		Low	Low	Very low	Extremely low	Negligible
Low			Very low	Very low	Extremely low	Negligible
Very low				Extremely low	Extremely low	Negligible
Extremely low					Negligible	Negligible
Negligible						Negligible

Time and volume of trade

One factor affecting the likelihood of entry is the volume and duration of trade. If all other conditions remain the same, the overall likelihood of entry will increase as time passes and the overall volume of trade increases.

Biosecurity Australia normally considers the likelihood of entry on the basis of the estimated volume of one year’s trade. This is a convenient value for the analysis that is relatively easy to estimate and allows for expert consideration of seasonal variations in pest presence, incidence and behaviour to be taken into account. The consideration of the likelihood of entry, establishment and spread and subsequent consequences takes into account events that might happen over a number of years even though only one year’s volume of trade is being considered. This difference reflects biological and ecological facts, for example where a pest or disease may establish in the year of import but spread may take many years.

The use of a one year volume of trade has been taken into account when setting up the matrix that is used to estimate the risk and therefore any policy based on this analysis does not simply apply to one year of trade. Policy decisions that are based on Biosecurity Australia’s method that uses the estimated volume of one year’s trade are consistent with Australia’s policy on appropriate level of protection and meet the Australian Government’s requirement for ongoing quarantine protection. Of course, if there are substantial changes in the volume and nature of the trade in specific commodities then Biosecurity Australia has an obligation to review the risk analysis and, if necessary, provide updated policy advice.

In assessing the volume of trade in this PRA, Biosecurity Australia assumed that a substantial volume of trade will occur.

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the likely consequences if the pests or disease agents were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. The requirements for assessing potential consequences are given in Article 5.3 of the SPS Agreement (WTO 1995), (FAO 2009) and ISPM 11 (FAO 2004a).

Direct pest effects are considered in the context of the effects on:

- plant life or health
- other aspects of the environment.

Indirect pest effects are considered in the context of the effects on:

- eradication, control, etc
- domestic trade
- international trade
- environment.

For each of these six criteria, the consequences were estimated over four geographic levels, defined as:

- **Local**: an aggregate of households or enterprises (a rural community, a town or a local government area).
- **District**: a geographically or geopolitically associated collection of aggregates (generally a recognised section of a state or territory, such as ‘Far North Queensland’).
- **Regional**: a geographically or geopolitically associated collection of districts in a geographic area (generally a state or territory, although there may be exceptions with larger states such as Western Australia).
- **National**: Australia wide (Australian mainland states and territories and Tasmania).

For each criterion, the magnitude of the potential consequence at each of these levels was described using four categories, defined as:

- **Indiscernible**: pest impact unlikely to be noticeable.
- **Minor significance**: expected to lead to a minor increase in mortality/morbidity of hosts or a minor decrease in production but not expected to threaten the economic viability of production. Expected to decrease the value of non-commercial criteria but not threaten the criterion’s intrinsic value. Effects would generally be reversible.
- **Significant**: expected to threaten the economic viability of production through a moderate increase in mortality/morbidity of hosts, or a moderate decrease in production. Expected to significantly diminish or threaten the intrinsic value of non-commercial criteria. Effects may not be reversible.
- **Major significance**: expected to threaten the economic viability through a large increase in mortality/morbidity of hosts, or a large decrease in production. Expected to severely or irreversibly damage the intrinsic ‘value’ of non-commercial criteria.

Values were translated into a qualitative impact score (A–G)[3] using Table 2.3.

Table 2.3 Decision rules for determining the consequence impact score based on the magnitude of consequences at four geographic scales

		Geographic scale			
		Local	District	Region	Nation
Magnitude	Indiscernible	A	A	A	A
	Minor significance	B	C	D	E
	Significant	C	D	E	F
	Major significance	D	E	F	G

The overall consequence for each pest is achieved by combining the qualitative impact scores (A–G) for each direct and indirect consequence using a series of decision rules (Table 2.4). These rules are mutually exclusive, and are assessed in numerical order until one applies.

Table 2.4 Decision rules for determining the overall consequence rating for each pest

Rule	The impact scores for consequences of direct and indirect criteria	Overall consequence rating
1	Any criterion has an impact of '**G**'; or more than one criterion has an impact of '**F**'; or a single criterion has an impact of '**F**' and each remaining criterion an '**E**'.	Extreme
2	A single criterion has an impact of '**F**'; or all criteria have an impact of '**E**'.	High
3	One or more criteria have an impact of '**E**'; or all criteria have an impact of '**D**'.	Moderate
4	One or more criteria have an impact of '**D**'; or all criteria have an impact of '**C**'.	Low
5	One or more criteria have an impact of '**C**'; or all criteria have an impact of '**B**'.	Very Low
6	One or more but not all criteria have an impact of '**B**', and all remaining criteria have an impact of '**A**'.	Negligible

2.2.4 Estimation of the unrestricted risk

Once the above assessments are completed, the unrestricted risk can be determined for each pest or groups of pests. This is determined by using a risk estimation matrix (Table 2.5) to combine the estimates of the probability of entry, establishment and spread and the overall consequences of pest establishment and spread. Therefore, risk is the product of likelihood and consequence.

When interpreting the risk estimation matrix, note the descriptors for each axis are similar (e.g. low, moderate, high) but the vertical axis refers to likelihood and the horizontal axis refers to consequences. Accordingly, a 'low' likelihood combined with 'high' consequences,

[3] In earlier qualitative IRAs, the scale for the impact scores went from A to F and did not explicitly allow for the rating 'indiscernible' at all four levels. This combination might be applicable for some criteria. In this report, the impact scale of A-F has changed to become B-G and a new lowest category A ('indiscernible' at all four levels) was added. The rules for combining impacts in Table 2.4 were adjusted accordingly.

is not the same as a 'high' likelihood combined with 'low' consequences – the matrix is not symmetrical. For example, the former combination would give an unrestricted risk rating of 'moderate', whereas, the latter would be rated as a 'low' unrestricted risk.

Table 2.5 Risk estimation matrix

Likelihood of pest entry, establishment and spread	Negligible	Very low	Low	Moderate	High	Extreme
High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
Very low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
Extremely low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Consequences of pest entry, establishment and spread

2.2.5 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. The band of cells in Table 2.5 marked 'very low risk' represents Australia's ALOP.

2.3 Stage 3: Pest risk management

Pest risk management describes the process of identifying and implementing phytosanitary measures to manage risks to achieve Australia's ALOP, while ensuring that any negative effects on trade are minimised.

The conclusions from pest risk assessment are used to decide whether risk management is required and if so, the appropriate measures to be used. Where the unrestricted risk estimate exceeds Australia's ALOP, risk management measures are required to reduce this risk to a very low level. The guiding principle for risk management is to manage risk to achieve Australia's ALOP. The effectiveness of any proposed phytosanitary measure (or combination of measures) is evaluated, using the same approach as used to evaluate the unrestricted risk, to ensure it reduces the restricted risk for the relevant pest or pests to meet Australia's ALOP.

ISPM 11 (FAO 2004a) provides details on the identification and selection of appropriate risk management options and notes that the choice of measures should be based on their effectiveness in reducing the probability of entry of the pest.

Examples given of measures commonly applied to traded commodities include:

- options for consignments – e.g., inspection or testing for freedom from pests, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on preparation of the consignment, specified treatment of the consignment, restrictions on end-use, distribution and periods of entry of the commodity
- options preventing or reducing infestation in the crop – e.g., treatment of the crop, restriction on the composition of a consignment so it is composed of plants belonging to resistant or less susceptible species, harvesting of plants at a certain age or specified time of the year, production in a certification scheme
- options ensuring that the area, place or site of production or crop is free from the pest – e.g., pest-free area, pest-free place of production or pest-free production site
- options for other types of pathways – e.g., consider natural spread, measures for human travellers and their baggage, cleaning or disinfestation of contaminated machinery
- options within the importing country – e.g., surveillance and eradication programs
- prohibition of commodities – if no satisfactory measure can be found.

Risk management measures are identified for each quarantine pest where the risk exceeds Australia's ALOP. These are presented in the 'Pest Risk Management' section of this report.

3 Pakistan’s commercial production practices for mangoes

This chapter provides information on Pakistan’s pre-harvest, harvest and post-harvest commercial production practices for mangoes. The export capability of Pakistan is also outlined.

3.1 Assumptions used in estimating unrestricted risk

Biosecurity Australia took the following information into consideration when estimating the unrestricted risk of pests that may be associated with the import of this commodity.

3.2 Climate in production areas

The climate in Pakistan is arid with hot summers and cool or cold winters (Blood 1996). There are wide variations in temperature extremes at any given location (Blood 1996). Annual rainfall across the country ranges from 125 mm in the southern plains to 500–900 mm in the northern plains (FAO 2004b). The majority of rainfall (up to 70%) occurs as heavy downpours as a result of the the summer monsoons (FAO 2004b). Summers, except in the mountainous areas, are very hot with maximum temperatures exceeding 40 °C, while the minimum temperatures in winter are marginally above freezing (FAO 2004b). Agricultural land use is influenced by geography and water availability.

3.3 Pre-harvest

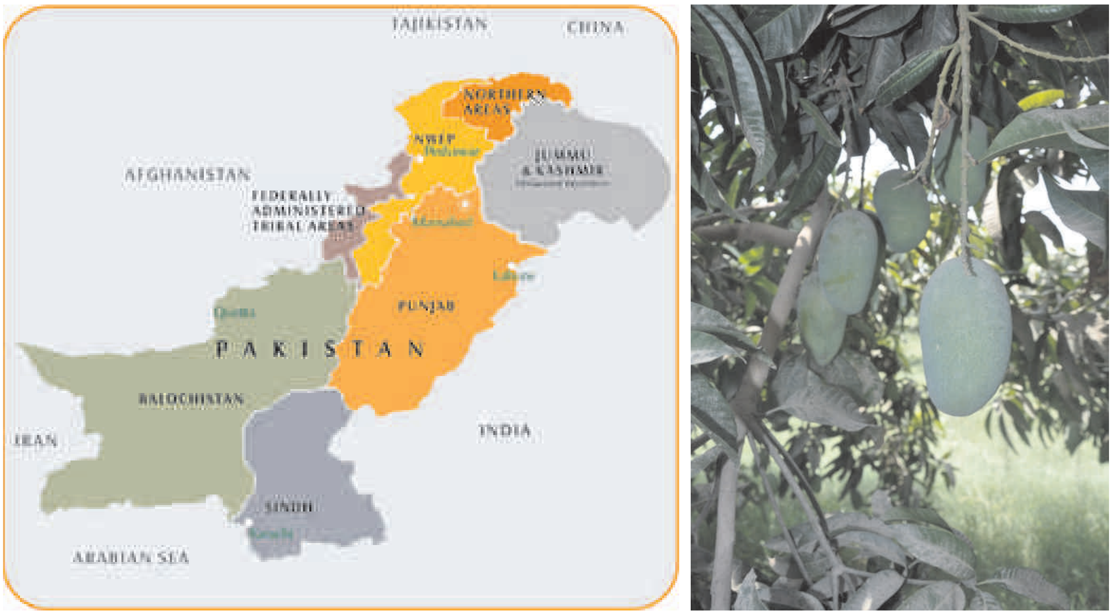
Pakistan is the world's fifth largest producer of mango fruits producing around 6% of the world’s total mango production (Amin *et al.* 2008). The export volume is a small portion of domestic production (4% of production) but makes Pakistan the world’s third largest exporter.

3.3.1 Production

Mango production in Pakistan is located primarily in the eastern states of Punjab and Sindh. The province of Punjab is the largest single mango growing region in Pakistan and accounts for 66% of Pakistan’s mango production (Amin *et al*. 2008). The main mango growing districts in the Punjab province are Bahawalpur, Garh, Multan, Muzzaffar and Rahim Yar Khan. The districts of Bahawalpur and Multan encompass 54% of the total area producing mangoes in Punjab (Bakhsh *et al*. 2006). The province of Sindh is the second largest mango growing region and produces 32.5% of Pakistan’s mango production (Amin *et al*. 2008). In Sindh, the primary production areas are in Hyderabad, Mirpur Khas and Thatta. A small amount of mango is also produced in the Baluchistan and North Western Frontier Province (Amin *et al.* 2008).

Mango is the second most cultivated fruit crop in Pakistan (Maqbool *et al*. 2007), with production in 2006 reaching 1.2 million tonnes (PHDEB 2005). In 2006, an estimated 184 000 tonnes of mango fruit was exported from Pakistan and it is predicted that this volume will increase to 200 000 tonnes by 2010. Pakistan currently exports mangoes to markets in Europe, the Middle East and has recently gained access to the Chinese and Iranian markets (PHDEB 2005).

Figure 1: Mango production occurs mainly in Punjab and Sindh provinces (left from Boardman 2010) and a Chaunsa variety mango in a commercial orchard in the province of Punjab (right)



3.3.2 Cultivars

In Pakistan, mangoes are grown in hot and humid regions, at elevations ranging from 200 to 300 metres. The suitable temperature range for mango production is 15–40 °C. Mangoes are harvested when the fruit is fully developed and mature. Autumn arrives about one month earlier in Sindh Province than in Punjab, and for this reason the early varieties of mango tend to be grown in Sindh, and the later varieties in Punjab. Mango varieties start ripening in May or June and continue until August (PARC 2011) with mango fruit being available for sale until mid-September. Some commercial varieties, the provinces in which mangoes are produced and seasonality of mangoes in Pakistan are summarised in Table 3.1.

Table 3.1 Commercial varieties, provinces and seasonality of Pakistan mangoes

Variety	Provinces	May	Jun	Jul	Aug	Sep
Dusehri	Punjab					
Chaunsa	Punjab					
Langra	NWFP, Punjab					
Rataul	Punjab					
Sammar Bahisht	NWFP, Punjab					
Sindhri	Baluchistan, Sindh					

3.3.3 Cultivation practices

The Pakistan Horticulture Development and Export Company (PHDEC) has implemented an integrated production system to improve the quality of export fruit through the Australia-Pakistan Agriculture Sector Linkages Program (ASLP) mango supply chain management project. The PHDEC and the University of Agriculture, Faisalabad are the implementing partners from Pakistan, while the University of Queensland, the Department of Employment, Economic Development and Innovation (DEEDI) in the Queensland Government, and the Department of Agriculture and Forestry in the Government of Western

Australia are collaborators. Through the ASLP mango supply chain management project, a variety of information is provided to farmers to increase the quality of fruit produced. To date, a mango maturity testing guide, mango skin colour guide, mango ripening guide and mango export training guide have been distributed to the farmers.

Orchard management

An integrated pest management strategy is used to control pests affecting mango orchards. The integrated pest management strategy includes cultural practices (for example, removal of fallen fruits), mechanical practices (for example, removal of malformed panicles; sticky bands to trap crawling mealybug nymphs) and chemical control measures (fungicidal and insecticidal spray). The orchards are managed by following good agricultural practices (GAP) and several orchards have been registered for export under global GAP certification (Table 3.2). New exporters have started mango trade under ASLP best practices in 2010. They have targeted the UK, UAE and European markets (particularly Denmark, Norway, and Sweden).

Table 3.2: Global GAP certified orchards for mango export

Registered mango orchards	Area (acres)
Ali Tareen Farms, Lodhran, Punjab	1000
JWD Orchards, Rahim Yar Khan, Punjab	350
Dhillon Agri Farm, Rahim Yar Khan, Punjab	170
Lutfa Abad Mango Farm, Multan, Punjab	137
Surbuland Mango Farm, Multan, Punjab	250
Atta Farid Fruit Farm, Multan, Punjab	75
Asim Agriculture Farm, Tando Allah Yar, Sindh	123

Officers from Biosecurity Australia travelled to Pakistan to observe the existing commercial production practices and processing procedures for fresh mango fruit in Punjab and Sindh provinces in July 2010. This visit clarified Biosecurity Australia's understanding of the cultivation and harvesting methods, pest control and management and the packing procedures proposed to produce and export fresh mango fruit to Australia.

3.3.4 Pest management

Mango growers in Pakistan use a range of fungicides and insecticides registered to control diseases and insects in orchards (Table 3.3). These chemical measures compliment cultural practices such as stock tapes to trap crawling nymphs, removal of fallen fruit, and removal of malformed panicles.

Fruit flies (*Bactocera dorsalis* and *B. zonatus*) are important pests of mango in Pakistan and populations are minimised by methyl eugenol impregnated insect traps (Ishaq *et al*. 2004) or the Male Annihilation Technique (MAT). Immature stages are controlled by both burial of routinely collected fallen fruit and by ploughing the soil between trees to expose pupae.

Drosicha stebbingi is an important pest of mango in Pakistan and is controlled by a combination of different cultural, biological and chemical methods (Ishaq *et al*. 2004). To prevent entry of mealybug nymphs, from November to December each year tree banding is conducted using a 15 cm polythene sheet and strips are then greased to trap the crawling nymphs. In addition, predatory lady beetles are used for biological control of mealybugs.

During a survey conducted by the Queensland Department of Primary Industries and Fisheries (QDPI&F) in March and April 2006 as part of an Australian Council for International Agriculture Research (ACIAR) funded project mango malformation, powdery mildew, blossom blight, foliar anthracnose and bacterial black spot were the diseases observed in mango orchards in Pakistan (QDPI&F 2006). The insect pests observed during this survey include mango leaf and blossom midge, leafhoppers, scales and bark beetles.

Table 3.3: Fungicides recommended by province agriculture departments for use in mango orchards with active ingredients listed in brackets (modified from Government of Sindh, Agriculture Department 2011)

Disease/insects	Fungicide	Time of application
Diseases		
Anthracnose	TopsinM® 70WP (Thiophanate-methyl); Antracol® 70WP (Propineb); Aliette® 80WP (Fosetyl-aluminium)	July – August and repeat in November –December
Powdery mildew	Score® 250EC (Difenoconazole); Baytan Foliar® 250EC (Triadimenol); Success™ 72 WP (Spinosad); Topas® 100EC (Penconazole)	Preventative sprays in January (floral bud stage) or curative spray in February March (fruit setting stage)
Sooty mould	Copper oxychloride 50WP (Copper oxychloride)	At the appearance of disease
Insect pests		
Mango hoppers	Confidor® SL200 (Imidacloprid); Karate® 2.5EC (Lambda-cyhalothrin); Actara® 25WG (Thiamethoxam); Jozar 202SL (Imidacloprid and Acetamiprid); Danitol® 30EC (Fenpropathrin)	
Thrips	Confidor® SL200 (Imidacloprid); Mospilan® 20SP (Acetamiprid); Jozer 202SL (Imidacloprid and Acetamiprid)	
Shoot-borer	Karate® 2.5EC (Lambda-cyhalothrin); Talstar® 10EC (Bifenthrin); Bulldock® 025EC (Beta-cyfluthrin); Danitol® 30EC (Fenpropathrin)	
Scales/ mealybugs	Lorsban® 40EC (Chloropyrifos); Curacron® 500EC (Profenofos); Acephate 75SP (Acephate)	
Mango midge	Baythroid® 525EC (Cyfluthrin); Basudin® 60EC (Diazinon); Decis Super® 100EC (Deltamethrin); Karate® 2.5EC (Lambda-cyhalothrin)	
Fruit flies	Dipterex® 80SP (Trichlorfon); Basudin® 60EC (Diazinon); Laser® 125EC (Cycloxydim)	

Figure 2: Inspection of a commercial orchard in the province of Punjab

Killer pads used in the MAT were observed in all the mango orchards visited by Biosecurity Australia officers in July 2010. MAT involves the use of a high density of bait stations consisting of a male lure combined with an insecticide, to reduce the male population of fruit flies to such a low level that mating does not occur. This is achieved by distributing cordelitos or caneite blocks impregnated with the lure/insecticide mixture.

3.4 Harvesting and handling procedures

Harvesting system

Mangoes are harvested from when green through to ripe. Care is taken as the skin and flesh of the fruit can be damaged by rough handling and by contact with mango sap. In Pakistan, mango fruit for export are selected for size and freedom from blemishes; they are picked by the stem. This system involves cutting the fruit off the tree with 10–20 cm of stem attached. This length of stem prevents sap release.

Figure 3: Mango harvesting for export in a commercial orchard in the province of Punjab

De-sapping is done either in the field or in the packing shed. The fruit harvested with stem is then carefully packed in plastic crates or bins and transported to the collection site in the field. Once in the field collection site, the fruit are dipped in a solution of detergent before de-stemming by hand. The washing of fruit with detergent solution helps to prevent them from sap burn. Fruits are then washed to remove the detergent before they are placed in plastic crates or bulk bins and delivered to the packing shed.

Figure 4: Washing mangoes in field to protect from sap burn

Washing in detergent may also remove insects present on the fruit and reduces the risk of introduction of contaminated fruit into the supply chain. However, this procedure will not affect any internal feeders like fruit flies.

3.5 Post-harvest

Hot water treatment and irradiation facilities are available for mango treatment in Pakistan. An experimental vapour heat treatment facility is also available but is not used for commercial consignments. Three hot water treatment facilities located in Karachi, Pakistan have been approved by China, Iran and Jordan for the treatment of mango. An irradiation facility located at Lahore has been approved by APHIS/USDA for the export of irradiated mango from Pakistan to the USA.

Biosecurity Australia officers visited a mango treatment facility at Karachi in July 2010 and observed a consignment being processed to export mangoes to the European Union and Malaysia. The process of cleaning, washing and hot water treatment at the facility is carried out via an automated system. This practice may be conducted as an alternative, or in addition, to standard in-field commercial practices. The fruit is moved through a treatment unit via adjustable speed roller conveyors. The thermostatically controlled hot water treatment unit is fully supervised and each process run is recorded. The whole treatment plant is covered and mango fruit is seen only as it moves from one treatment tank to another tank, as it progresses through cleaning or washing, de-sapping, hot water treatment and the application of wax emulsion.

Initial grading of mango fruit from registered orchards occurs during unloading at the packing house facility where it undergoes a quality control inspection; damaged or diseased fruits received are segregated into crates. This process reduces the risk of introduction of contaminated fruit into the supply chain.

Cleaning and washing of mango fruit is carried out through an automated washing system fitted with overhead sprayers and rotating brushes. Water is mixed with a detergent and fruit is washed for a period of 3–5 minutes at 45–48 °C.

Hotwater treatment

Hot water treatment is undertaken after cleaning. The treatment of fruit is carried out in treatment tanks fitted with thermostatic controls to maintain a constant temperature of 48 °C for 60 minutes (pulp temperature 46.2–46.6 °C). Once the treatment is finished, the fruit are placed in a wax emulsion tank for waxing. The fruit is then dried, graded and sorted.

Sorting and grading of mangoes involves sorting fruit into export quality and other fruit. Any immature, scarred, blemished or otherwise damaged fruit are removed from the export pathway.

Mango is packed according to the market requirements and after packing is kept for two hours at room temperature before being stored in a cooling room at 10–13 °C.

Irradiation

After cleaning and washing treatment, mangoes are sorted into export quality and other fruit. Any immature, scarred, blemished or otherwise damaged fruit are removed from the export pathway. Mango fruit is packed according to the market requirements and sent for irradiation.

3.5.1 Packing house

After de-sapping mango fruit from registered orchards, the fruit is unloaded at the packing house facility and undergoes another quality control inspection. Any damaged or diseased fruits received are segregated into crates and are removed from the export pathway.

4 Pest risk assessments for quarantine pests

Quarantine pests associated with the mangoes from Pakistan are identified in Appendix A. This chapter assesses the probability of the entry, establishment and spread of these pests and the likelihood of associated potential economic, including environmental, consequences. The quarantine pests of concern of mango fruit from Pakistan are shown in Table 4.1. The majority of the pests (fruit flies, armoured scales, mealybugs, thrips and mango malformation) have previously been assessed in the policy for the Importation of Fresh Mangoes (*Mangifera indica* L.) from Taiwan (Biosecurity Australia 2006) and the Final Import Risk Analysis Report for Fresh Mango Fruit from India (Biosecurity Australia 2008). However, mango bark beetle potentially carrying propagules of the pathogen complex associated with mango sudden death syndrome (MSDS) has not been previously considered. Therefore, a complete pest risk assessment on mango bark beetle potentially carrying propagules of the pathogen complex associated with mango MSDS was conducted. Full details of the pest categorisation are provided in Appendix A.

Table 4.1: Quarantine pests for mango fruits from Pakistan

Pest	Common name
Bark beetle [Coleoptera: Scolytinae]	
Hypocryphalus mangiferae (Stebbing 1914)[4]	Mango bark beetle
Fruit flies [Diptera: Tephritidae]	
Bactrocera correcta (Bezzi, 1916)	Guava fruit fly [EP]
Bactrocera dorsalis (Hendel, 1912)	Oriental fruit fly [EP]
Bactrocera zonata (Saunders, 1841)	Peach fruit fly [EP]
Armoured scales [Hemiptera: Diaspididae]	
Parlatoria crypta (McKenzie, 1943)	Mango white scale [EP]
Parlatoria pseudaspidiotus (Lindinger, 1905)	Vanda scale [EP, WA]
Mealybugs [Hemiptera: Pseudococcidae]	
Ferrisia virgata (Cockerell, 1893)	Striped mealybug [EP, WA]
Rastrococcus invadens (Williams 1986)	Mango mealybug [EP]
Rastrococcus spinosus (Robinson, 1918)	Philippine mango mealybug [EP]
Thrips [Thysanoptera: Thripidae]	
Rhipiphorothrips cruentatus (Hood, 1919)	Mango thrips [EP]
Fungi	
Fusarium mangiferae (Britz, M.J., Wingf. and Marasas 2002)	Mango malformation [EP]
WA: Quarantine pest for the state of Western Australia	
EP: Species has been assessed previously and for which import policy already exists.	

Where previous policy exists, assessments of the probabilities of entry, establishment and spread for quarantine pests were not conducted in this non-regulated review of existing policy. The rationale for this was:

[4] The mango bark beetle is considered in this risk analysis as a vector for propagules of the pathogen complex of mango sudden death syndrome (*Ceratocystis manginecans*). The causal agents of MSDS, *C. manginecans*, are considered in this risk assessment for their potential to be vectored by the mango bark beetle; they are not known to independently be associated with the fruit import pathway.

- Biosecurity Australia reviewed the available literature and determined that the association of these pests with mango fruit from Pakistan is comparable to India and Taiwan. For example:
  - no published evidence was found indicating differences in the prevalence of these pests in Pakistan and India or Taiwan;
  - pest management practices and commercial procedures applied are similar for these countries; and
  - commercial procedures (e.g. refrigeration) applied to consignments during transport and storage in the country of origin, and during transport to Australia are likely to be similar for these countries.

  For this reason, Biosecurity Australia considers that the probability of importation of these pests with fresh mango fruit from Pakistan would be the same as that for mango fruit from India and Taiwan.
- Once mango fruits (and any associated pests) have entered Australia with trade, the country of origin is not likely to affect the probability of distribution, establishment, or spread. For this reason, Biosecurity Australia considers that the probability of distribution, establishment and spread of these pests with fresh mango fruit from Pakistan would be the same as that for mango fruit from India and Taiwan.
- Stakeholders were consulted on the outcome of previous assessments and comments provided by stakeholders were considered in finalising the documents.

Accordingly, the existing assessments of entry, establishment and spread for these pests conducted for India and Taiwan are considered appropriate for the importation of fresh mango fruit from Pakistan. Consequently, the unrestricted risk estimate for quarantineable pests of mango in Pakistan is considered to be equivalent to the unrestricted risk of quarantineable pests in India and Taiwan.

The assessment of potential consequences for quarantine pests of mango from Pakistan, determined through the process of pest categorisation (Table 4.1), has been previously undertaken in the Policy for the Importation of Fresh Mangoes from Taiwan (Biosecurity Australia 2006) and Final Import Risk Analysis Report for Fresh Mango Fruit from India (Biosecurity Australia 2008).

Once a pest has established in Australia, the country of origin is not likely to affect the potential for economic consequences. Accordingly, there is no need to re-assess this component.

As indicated above, fruit flies, mealybugs, mango thrips and members of the *Fusarium*-complex associated with mango malformation have been assessed in detail with the importation of mango from India (Biosecurity Australia 2008) and Taiwan (Biosecurity Australia 2006). This existing policy is adopted for mango fruit from Pakistan and therefore, detailed risk assessments are not presented here for these pests. A description of the pests and a summary of the risk ratings are presented below.

4.1 Fruit flies [Diptera: Tephritidae]

Fruit flies in the genus *Bactrocera* are one of the four fruit fly genera that are of most concern globally. Fruit flies are considered to be among the most damaging pests to horticulture (White and Elson-Harris 1992; Peña *et al.* 1998). *Bactrocera* spp. attack a wide range of fruit crops including tropical, semitropical and temperate fruit in South-East Asia, Oceania, the subcontinent and parts of Africa. Fruit flies complete their feeding and development within their host fruit (Fletcher 1989a), but are free-living in the adult stage. The transportation of infected fruit is one of the major means of movement and dispersal of fruit flies (Fletcher 1989b) and as such they are considered important pests (White and Elson-Harris 1992).

The fruit flies of quarantine concern associated with mango fruit are:

- *Bactrocera correcta* – Guava fruit fly **EP**
- *Bactrocera dorsalis* – Oriental fruit fly **EP**
- *Bactrocera zonata* – Peach fruit fly **EP**

Bactrocera dorsalis was previously assessed with the importation of mangoes from India (Biosecurity Australia 2008) and Taiwan (Biosecurity Australia 2006); and *Bactrocera correcta* and *Bactrocera zonata* were previously assessed with the importation of mangoes from India (Biosecurity Australia 2008). This existing policy is adopted for mango from Pakistan. Therefore, a risk assessment is not presented here. A summary of the unrestricted risk of assessment conducted in the mango import policy documents from India and Taiwan is presented below.

Table 4.2: Summary of the pest risk assessment for fruit flies for fresh mango fruit from India and Taiwan

PRA criterion	Risk Rating
Probability of importation	High
Probability of distribution	High
➔ Probability of entry	High
Probability of establishment	High
Probability of spread	High
➔ Overall probability of entry, establishment and spread	High
Consequences	High
Unrestricted risk	High

4.1.1 Unrestricted risk estimate

The unrestricted risk estimate for *Bactrocera correcta*, *B. dorsalis* and *B. zonata* is 'high', which is above Australia's ALOP. Therefore, specific risk management measures are required for these fruit flies.

Bactrocera cucurbitae was identified as a pest of quarantine concern associated with mango fruit in previous policies (India, the Philippines and Taiwan). However, this species has a strong preference for plants in the Cucurbitaceae [melon] family (White and Elson-Harris 1992). *Bactrocera cucurbitae* is a very serious pest of cucurbit crops and has been recorded from a few non-cucurbit hosts (Allwood *et al.* 1999; White and Elson-Harris 1992). White and Elson-Harris (1992) note that many of the non-cucurbit host records may have been based on casual observation of adults resting on plants or caught in traps set in non-host trees, but not necessarily records of development within fruit of non-cucurbit hosts.

Adult *B. cucurbitae* have been observed to 'roost' in mango trees, as well as on citrus and guava, where they feed on honeydew produced by aphids and mealybugs (Lall and Singh

1969; Dhillon *et al.* 2005). Adults migrate from roosting sites to fruits of preferred hosts to lay eggs (Lall and Singh 1969).

Mango is not listed as a host of *B. cucurbitae* by some researchers (Allwood *et al.* 1999), but others list mango as either an occasional host (Weems *et al.* 2004) or a secondary host (Botha *et al.* 2004). There are no records to support that this fruit fly lays eggs on, or its larvae develop within, mango fruit. Consequently, *B. cucurbitae* is not considered further in this review of policy.

4.2 Armoured scales [Hemiptera: Diaspididae]

Armoured scales construct a wax-like, fibrous 'scale' that covers the insect (Carver *et al.* 1991). This 'scale' protects the insect against physical and chemical aggressions (Foldi 1990) and strongly affixes the insect to the plants on which they occur (Burger and Ulenberg 1990). Scale insects are small and often inconspicuous and can spread widely on plants and plant products. Armoured scales are unlikely to be killed by a washing solution, as the physical properties of their protective cover provide an effective barrier against contact toxicants (Foldi 1990).

The armoured scales of quarantine concern associated with mango fruit are:

- *Parlatoria crypta* – Mango white scale [EP]
- *Parlatoria pseudaspidiotus* – Vanda orchid scale [EP, WA]

Parlatoria crypta was previously assessed with the importation of mangoes from India (Biosecurity Australia 2008) and *Parlatoria pseudaspidiotus* was previously assessed with the importation of mangoes from Taiwan (Biosecurity Australia 2006). This existing policy is adopted for mango from Pakistan. Therefore, a risk assessment is not presented here. A summary of the unrestricted risk assessment conducted in the mango import policy documents from India and Taiwan is presented below.

Table 4.3: Summary of the pest risk assessment for armoured scales for fresh mango fruit from India and Taiwan

PRA criterion	Risk rating (*P. crypta*)	Risk rating (*P. pseudaspidiotus*)
Probability of importation	High	High
Probability of distribution	Low	Moderate
➔ Probability of entry (importation x distribution)	Low	Moderate
Probability of establishment	High	High
Probability of spread	Moderate	Moderate
➔ Overall probability of entry, establishment and spread	Low	Low
Consequences	Low	Low
Unrestricted risk	Very low	Very low

4.2.1 Unrestricted risk estimate

The unrestricted risk estimate for these armoured scales is 'very low', which meets Australia's ALOP. Therefore, no specific risk management measures are required for these armoured scales.

4.3 Mealybugs [Hemiptera: Pseudococcidae]

Mealybugs are sucking insects that injure plants by extracting large quantities of sap and producing honeydew which serves as a substrate for the development of sooty mould. Mealybugs generally prefer warm, humid and sheltered sites away from adverse environmental conditions and natural enemies. Many mealybug species pose problems to agriculture, particularly when introduced into new areas of the world where their natural enemies are not present (Millar *et al.* 2002).

The mealybugs of quarantine concern associated with mango fruit are:

- *Ferrisia virgata* – Striped mealybug [EP, WA]
- *Rastrococcus invadens* – Mango mealybug [EP]
- *Rastrococcus spinosus* – White mealybug [EP]

Rastrococcus spinosus was previously assessed with the importation of mangoes from India (Biosecurity Australia 2008) and Taiwan (Biosecurity Australia 2006), and *Ferrisia virgata* and *Rastrococcus invadens* were previously assessed with the importation of mangoes from India (Biosecurity Australia 2008). This existing policy is adopted for mango fruit from Pakistan. Therefore, a risk assessment is not presented here. A summary of the unrestricted risk of assessment conducted in the mango import policy documents from India and Taiwan is presented below.

Table 4.4: Summary of the pest risk assessment for mealybugs for fresh mango fruit from India and Taiwan

PRA Criterion	Risk rating
Probability of importation	High
Probability of distribution	Moderate
➔ Probability of entry (importation x distribution)	Moderate
Probability of establishment	High
Probability of spread	High
➔ Overall probability of entry, establishment and spread	Moderate
Consequences	Low
Unrestricted risk	Low

4.3.1 Unrestricted risk estimate

The unrestricted risk estimate for *Ferrisia virgata*, *Rastrococcus invadens* and *R. spinosus* is ‘low’, which is above Australia’s ALOP. Therefore, specific risk management measures are required for these mealybugs.

4.4 Mango/Grapevine thrips [Thysanoptera: Thripidae]

The mango/grapevine thrips (*Rhipiphorothrips cruentatus*) is considered one of the major pests of mango in Pakistan (Buriro 2006; PHDEB 2007). *Rhipiphorothrips cruentatus* causes damage by laying eggs in the panicle and feeding on floral parts. This causes a reduction in pollination, yield loss and a reduction in market value of mango fruits (Lee and Wen 1982; Khuhro *et al.* 1996; Buriro 2006). Additionally, nymphs and adults feed on leaves and fruits of host plants (Lee and Wen 1982; Srivastava 1997; Shanthi *et al.* 2007). Feeding *R. cruentatus* excrete a reddish fluid on the surface of fruits (Lee and Wen 1982). Fruit growth is retarded and the feeding site serves as a source of entry for fungal attack (Lee and Wen 1982; Srivastava 1997). *Rhipiphorothrips cruentatus* has a wide range of hosts including almond, cashew nut, grapevine, guava, mango, pomegranate and wax apple (Lewis 1997; Srivastava 1997; Dahiya and Lakra 2001).

Rhipiphorothrips cruentatus was previously assessed with the importation of mangoes from India (Biosecurity Australia 2008) and Taiwan (Biosecurity Australia 2006). This existing policy is adopted for mango from Pakistan. Therefore, a risk assessment is not presented here. A summary of the unrestricted risk of assessment conducted in the Taiwan mango pest risk analysis is presented below.

Table 4.5: Summary of the pest risk assessment for mango thrips for fresh mango fruit from India and Taiwan

PRA criterion	Risk rating
Probability of importation	Moderate
Probability of distribution	Moderate
➔ Probability of entry (importation x distribution)	Low
Probability of establishment	High
Probability of spread	High
➔ Overall probability of entry, establishment and spread	Low
Consequences	Low
Unrestricted risk	Very low

4.4.1 Unrestricted risk estimate

The unrestricted risk estimate for mango/grapevine thrips is ‘very low’, which meets Australia's ALOP. Therefore, no specific risk management measures are required for mango/grapevine thrips.

4.5 Mango malformation disease syndrome

Mango malformation disease (MMD) syndrome is a serious disease of mango in tropical and subtropical regions of the world (Steenkamp *et al*. 2000) caused by species of *Fusarium* (Marasas *et al.* 2006). The most prominent symptom is deformed flowers (Kumar *et al*. 1993). Floral malformation is expressed on the plant as abnormally thick, fleshy and copiously branched panicles covered by enlarged flowers (Kumar *et al*. 1993). Malformed inflorescences do not bear commercial fruit; the fruit fails to develop and may be aborted prematurely (Kumar *et al*. 1993; Varma *et al*. 1974). A second important symptom of this disease is deformed mature trees (Kumar *et al*. 1993). The fungus produces both macro- and micro-conidia (Freeman *et al.* 2004). Bud and flower tissues are primary infection sites and wounds provide points of entry for the pathogen (Freeman *et al.* 1999).

Mango malformation was first recognised in 1910 and was attributed to a number of different causal agents (Kumar *et al*. 1993) including several fungal species. A new species, *Fusarium mangiferae*, was described from isolates previously attributed other names in Egypt, India, Israel, Malaysia, South Africa and the USA (Britz *et al.* 2002; Marasas *et al.* 2006) and is considered the main causal agent of mango malformation in Pakistan (Iqbal *et al.* 2006b). In late 2007, there was an isolated outbreak of mango malformation in the Northern Territory, Australia. After confirmation of the pathogen, quarantine measures were put in place and the infected trees were subsequently burnt. No interstate trade restrictions were enforced for the movement of fruit. The species is currently the subject of an ongoing eradication program.

Fusarium mangiferae was previously assessed with the importation of mangoes from India (Biosecurity Australia 2008). This existing policy is adopted for mango from Pakistan. Therefore, a risk assessment is not presented here. A summary of the unrestricted risk of assessment conducted in the Indian mango import risk analysis is presented below.

Table 4.6: Summary of the pest risk assessment for mango malformation disease syndrome for fresh mango fruit from India

PRA criterion	Risk rating
Probability of importation	Moderate
Probability of distribution	Very low
➔ Probability of entry (importation x distribution)	Very low
Probability of establishment	Moderate
Probability of spread	Moderate
➔ Overall probability of entry, establishment and spread	Very low
Consequences	Moderate
Unrestricted risk	Very low

4.5.1 Unrestricted risk estimate

The unrestricted risk estimate for *Fusarium mangiferae* is ‘very low’, which meets Australia's ALOP. Therefore, no specific risk management measures are required for *Fusarium mangiferae*.

4.6 Mango bark beetle [Coleoptera: Scolytidae] carrying propagules of pathogen complex which cause MSDS

Mango bark beetle (*Hypocryphalus mangiferae*) is now considered to be the primary vector of the causal agents of mango sudden death syndrome (MSDS) (Masood *et al.* 2010a). The beetle is frequently associated with diseased mango trees (Masood *et al*. 2008) and is also known to colonize dead parts of infected trees (Al-Adawi *et al.* 2006; Masood *et al.* 2009), as well as playing a significant role in the spread of the pathogens to healthy trees (Masood *et al*. 2010a).

MSDS is a serious disease of mango trees which is known to cause significant reduction in mango production through premature death of trees (Al-Sadi *et al.* 2010). It is caused by a pathogen complex that is comprised of several *Ceratocystis* species and *Lasiodiplodia theobromae* (Malik *et al*. 2005; Al-Adawi *et al*. 2006; Al-Subhi *et al*. 2006; Kazmi *et al*. 2007). Specifically, *Ceratocystis fimbriata*, *Ceratocystis omanensis* and *Lasiodiplodia theobromae* have been identified as pathogens associated with MSDS (Malik *et al*. 2005; Al-Adawi *et al*. 2006; Al-Subhi *et al*. 2006; Kazmi *et al*. 2007). Based on DNA techniques, some re-classification of *C. fimbriata* has now been suggested, including *Ceratocystis manginecans* as the causal agent in Pakistan (van Wyk *et al*. 2007) and a novel species, yet to be formally described, in Brazil (van Wyk *et al*. 2007). In this risk assessment, reference to *C. fimbriata* or the pathogen complex refers to the causal agent of the disease in Pakistan (*Ceratocystis manginecans*).

The origin of pathogen complex associated with MSDS is not known, but it has been reported that the pathogen complex was introduced on planting material from Brazil into Oman and Pakistan (van Wyk *et al*. 2007). Mango seedlings inoculated with *Ceratocystis fimbriata* developed gummosis and extensive lesions. Lesions also developed on plants inoculated with *C. omanensis* and *L. theobromae*, but mean lesion length was significantly longer on stems inoculated with *C. fimbriata* compared with *C. omanensis* or *L. theobromae* demonstrating that *C. fimbriata* is the primary causal organism of MSDS in Oman (Al-Adawi *et al*. 2006). *Ceratocystis omanensis* has not been detected in Pakistan. Mango seedlings inoculated with *Ceratocystis manginecans* in a controlled environment produced similar symptoms to other *Ceratocystis* species, including wilting, oozing gum, vascular necrosis and discolouration (Al-Sadi *et al*. 2010). Similar symptoms have been observed under field conditions (Al-Adawi *et al*. 2006). Fungal mycelium blocks the vascular system of infected plants and causes the subsequent death of the plant (Al-Sadi *et al*. 2010).

In this risk assessment, both the pathogens that cause MSDS and the vector of the pathogens are considered in detail. As the vector, the mango bark beetle, is not quarantinable for Australia (it is present in Australia and not under official control), it is considered solely for its role in transporting the pathogen complex. Consequently, probability of entry contains an assessment of the ability of the beetle to enter Australia (carrying the pathogen) and probability of spread includes information on the beetle's ability to spread the pathogen after the pathogens arrival in Australia. Other sections focus primarily on the pathogens which cause MSDS.

4.6.1 Probability of entry

The probability of entry is considered in two parts, the probability of importation and the probability of distribution, which consider pre-border and post-border issues, respectively.

Probability of importation

The likelihood that pathogen complex that causes mango sudden death syndrome (*Ceratocystis fimbriata* and *Lasiodiplodia theobromae*) will arrive with *Hypocryphalus mangiferae* carrying propagules of these pathogens from countries where the pathogen complex and the beetle is present is **LOW**.

- The pathogen complex that causes MSDS (*Ceratocystis fimbriata* and *Lasiodiplodia theobromae*) is vectored primarily by *Hypocryphalus mangiferae* (Masood *et al*. 2010a). The propagules of these pathogens have been isolated from the beetle (Masood *et al*. 2010a). Therefore, mango bark beetles carrying the propagules of the pathogen complex that causes MSDS provide a pathway for the entry of these pathogens.
- The bark beetle is attracted to bleeding sap, and infected trees, suggesting pathogen infection is an important attractant for the beetle (Masood *et al*. 2010a). The mango bark beetle becomes contaminated with fungal propagules on its body during feeding on diseased trees (Masood *et al.* 2009) and can subsequently vector the pathogen.
- Forms of *Ceratocystis fimbriata* that infect *Platanus* spp. are known to be able to survive for 7–15 days on the surface of tree wounds before infecting the plant (EPPO 2006). This suggests that the pathogen is likely to be able to survive extended periods of time in transit prior to finding a suitable host.
- The beetles carrying the propagules of the pathogen complex could provide potential infection hot spots on healthy trees as the immature beetles feed on twigs and branches of healthy trees in order to reach reproductive maturity (Masood *et al*. 2009). Otherwise,

further development and breeding does not occur until food becomes available (Masood *et al*. 2009).

- Multiple generations of the mango bark beetle (3–4) have been reported within the same host plant (Masood *et al*. 2009), with beetles completing their life cycle (reproduction, development and maturation) under the inner bark of trees (Lieutier *et al*. 2007). After maturation, adults emerge and colonise healthy or stressed plants (Lieutier *et al*. 2007). Therefore, under high population densities the adult beetles may contaminate mango consignments.
- The bark beetles are active from May to August in Pakistan (Masood *et al*. 2009) and may contaminate harvested mango consignments during this period.
- Mango bark beetles are also known to have an overwintering period, which includes hibernation (Saeed *et al.* 2010). This period is usually induced by the low temperatures which occur from September to February (Saeed *et al.* 2010). This ability to overwinter may contribute to the species ability to survive transport to Australia.
- Mango bark beetles, *Hypocryphalus mangiferae*, have been detected at the US border contaminating crates of yam (*Discorea* spp.) destined for New York and Pennsylvania from Brazil (Haack 2001). However, it is unclear if the beetle was contaminating the produce or associated with wooden packaging material.

The association of the pathogen complex with the beetle and a record of beetle being intercepted as a contaminant from an infested country support an assessment of ‘low’.

Probability of distribution

The likelihood that the pathogen complex which causes MSDS will be distributed within Australia with *Hypocryphalus mangiferae* carrying propagules of these pathogens to suitable hosts from countries where the pathogen complex is present is **MODERATE**.

- *Hypocryphalus mangiferae* carrying propagules of MSDS contaminating mango consignments may be distributed throughout the PRA area. However, for the pathogen complex of MSDS to be transferred to a plant host from *Hypocryphalus mangiferae*, the beetles would need to find a suitable host and feed to transmit the pathogens to a host.
- *Hypocryphalus mangiferae* is capable of introducing the pathogen complex of MSDS into healthy mango trees as this beetle can act as a wounding agent and introduce propagules of the pathogens (Al-Adawi *et al*. 2006). For bark beetle attacks on healthy trees to be successful, the beetles must be present in sufficient numbers to overcome the natural defences of the tree (Lieutier *et al*. 2007).
- Mango bark beetles are attracted to the bleeding sap of trees and fungal infection of healthy or damaged trees (Masood *et al.* 2009). If the beetles attraction to bleeding sap and gummosis is due to the presence of the pathogen causing those symptoms, the absence of the disease from Australia, may hinder the beetles ability to find a suitable host.
- The bark beetles are sensitive to extremes of temperature. The optimum temperature for development is 25–30 °C and development is stoped under 5–10 °C (Lieutier *et al.* 2007). Temperatures around 35–40 °C and higher are lethal for their development (Lieutier *et al.* 2007). These temperatures do exist in Australia and may affect the survival of *Hypocryphalus mangiferae* carrying propagules of MSDS.
- *Hypocryphalus mangiferae* is able to fly, with flight activity being dependent on temperature (Lieutier *et al.* 2007). The mango bark beetles host range includes many members of the genus *Mangifera*. These plant hosts are common across northern parts of Australia in parkland, urban areas, orchards and the natural environment.

The mobile nature of the beetle, the presence of the host plant across the northern parts of Australia and the ability of the beetle and pathogen to survive supports an assessment of 'moderate'.

Probability of entry (importation x distribution)

The probability of entry is determined by combining the probability of importation with the probability of distribution using the matrix of rules shown in Table 2.2.

The probability that *Hypocryphalus mangiferae* carrying pathogen complex causing MSDS will arrive in Australia, be distributed within Australia and transferred to a suitable host as a result of fresh mango fruits from Pakistan is **LOW**.

4.6.2 Probability of establishment

The likelihood that the pathogen complex causing MSDS will establish within Australia, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction is: **HIGH**.

- *Ceratocystis fimbriata* associated with MSDS has a narrow host range (Al-Adawi *et al*. 2006; van Wyk *et al.* 2007; Masood *et al*. 2009; Tarigan *et al.* 2010) and these plant hosts are distributed in parts of Australia. The availability of hosts in the PRA area may affect the establishment of *Ceratocystis fimbriata* associated with MSDS in Australia. However, *Lasiodiplodia theobromae* has a wide host range and is already established in the PRA area.
- The pathogen complex causing MSDS is established in areas with a wide range of climatic conditions including Brazil, Oman and Pakistan (van Wyk *et al*. 2007). The current reported distribution of the pathogen complex of MSMD suggests that there are similar environments in parts Australia that would be suitable for their establishment.
- *Ceratocystis fimbriata* associated with MSDS is thought to have established in Oman and Pakistan after introduction from Brazil in nursery stock (van Wyk *et al*. 2007), indicating that the pathogen has the potential to establish in new areas.
- Initial symptoms caused by the pathogen complex of MSDS include gummosis from the bark and branch death on affected trees, and vascular discolouration beneath the gummosis. Tree death usually occurred within six months of first symptom appearance (Al-Adawi *et al*. 2006).

The narrow host range supports an assessment of 'moderate', but the recent introduction and establishment through propagative material in countries and areas with a wide range of climates and environments support as assessment of 'high'.

4.6.3 Probability of spread

The likelihood that the pathogen complex of MSDS will spread within Australia, based on a comparison of those factors in source and destination areas that affect the expansion of the geographic distribution of the pest, is: **HIGH**.

- The pathogen complex of MSDS can spread both independently and in association with infected planting material (van Wyk *et al*. 2007).
- The pathogen is present in Brazil, Oman and Pakistan (van Wyk *et al*. 2007). There are similarities in the natural and urban environments of these areas with those in Australia, which suggests that the pathogen complex of MSDS could spread in Australia.

- The pathogen complex of MSDS is thought to have been spread from Brazil to Oman and Pakistan in nursery stock (van Wyk *et al*. 2007), indicating its ability to spread over long distances with human assistance.
- MSDS was first reported from the Barka area in Oman in 1998. Since then it has spread to adjacent mango growing regions (Al-Adawi *et al*. 2006). This indicates the ability of the pathogen complex to spread amongst host trees in managed orchards. Similar spread may be possible in mango growing regions of Australia.
- The pathogen complex of MSDS sporulates on wood and wood products and produce sticky spores that can be vectored by insects (Hinds 1972). By this means the pathogens can spread to other trees. The pathogen requires fresh wounds on the trunk or branches to infect the host (Fateh *et al*. 2006). These may be caused by the bark beetles or other wounding of host plants.
- *Hypocryphalus mangiferae* is present in parts of Australia (Wood 1982) and will help spread the pathogen complex of MSDS in mango growing regions of Australia. The beetle makes tiny holes (1.9–2.0 mm) on the main trunk and expels frass containing fungal spores, which act as an inoculum source of the pathogen complex which causes MSDS and may help spread the pathogens (Al-Adawi *et al*. 2006; Masood *et al*. 2009).
- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of the beetle and the pathogen complex causing MSDS. In the absence of statutory control it is likely that the pathogen complex causing MSDS will be spread quickly in Australia by trade in host propagative material.

The suitability of the environment, the presence of host plants in parts of Australia, the potential to spread in propagative material and the potential for rapid spread with vectors already present in Australia supports an assessment of 'high'.

4.6.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probabilities of entry, of establishment and of spread (Table 2.2).

The likelihood that the mango bark beetle and the pathogen complex of MSDS will enter Australia as a result of trade in mango fruit from Pakistan, be distributed in a viable state to a susceptible host, establish in Australia and subsequently spread within Australia is: **LOW**.

4.6.5 Consequences

The consequences of the entry, establishment and spread of the mango bark beetle and the pathogen complex of MSMD in Australia have been estimated according to the methods described in Tables 2.3.

The assessment of potential consequences is provided below.

<table>
<tr><th>Criterion</th><th>Estimate and rationale</th></tr>
<tr><td colspan="2">Direct Impact</td></tr>
<tr><td>Plant life or health</td><td>Impact score: E – Significant at the regional level.
The pathogen complex of MSDS (Ceratocystis fimbriata and Lasiodiplodia theobromae) has become a major production constraint on mango production in Oman (Al-Adawi et al. 2006) and Pakistan (Malik et al. 2009).
• Symptoms produced by the pathogen complex of MSDS include discolouration of the vascular tissue, gummosis, galleries of the mango bark beetle, wilting and rapid death (van Wyk et al. 2007). Tree death usually occurs within six months of first symptom appearance (Al-Adawi et al. 2006).
• The pathogen complex of MSDS has three phases. The dieback phase causes a gradual drying of twigs from the top of the canopy downward. Affected trees remain alive but become less productive. Quick dieback can cause mango trees to weaken and lose vigour, leaves become chlorotic and may drop and tree trunks exude gum of different colours (Khanzada et al. 2004). The sudden death phase leads to the rapid death of the tree. The trunks of affected tree show frequent gummosis (Khanzada et al. 2004).
• Water stress has been suggested as enhancing the severity of the disease, with stressed plants demonstrating worse symptoms than regularly watered plants (Khanzada et al. 2004).
• In Oman, over 60 000 trees have been killed or removed due to the disease since its first occurrence resulting in a reduction of 43% in mango production (Al-Sadi et al. 2010).</td></tr>
<tr><td>Other aspects of the environment</td><td>Impact score: B – Minor significance at the local level.
• There are no known direct consequences of the pathogen complex of MSDS on the natural or built environment as the host range of these pathogens is limited to mangoes only.</td></tr>
<tr><td colspan="2">Indirect Impact</td></tr>
<tr><td>Eradication, control etc.</td><td>Impact score: D – significant at the district level
If the pathogen complex of MSDS was introduced to mango growing regions of Australia, variable costs of mango production would increase due to the need for changes in management strategies. The pathogen complex of MSDS can destroy affected plants within a very short period of time (Khanzada et al. 2004; Al-Adawi et al. 2006), so early detection is critical to control the pathogens.
• Programs to minimise the impact of the pathogen complex of MSDS on mango are likely to be costly and include removal of infected trees and management of the mango bark beetle.
• An eradication campaign for the pathogen complex of MSDS, should it be detected early, is likely to be expensive as it would require eradication of many infected plants. As the pathogen complex of MSDS is able to infect via roots, removal of only symptomatic plants may allow nearby infected plants to remain in the mango orchards. Therefore, plants adjacent to symptomatic plants would also need to be removed.
• The eradication program for the pathogens will also involve the eradication, or strict control, of mango bark beetles from infected areas, as the beetles are known to spread the fungus to healthy trees. This is likely to increase the costs of insecticidal treatments applied to orchards.
• The presence of pathogens of the MSDS in Australia would require testing for absence in the production of propagative material to obtain ‘area freedom certification’ and planting resistant cultivars. This would add significant costs to mango nursery stock production in Australia.</td></tr>
</table>

Criterion	Estimate and rationale
Domestic trade	**Impact score: D** – Significant at district level • The presence of the pathogen complex of MSDS in mango production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – Significant at district level • The pathogen complex of MSDS is only reported from Brazil, Oman and Pakistan. It is absent from Australia and other mango growing countries. Restrictions on Australian exports of nursery stock to countries free from the pathogen complex of MSDS would be anticipated if the pathogen complex of MSDS was to become established in Australia.
Environmental and non-commercial	**Impact score: B –** minor significance at the local level • Additional control activities may be required to control and/or eradicate the pathogen complex of MSDS. However, this is not considered to have significant consequences for the environment.

Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are '**E**', the overall consequences are estimated to be **MODERATE**.

4.6.6 Unrestricted risk estimate

Unrestricted risk is the result of combining the probability of entry, establishment and spread with the outcome of overall consequences. Probabilities and consequences are combined using the risk estimation matrix shown in Table 2.5.

Unrestricted risk estimate for the mango bark beetle carrying the pathogen complex of MSDS	
Overall probability of entry, establishment and spread	Low
Consequences	Moderate
Unrestricted risk	Low

As indicated, the unrestricted risk estimate for the mango bark beetle (*Hypocryphalus mangiferae*) carrying the pathogen complex of MSDS of 'low' is above Australia's ALOP. Therefore, specific risk management measures are required to manage the risk from these pathogens.

4.7 Pest risk assessment conclusion

Conclusions drawn from the detailed risk assessments conducted previously (mango fruit from India and Taiwan) for the quarantine pests are presented in Table 4.7. These provided the unrestricted risk estimates for the quarantine pests also associated with fresh mango fruit from Pakistan.

Any pest with an unrestricted risk estimated as 'low', 'moderate' 'high' or 'extreme' does not meet Australia's ALOP and requires risk management measures.

Key to Table 4.7

Genus species [EP]	pests for which policy already exists. The outcomes of previous assessments and/or reassessments in this IRA are presented in table 4.2
Genus species [state/territory]	state/territory in which regional quarantine pests have been identified

Likelihoods for entry, establishment and spread

N	negligible
EL	extremely low
VL	very low
L	low
M	moderate
H	high
P[EES]	overall probability of entry, establishment and spread

Assessment of consequences from pest entry, establishment and spread

PLH	plant life or health
OE	other aspects of the environment
EC	eradication control etc
DT	domestic trade
IT	international trade
ENC	environmental and non-commercial
A-G	consequence impact scores are detailed in section 2.2.3
URE	unrestricted risk estimate. This is expressed on an ascending scale from negligible to extreme.

Table 4.7: Unrestricted risk summary

Pests/pathways	Entry			Establishment	Spread	P[EES]	Consequences							URE
	Importation	Distribution	Overall				Direct		Indirect				Overall	
							PLH	OE	EC	DT	IT	RNC		
Copleoptera: Scolytidae (bark beetles)														
Hypocryphalus mangiferae [5]	L	M	L	H	H	L	E	B	D	D	D	M	M	L
Diptera: Tephritidae (fruit flies)														
Bactrocera correcta [EP]	H	H	H	H	H	H	E	C	F	E	E	D	H	H
Bactrocera dorsalis [EP]	H	H	H	H	H	H	E	C	F	E	E	D	H	H
Bactrocera zonata [EP]	H	H	H	H	H	H	E	C	F	E	E	D	H	H
Hemiptera: Diaspididae (armoured scales)														
Parlatoria crypta [EP]	H	L	L	H	M	L	D	B	D	C	D	B	L	VL
Parlatoria pseudaspidiotus [EP, WA]	H	M	M	H	M	L	D	B	D	C	C	B	L	VL
Hemiptera: Pseudococcidae (mealybugs)														
Ferrisia virgata [EP, WA]	H	M	M	H	H	M	D	B	D	C	D	B	L	L
Rastrococcus invadens [EP]	H	M	M	H	H	M	D	B	D	C	D	B	L	L
Rastrococcus spinosus [EP]	H	M	M	H	H	M	D	B	D	C	D	B	L	L
Thysanoptera: Thripidae (thrips)														
Rhipiphorothrips cruentatus [EP]	M	M	L	H	H	L	D	B	C	C	D	B	L	VL
Fungi														
Fusarium mangiferae [EP]	M	VL	VL	M	M	VL	E	A	D	D	B	A	M	VL

[5] Mango bark beetle carrying the propagules of the pathogen complex of MSDS.

5 Pest risk management

Pest risk management evaluates and selects risk management options to reduce the risk of entry, establishment or spread of quarantine pests for Australia when they have been assessed to have an unrestricted risk above Australia's ALOP. The pest risks identified in the risk assessment (Table 4.7) represent a baseline biosecurity risk associated with the importation of fresh mango fruit from Pakistan in the absence of any risk management measures.

The unrestricted risk estimates of fruit flies and mealybugs exceed Australia's ALOP. Specific risk management measures are therefore required for the import of fresh mango fruits from Pakistan into Australia to adequately address the potential quarantine risk.

Australia currently has a well established policy to import fresh mango fruit for consumption from several countries. This extension of existing policy builds on the existing policy for the importation of mango from India, the Philippines and Taiwan which includes all pests identified in Table 5.1. Therefore, identical or equivalent management measures have been considered and recommended in this extension of existing policy. Thus, the management options recommended are consistent with these existing policies.

Consistent with the existing policy, fresh mango fruit from Pakistan would be subject to the existing measures to meet Australia's ALOP. Biosecurity Australia has evaluated the existing policy and proposed additional measures where required (Table 5.1).

Table 5.1 Proposed phytosanitary measures for fresh mango fruit from Pakistan

Pest	Common name	Proposed measures
Bark beetle [Coleoptera: Scolytidae]		
Hypocryphalus mangiferae (carrying propagules of the pathogen complex which causes MSDS, particularly *Ceratocystis manginecans*)	Mango bark beetle	Orchard management (removal infected plants from export orchards) Orchard inspection by NPPO to verify orchard control prior to export
Fruitflies (Diptera: Tephritidae)		
Bactrocera correcta	Guava fruit fly	Existing policy is supported: Pre-export iiradiation, or hot water dipping treatement or vapour heat treatment
Bactrocera dorsalis	Oriental fruit fly	
Bactrocera zonata	Peach fruit fly	
Mealybugs (Hemiptera: Pseudococcidae)		
Ferrisia virgata WA	Striped mealybug	Existing policy is supported: Inspection and remedial action **or** irradiation
Rastrococcus invadens	Mango mealybug	
Rastrococcus spinosus	Philippine mango mealybug	
If applicable, Australian regional quarantine pests are indicated with the region(s) concerned in superscript.		

Biosecurity Australia considers the existing risk management measures for fruit flies and mealybugs will achieve Australia's ALOP. Consistent with the principle of equivalence detailed in ISPM 1 (FAO 2006), Biosecurity Australia will consider any alternative measure proposed by MINFA, providing that it achieves an equivalent level of quarantine protection. Evaluation of such measures or treatments will require a technical submission from MINFA that details the proposed treatment and includes data from suitable treatment trials.

5.1 Existing risk management measures for fresh mango fruit

Australia has well established policies to import mango fruit from Haiti, India, Mexico, the Philippines and Taiwan. In addition to specific conditions for each of these countries, all imports of fresh mango fruit for consumption are subjected to the general fruit and vegetable import requirements (C6000). The general requirements include:

- an AQIS import permit;
- a quarantine entry must be lodged;
- a Phytosanitary Certificate;
- freedom from regulated articles; and
- on-arrival inspection by AQIS.

Australia has a well-established policy to mitigate the risks posed by identified fruit flies and mealybugs.

5.1.1 Existing policy for fruit flies

Australia's existing policies to mitigate the risk of fruit flies associated with fresh mango fruit for consumption includes:

- mandatory vapour heat treatment (the Philippines, Taiwan);
- mandatory hot water dipping treatement (Mexico); or
- mandatory irradiation (India).

Mandatory vapour heat treatment (VHT)

VHT is used as an effective disinfestation treatment for fruit fly species in certain fruits in international trade. Australia accepts VHT as an effective phytosanitary measure for the disinfestation of fruit flies associated with mango fruits from the Philippines and Taiwan. Mango fruit must be treated at or above 46.5 °C (fruit pulp temperature) for a minimum of 30 minutes. Australia also uses VHT to mitigate the risk of fruit flies for the export of Australian mangoes to Japan.

Mandatory hot water dipping treatment

Hot water dipping treatment (HWDT) is used as an effective disinfestation treatment for some species of *Anastrepha* and *Ceratitis* fruit flies in certain fruits in international trade. Australia accepts HWDT as an effective phytosanitary measure for the disinfestation of these fruit flies to mitigate the risk of fruit flies of quarantine concern associated with mango fruit from Mexico. Australia has accepted HWDT as an effective treatment to mitigate the risk of fruit flies of quarantine concern associated with mango fruit from India. Mango fruit must be treated at or above 48 °C (fruit pulp temperature) for a minimum of 60 minutes.

Mandatory irradiation

The International Plant Protection Convention (IPPC) acknowledges the application of ionising irradiation as a phytosanitary treatment for regulated pests or articles in ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure* (FAO 2003). Irradiation dose rates up to a maximum of 1000 Gy are permitted for quarantine purposes for a range of tropical fruits, including mango, in the Food Standards Australia and New Zealand Code in Standard 1.5.3: *Irradiation of Food* (FSANZ 2000).

Australia accepts irradiation as an effective phytosanitary measure for arthropod pests, including fruit flies, associated with mango fruits from India. Australia requires that mango fruit receive a minimum absorbed dose rate of 400 Gy and for this to be applied in accordance with ISPM 18 (FAO 2003). A minimum absorbed dose rate of 400 Gy is required for mango pulp weevil in view of the lack of specific data supporting a lower irradiation dose. The minimum absorbed dose rate of 400 Gy is considered sufficient to achieve sterility for all quarantine arthropod pests of mango, including mango pulp weevil, mango seed weevil, fruit flies, mealybugs and red-banded mango caterpillar. Australia also uses irradiation to mitigate the risk of fruit flies for the export of Australian mangoes to New Zealand.

5.1.2 Existing policy for mealybugs

Australia's existing policies to mitigate the risk of mealybugs associated with fresh mango fruit for consumption include:

- mandatory inspection and remedial action (the Philippines, Taiwan); or
- mandatory irradiation (India).

Mandatory inspection and remedial action

Visual inspection is a measure that might be applied to manage the risk posed by mealybugs. Australia accepts visual inspection as a measure for the detection of mealybugs associated with mango fruit from the Philippines and Taiwan. Australia also uses visual inspection to certify freedom from several insect pests associated with other fruit and vegetable commodities.

The objective of this measure is to ensure that consignments of mango fruit from Pakistan infested with these pests can be readily identified and subjected to appropriate remedial action. This measure is considered to reduce the risk associated with mealybugs to a very low level. Remedial action, if required, would include fumigation with methyl bromide at AQIS's standard rates (Table 5.2).

Table 5.2: Methyl bromide fumigation standard rates for 24 hour exposure period (AQIS 2010)

Temperature	Dose rate
21 °C and above	48 g/m^3
16–20 °C	56 g/m^3
11–15 °C	64 g/m^3
10 °C *	72 g/m^3

* Methyl bromide fumigation is not permitted if the ambient temperature falls below 10 °C.

Biosecurity Australia considers that visual inspection and remedial action, if required, is adequate to address the risk posed by mealybugs associated with fresh mango fruit from Pakistan.

Mandatory irradiation

Australia accepts irradiation as an effective phytosanitary measure for arthropod pests, including mealybugs, associated with mango fruits from India. Australia requires that mango fruit receive a minimum absorbed dose rate of 400 Gy and for this to be applied in accordance with ISPM 18 (FAO 2003). A minimum absorbed dose rate of 400 Gy is required for mango pulp weevil in view of the lack of specific data supporting a lower irradiation dose. The minimum absorbed dose rate of 400 Gy is considered sufficient to achieve sterility for all the quarantine arthropod pests of mango, including mango pulp weevil, mango seed weevil, fruit flies, mealybugs and red-banded mango caterpillar.

5.2 Proposed risk management measures

Biosecurity Australia considers that existing policy is adequate to address risks posed by fruit flies and mealybugs associated with mango fruit from Pakistan. However, Biosecurity Australia noted that some minor adjustments are required. Therefore, Biosecurity Australia proposes the following alternative methods of pest risk management to reduce the risk from fruit flies and mealybugs, to meet Australia's ALOP.

5.2.1 Proposed risk management for fruit flies

Option 1: Pre-export irradiation

DAFF proposes that pre-export irradiation treatment at a lower dose (250 Gy) is effective against all quarantine fruit flies identified in this pest risk analysis. The proposed pre-export irradiation treatment dose (250 Gy) differs from existing policy for arthropods associated with mango fruit from India (400 Gy).

The higher irradiation dose (400 Gy) was approved as effective against fruit flies, as well as mango pulp weevil (*Sternochetus frigidus*), mango seed weevil (*Sternochetus mangiferae*), red-banded mango caterpillar (*Deanolis sublimbalis*) and mealybugs. Mango pulp weevil, mango seed weevil and red-banded mango caterpillar are not present in Pakistan (Appendix 1); therefore, a higher irradiation dose (400 Gy) is not required for fresh mangoes from Pakistan. Biosecurity Australia proposes the option of pre-export irradiation for all mango fruit varieties from Pakistan at the lower irradiation dose of 250 Gy, which would be appropriate for fruit flies (Bustos *et al.* 2004; Follett 2004).

Successful irradiation treatment results in sterility, or prevention of adult emergence, not mortality of targeted fruit flies. Consequently, the presence of live fruit flies post-treatment does not necessarily represent non-compliance.

In November 2009, Pakistan formally advised Australia that it has operational facilities able to treat fresh mango fruit for export to Australia at a minimum absorbed dose rate of 250 Gy to mitigate the risk from fruit flies.

Option 2: Hot water dipping treatment

Hot water dipping treatment (HWDT) is used as an effective disinfestation treatment for fruit flies in certain fruits in international trade. Australia accepts HWDT as an effective phytosanitary measure for the disinfestation of fruit flies associated with mango fruits from Mexico. Mango fruit must be treated at or above 48 °C (fruit pulp temperature) for a minimum of 60 minutes. Pakistan is currently using HWDT for the disinfestation of fruit flies associated with mango fruits to China, Iran and Jordan.

DAFF proposes an option of a pre-export hot water treatment for specified mango fruit weight classes. The water temperature and dipping times for these are:

- 48 °C or above for 60 minutes for mango fruit up to 500 grams;
- 48 °C or above for 75 minutes for mango fruit between 501 and 700 grams; or
- 48 °C or above for 90 minutes for mango fruit between 701 and 900 grams

Option 3: Pre-export vapour heat treatment

Biosecurity Australia proposes the option of a pre-export VHT of 46.5 °C (fruit pulp temperature) for 30 minutes for all mango fruit varieties from Pakistan as an effective treatment against all quarantine fruit flies identified in this pest risk analysis. The total treatment time would be for a minimum of two hours, including both the warming and cooling periods to bring the fruit to the target temperature. Treatments would commence when the fruit pulp temperature of all monitored fruit reaches, or is above, the required temperature of 46.5 °C and the temperature is maintained for the required period of 30 minutes.

Vapour heat treatment is one of Australia's approved treatments for mangoes against fruit flies (*Bactrocera* species). This treatment has been effectively used to treat fresh mango fruits for consumption from the Philippines and Taiwan. No fruit fly has been intercepted from vapour heat treated fresh mango fruit imported from the Philippines and Taiwan since exports began.

Approval for pre-export VHT of fresh mango fruits is subject to confirmation of the availability of suitable equipment and facilities to carry out VHT in Pakistan.

5.2.2 Proposed risk management for mealybugs

Option 1: Pre-export irradiation

DAFF proposes that pre-export irradiation treatment at a lower dose (250 Gy) is effective against all quarantine mealybugs identified in this pest risk analysis. The proposed pre-export irradiation treatment dose (250 Gy) differs from existing policy for arthropods associated with mango fruit from India (400 Gy).

A higher irradiation dose (400 Gy) was approved as effective against fruit flies, as well as mango pulp weevil (*Sternochetus frigidus*), mango seed weevil (*Sternochetus mangiferae*), red-banded mango caterpillar (*Deanolis sublimbalis*) and mealybugs. Since mango pulp weevil, mango seed weevil and red-banded mango caterpillar are not present in Pakistan a higher irradiation dose (400 Gy) is not required for fresh mangoes from Pakistan. DAFF proposes the option of pre-export irradiation for all mango fruit varieties from Pakistan at the lower irradiation dose of 250 Gy, which would be appropriate for mealybugs (Corcoran and Waddell 2003; Jacobsen and Hara 2003).

Successful irradiation treatment results in sterility, or prevention of adult development, not mortality of targeted mealybugs. Consequently, the presence of live mealybugs post-treatment does not necessarily represent non-compliance.

A minimum absorbed dose rate of 250 Gy is considered sufficient to achieve sterility for all the quarantine arthropod pests associated with fresh mango fruit from Pakistan.

In November 2009, Pakistan formally advised Australia that it has operational facilities able to treat fresh mango fruit for export to Australia.

Option 2: Visual inspection and remedial action

It is proposed that MINFA inspects mango fruit after treatment for the presence of arthropod pests. Sample rates must achieve a confidence level of 95% that not more than 0.5% of the units in the consignment are infested. This equates to a level of zero units infested by quarantine pests in a random sample size of 600 units from the homogenous lot[6] in the consignment. The 600 unit sample must be selected randomly from every treatment lot in the consignment. Where mealybugs are found, a suitable treatment, e.g. fumigation of the entire lot with methyl bromide, is applied, or lots are rejected.

Records of the interceptions made during these inspections (live quarantine pests, dead fruit flies and regulated articles) are to be maintained by MINFA and made available to DAFF as requested. This information will assist in future reviews of this import pathway and consideration of the appropriateness of the phytosanitary measures that have been applied.

The objective of visual inspection is to ensure that consignments of mango fruit from Pakistan infested with mealybugs are identified and subjected to appropriate remedial action. The remedial action will reduce the risk associated with mealybugs to a very low level to meet Australia's ALOP.

Remedial action, if required, could include any treatment known to be effective against the target pests. Currently, standard methyl bromide fumigation rates for external pests are recognised. However, DAFF would also consider any other treatment that MINFA proposes, if it provides an equivalent level of protection.

The consignment would not be released from quarantine until the remedial action has been undertaken.

5.2.3 Proposed risk management for mango bark beetle and MSDS

Orchard control

The objective of this measure is to reduce risk of mango bark beetle carrying propagules of MSDS contaminate mango fruit for export to Australia. Mango bark beetles are attracted to MSDS infected trees; therefore, infected trees must be removed from the orchards to reduce the incidence of mango bark beetle in the registered orchards. Orchard control must include:

- removal of potential sources of MSDS inoculum, and mango bark beetles associated with that inoculum, such as diseased trees; and
- an orchard survey before harvest, by MINFA nominated representatives, to verify the effectiveness of the orchard control measures for MSDS.

5.3 Alternative measures requiring further evaluation

Consistent with the principle of equivalence detailed in ISPM 11 (FAO 2004a), DAFF will consider any alternative measure proposed by MINFA, providing that it achieves an equivalent level of quarantine protection. Evaluation of such measures or treatments will require a technical submission from MINFA that details the proposed treatment and includes data from suitable treatment trials. Some alternative measures that MINFA may wish to consider are outlined in the text below.

---

[6] An inspection 'lot' is no greater than all mango fruit treated for export to Australia on one day from one registered treatment centre.

5.3.1 Options for fruit flies

Sourcing fruit from pest free areas

Area freedom is a measure that might be applied to manage the risk posed by fruit flies of concern in fresh mango fruits from Pakistan. The requirements for establishing pest free areas or pest free places of production are set out in ISPM 4: *Establishment of pest free areas* (FAO 1996) and ISPM 10: *Requirements for the establishment of pest free places of production and pest free production sites* (FAO 1999).

Before area freedom could be adopted as a phytosanitary measure it would be necessary for Pakistan to scientifically demonstrate the establishment, maintenance and verification of area freedom. Australia's evaluation and acceptance of this claim will be based on ISPM 4 or ISPM 10 guidelines (as appropriate) and must be consistent with Australia's ALOP. Failure to adequately establish, maintain or verify area freedom is likely to result in the presence of these fruit flies in fresh mango fruit for consumption.

If MINFA wishes to consider pest free areas as a management measure for fruit flies of quarantine concern to Australia, Biosecurity Australia will assess any proposal from Pakistan supporting area freedom. No information to support area freedom from these fruit flies has yet been received by Biosecurity Australia. If such information were made available, area freedom from these quarantine pests could be considered.

Areas of low pest prevalence

Low pest prevalence is a measure that might be applied to manage the risk posed by fruit flies of concern in fresh mango fruits from Pakistan. The requirements for establishing areas of low pest prevalence are set out in ISPM 22: *Requirements for the establishment of areas of low pest prevalence* (FAO 2005).

Trapping data for these fruit flies, which demonstrates low pest numbers, will require additional or different criteria for recognition of areas of low pest prevalence. Any application for recognition of areas of low pest prevalence will be assessed by Biosecurity Australia.

No information to support areas of low pest prevalence from these fruit flies has yet been received by Biosecurity Australia. If such information were made available, areas of low pest prevalence from these quarantine pests could be considered.

5.4 Operational systems for the maintenance and verification of phytosanitary status

Biosecurity Australia requires, regardless of treatment method, an operational system for the maintenance and verification of the quarantine status of fresh mango fruit for consumption from Pakistan.

It is necessary to have a system of operational procedures in place to ensure that the phytosanitary status of fresh mango fruits from Pakistan is maintained and verified during the process of export to Australia. Biosecurity Australia proposes a system that is consistent with, and equivalent to, the systems currently in place for the importation of fresh mango fruit from India, the Philippines and Taiwan.

Details of the operational system, or equivalent, will be determined by agreement between Pakistan's NPPO, or other relevant agency nominated by the NPPO and DAFF that describes the phytosanitary procedures for the pests of quarantine concern for Australia and the various responsibilities of all parties involved in meeting this requirement. The components of the proposed operational system would include the following:

5.4.1 Registration of export orchards

All mangoes for export to Australia must be sourced from export orchards registered with Pakistan's MINFA. Copies of the registration records must be made available to DAFF if requested. MINFA is required to register export orchards prior to commencement of exports.

All export orchards are expected to produce mango fruit under standard commercial cultivation, harvesting and packing activities, for example, in-field hygiene and management of pests (e.g. orchard control program), cleaning and hygiene during packing and commercial quality control activities.

5.4.2 Orchard Control Program

Registered growers will have an orchard control program approved by MINFA for mango bark beetle and the causal agents of MSDS. MINFA will be responsible for ensuring export orchards are subject to field sanitation and control measures against MSDS. Registered growers must keep records of control measures for auditing purposes. If required, the details of the pest control program will need to be submitted to DAFF, through MINFA.
The orchard control program will include:

- Field sanitation:
  - Removal of sources of potential disease inoculum of MSDS, such as debris; and
  - Regular removal of diseased, declining or dead plants from export orchards.
- An orchard disease survey before harvest, by MINFA nominated representatives, to verify the effectiveness of the orchard control measures for MSDS.
- MINFA to audit growers' compliance with the orchard control program. Orchards found not to be complying with the program must have their export registration suspended.
- MINFA grower audit records are to be available for review by DAFF as requested.

5.4.3 Registration of packinghouses and treatment facilities and auditing of procedures

All treatment facilities and packinghouses intending to export mango fruit to Australia must be registered with MINFA.

DAFF will only accredit designated and identified irradiation, HWDT or VHT facilities and packinghouses that are registered by MINFA. Prior to the commencement of trade, officers from DAFF will visit and audit the treatment facilities. DAFF accreditation of facilities will be contingent on registration by MINFA and subsequent verification and audit by DAFF officers.

DAFF requires that all irradiation, HWDT and VHT treatment facilities and packinghouses must:

- be registered by MINFA;
- have systems in place to ensure traceability of fruit to the MINFA registered export orchard of production (where packinghouses are separate from treatment facilities, traceability to the orchard must be continuous via the respective treatment facility);
- be designed to prevent the entry of fruit flies and other pests into areas where unpacked treated fruit is held;

- ensure all areas of the facility are hygienically maintained (cleaned daily of damaged, blemished, infested fruit);
- maintain complete isolation of treated fruit from untreated fruit (untreated fruit must not be stored in the same storage room as treated fruit);
- ensure a minimum of one metre segregation of fruit for export to Australia from fruit for other markets throughout the treatment, packing, storage and transport stages, before exports commence (if cool storage is used, segregation can be reduced to 100 mm); and,
- maintain records of treatments of all fruit lots for MINFA audit and DAFF monitoring purposes.

In addition to these requirements, DAFF requires that all irradiation, HWDT and VHT treatment facilities must:

- have heat treatment equipment capable of achieving and holding the required fruit pulp temperatures;
- ensure that treated fruit is discharged directly into insect proof and secure packing rooms; or
- where packinghouses are separate from treatment facilities, treated fruit is discharged directly into insect proof containers in secure dispatch rooms prior to transfer to registered packinghouses under insect secure transport.

All irradiation treatment facilities must have equipment capable of applying appropriate dose rates as specified in this policy. Treatment facilities are required to meet standards outlined in ISPM 18 (FAO 2003) and must keep records of treatments of all fruit lots for audit purposes.

Managers of the treatment facilities and packinghouses will be required to provide details of the systems in place to ensure compliance with DAFF requirements during all stages of fruit handling, before export commences. MINFA will audit the facilities and packinghouses to ensure compliance with DAFF requirements before the initiation of exports.

After the approval of registered treatment facilities and packinghouses in the initial export season, DAFF will require MINFA to audit facilities and packinghouses at the beginning of each subsequent season to ensure they comply with DAFF requirements. Once MINFA auditing has occurred at the start of an export season, registration of that facility or packinghouse can be renewed. MINFA will then monitor the treatment facilities and packinghouses on an ongoing basis during their operational season to ensure their continued compliance with DAFF requirements. Reports of audits, noting any non-conformity together with appropriate corrective action, will be submitted to DAFF if required.

MINFA must supervise all irradiation, HWDT or VHT treatments. The phytosanitary security of the product must be maintained after treatments to prevent reinfestation by fruit flies or any other external pests. Phytosanitary inspection of the treated fruit must be conducted by MINFA and the details of the treatment included on the Phytosanitary Certificate. For treated fruit securely transferred from a treatment facility to a separate packinghouse, MINFA must conduct its phytosanitary inspection at the packinghouse. DAFF may audit the treatment facilities and packinghouses at any time to ensure continued compliance.

5.4.4 Packing and labelling

The fruit is to be packed in new cartons sealed with a MINFA sticker or a secure seal placed across the carton opening. No unprocessed packing material of plant origin is to be used.

Any openings in cartons are to be either screened with mesh no greater than 1.6 mm diameter or covered with tape to ensure any opening greater than 1.6 mm diameter is closed.

All cartons will be marked “For Australia”, labelled with a packing date, registered packing house name or number and registered treatment centre establishment name or number.

The objectives of the requirement for packaging and labelling are to ensure that:

- mangoes exported to Australia are not contaminated by quarantine pests or regulated articles (e.g. trash, soil and weed seeds);
- unprocessed packing material (which may vector pests not identified as being on the pathway) is not imported with the mango fruit;
- all wood material used in packaging of the commodity complies with AQIS conditions (see AQIS publication ‘Cargo Containers: Quarantine aspects and procedures’);
- secure packaging is used to prevent post-treatment infestation; and
- the packaged mango fruit is labelled in such a way as to identify the treatment facility and other identifying features for the purposes of trace-back in the event that this is necessary.

5.4.5 Pre-export irradiation requirements

It is mandatory that where irradiation is used as a phytosanitary treatment, irradiation of mango fruit takes place on already packed fruit prior to export. This process can only be undertaken in facilities that have been registered with MINFA for this purpose. The irradiation facilities must comply with the standards set out by the Department of Plant Protection, Government of Pakistan and other relevant international standards. Irradiation facilities must comply with ISPM 18 (FAO 2003). The minimum absorbed dose rate of 250 Gy is considered sufficient to achieve sterility for all the quarantine arthropod pests associated with fresh mango fruit from Pakistan.

The required response of regulated arthropod pests that have undergone irradiation treatment is the prevention of adult emergence or adult sterility (not mortality). Therefore, live (but non-viable) regulated arthropods may be present within a consignment. If MINFA detects regulated arthropods at pre-export phytosanitary inspection an investigation needs to be implemented to determine whether the treatment has been applied correctly and if all evidence indicates the treatment has been applied correctly then a Phytosanitary Certificate can be issued. The integrity of the treatment system will be verified by audit.

5.4.6 Pre-export hot water dipping requirements

It is mandatory that where HWDT is used as a phytosanitary treatment, HWDT of mango fruit takes place prior to export. This process can only be undertaken in facilities that have been registered with MINFA for this purpose. HWDT sensors will be calibrated by the appropriate MINFA officer using a certified thermometer. All certified thermometers will be checked annually against a reference thermometer calibrated by the appropriate national standards authority.

For continuous flow systems, a minimum of 10 evenly spaced sensors per tank are required. At least two sensors are required per tank for batch tank systems, and for batch tank systems using multiple baskets, there must be at least one sensor per basket. In all systems, sensors must be positioned in the lower third of the tank.

Prior to treatment, mangoes must be pre-sorted by weight class (Table 5.3). Each weight class will be treated independently of other weight classes and treatment of mixed loads is not allowed.

Table 5.3: Hot water dipping time for Pakistani mango weight classes

Fruit weight (grams)	Water temperature	Dip time**
up to 500 grams	48 °C or above	60 minutes
500 to 700 grams	48 °C or above	75 minutes
701 to 900 grams	48 °C or above	90 minutes

** dipping time must be extended for an additional 10 minutes if hydrocooling starts immediately after the hot water immersion treatment.

For hot water submersion treatment mangoes would be treated in accordance with the following schedule:

1. Fruit pulp temperature would be 21 °C or above prior to commencing treatment.
2. Fruit would be submerged at least 10 cm below the water surface.
3. Water would circulate constantly and be kept at 48 °C or above throughout the treatment period, with the following tolerances:
   a) During the first five minutes of the treatment – temperatures may fall as low as 47.4 °C provided the temperature is at least 48 °C at the end of the five minute period.
   b) For treatments lasting 60 minutes temperatures may fall as low as 47.4 °C for no more than 10 minutes.
   c) For treatments lasting 75 to 90 minutes temperatures may fall as low as 47.4 °C for no more than 15 minutes.
4. The dip time must be extended for an additional 10 minutes if hydrocooling starts immediately after the hot water immersion treatment.

HWDT would be conducted in Pakistan in facilities registered with and audited by MINFA. Temperature values need to be recorded to standards agreed between MINFA and DAFF and monitored by MINFA.

The phytosanitary security of the product would be maintained after HWDT to prevent reinfestation by fruit flies. Phytosanitary inspection of the treated fruit would be conducted by MINFA and the details of the treatment included on the Phytosanitary Certificate.

5.4.7 Pre-export vapour heat treatment requirements

As with HWDT, it is mandatory that where vapour heat treatment is used as a phytosanitary treatment, VHT of mango fruit takes place prior to export. This process can only be undertaken in facilities that have been registered with MINFA for this purpose. VHT sensors will be calibrated by the appropriate MINFA officer using a certified thermometer. All certified thermometers will be checked annually against a reference thermometer calibrated by the appropriate national standards authority. Calibration records will be retained for MINFA audit and DAFF monitoring purposes.

The number and location of fruit sensors in each chamber will depend on the make and model of the treatment unit, which will be specified by DAFF.

Sensors will be placed in fruit chosen from amongst the largest size fruit in each chamber load. Placement of probes within the chamber and the method used to insert probes will be specified by DAFF.

Treatment time will commence when the pulp core temperature of all probe monitored fruit reaches 46.5 °C or 47.5 °C, and this temperature will be maintained for 30 minutes or 20 minutes respectively. The total treatment time would be for a minimum of two hours, including both the warming and cooling periods to bring the fruit to the target temperature.

MINFA will ensure that copies of the data logger records for each treatment, supplied to MINFA by the respective registered facility operators after each treatment, are forwarded to DAFF. This documentation will include the Phytosanitary Certificate numbers and import permit number that are applicable to that treatment. Information regarding the mode of conveyance and port of entry will be included in the relevant sections on the Phytosanitary Certificate.

5.4.8 Storage and movement of treated fruit

The objective of this proposed procedure is to ensure that the phytosanitary status of the product is maintained during storage and movement.

Packed product and packaging is to be protected from pest contamination during and after packing, during storage and during movement between locations (that is, packing house to cool storage/depot, to inspection point, to export point). Product for export to Australia that has been inspected and certified by MINFA must be maintained in secure holdings that will prevent mixing with fruit for domestic consumption or for export to other destinations. Security of the consignment is to be maintained until release from quarantine in Australia.

Arrangements for secure storage and movement of produce are to be developed by MINFA in consultation with DAFF.

5.4.9 Pre-export inspection by NPPO

The objective of this proposed procedure is to ensure that all consignments are inspected by MINFA in accordance with official procedures for all visually detectable quarantine pests and other regulated articles (including soil, animal and plant debris) at a standard 600 unit sampling rate per lot whereby one unit is one mango fruit. The pre-export inspection by MINFA is to occur after all required treatments have been completed.

An inspection ‘lot’ is no greater than all mango fruit treated for export to Australia on one day from one registered treatment centre.

Irradiated fruit

The response of regulated arthropod pests that have undergone irradiation treatment is sterility or the prevention of adult emergence (not mortality). Live (but non-viable) regulated arthropods may be present within a consignment following treatment. If MINFA detects regulated arthropods at pre-export phytosanitary inspection an investigation needs to be implemented to determine whether the treatment has been applied correctly and if all evidence indicates the treatment has been applied correctly then a Phytosanitary Certificate can be issued. The integrity of the treatment system will be verified by audit. Failure of the facility to meet the criteria listed in Annex 2 of ISPM 18: *Guidelines for the use of irradiation as a phytosanitary measure* (FAO 2003) may indicate that the integrity of the treatement system is inadequate.

Hot water dip or Vapour heat treated fruit

Pre-export inspection is to be completed after HDWT or VHT. The inspection undertaken by MINFA will be required to provide a confidence level of 95% that not more than 0.5% of the units are infested with pests of quarantine concern in the consignment. This equates to a level of zero units infested by quarantine pests in a random sample size of 600 units from the homogenous lot in the consignment. The 600 unit sample must be selected randomly from every lot in the consignment. The sample fruit will be examined externally first and only fruit suspected of having pest infestation will be cut to check for internal feeding insects.

Detection of live quarantine pests, or other regulated articles will result in failure of the consignment. If a consignment fails inspection by MINFA, the exporter will be given the option of treatment and re-inspection of the consignment or removal of the consignment from the export pathway.

Internal feeding insects found in the sampled fruit must be identified by a designated technical expert and the resulting identification, together with the source and date of harvest, submitted to DAFF. No fruits are permitted to be exported to Australia while identification is pending.

5.4.10 Phytosanitary certification by NPPO

MINFA will issue an International Phytosanitary Certificate (IPC) for each consignment after completion of the pre-export treatments and pre-export phytosanitary inspection. The objective of this proposed procedure is:

- to provide formal documentation to DAFF verifying that the relevant measures have been undertaken offshore.

Each IPC is to contain the following information that is consistent with ISPM 7: *Export Certification Systems* (FAO 1997):

Description of consignment

The packhouse registration number/treatment facility registration number, orchard registration number, number of boxes per consignment, weight, and container and seal numbers (as appropriate, for sea freight only); to ensure trace-back to the orchard in the event that this is necessary.

Additional declarations

"*The mangoes in this consignment have been produced in Pakistan in accordance with the conditions governing entry of fresh mango fruit to Australia and inspected and found free of quarantine pests*"

Treatments

Details of disinfestation treatments, including date of treatment, dose rate and treatment facility number.

5.4.11 Monitoring by DAFF in Pakistan

DAFF officers will observe the application of the treatments and the phytosanitary inspection by MINFA officers in Pakistan at the commencement of the initial export season and at other times as necessary. This requirement will be reviewed annually.

5.4.12 On-arrival quarantine inspection by DAFF

AQIS will undertake a documentation compliance examination for consignment verification purposes, followed by inspection before release from quarantine. The following conditions will apply:

- The shipment must have a Phytosanitary Certificate that identifies registered treatment facilities, registered packing houses and bears the required additional declaration.
- Any shipment with incomplete documentation or certification that does not conform to conditions may be refused entry, with the option of re-export or destruction. AQIS would notify MINFA immediately of such action, if taken, and request them to investigate the incident.
- For consignments treated with VHT or HWDT, DAFF will draw a representative sample of the consignment (usually 600 fruit) and inspect the sample for signs of quarantine pests. Fruit showing damage or punctures may be cut for internal examination. Australia maintains the right to select consignments of irradiated fruit for random quarantine inspection on-arrival in Australia.

5.4.13 Remedial action(s) for non-compliance detected on-arrival in Australia

Where inspection lots are found to be non-compliant with requirements on-arrival in Australia, remedial action must be taken. The remedial actions for consignments (subject to on-arrival inspection) where quarantine pests are detected will depend on the type of pest and the mitigation measure that the risk assessment has determined for that specific pest. Remedial actions could include:

- re-export of the consignment; or
- destruction of the consignment; or
- treatment of the consignment and re-inspection to ensure that the pest risk has been addressed.

Separate to the corrective measures mentioned above, other remedial actions may be necessary depending on the specific pest intercepted and the risk management strategy put in place against that pest in the protocol. In the event that an uncategorised pest is detected, MINFA will be asked to investigate the association of that pest with the commodity.

DAFF reserves the right to suspend the export program and conduct an audit of the risk management systems in Pakistan. The program will recommence only after DAFF (in consultation with the relevant state departments if required) is satisfied that appropriate corrective action has been taken.

5.5 Review of policy

Australia reserves the right to review and amend the import policy after a substantial volume of trade has occurred, or earlier if phytosanitary circumstances change.

The NPPO, or other relevant agency nominated by the NPPO, must inform DAFF immediately on detection of any new pests of mango fruit that are of potential quarantine concern to Australia For example, red-banded mango caterpillar (*Deanolis sublimbalis*), mango pulp weevil (*Sternochetus frigidus*) and mango seed weevil (*Sternochetus mangiferae*) are currently absent from Pakistan. Should any of these pests be detected in Pakistan, MINFA must immediately advise DAFF of the changed pest status.

5.6 Uncategorised pests

If an organism is detected on mango fruit prior to export or on-arrival in Australia that has not been categorised, it will require assessment by DAFF to determine its quarantine status and if phytosanitary action is required. MINFA is responsible for notifying DAFF or any uncategorised pests detected in Pakistan during pre-export inspection. Assessment is also required if the detected species was originaly categorised as not likely to be on the import pathway. If the detected species was categorised as on the pathway but assessed as having an unrestricted risk that achieves Australia's ALOP due to the rating likelihood of importation, then it would require reassessment. The detection of any pests of quarantine concern not already identified in the analysis may result in remedial action and/or temporary suspension of trade while a review is conducted to ensure that existing measures continue to provide the appropriate level of protection for Australia.

6 Conclusion

The findings of this draft extension of existing policy report are based on a comprehensive analysis of relevant scientific literature. Biosecurity Australia considers that the risk management measures proposed in this draft extension of existing policy report will provide an appropriate level of protection against the pests identified in this risk analysis. A range of risk management measures may be suitable to manage the risks associated with mangoes from Pakistan. Biosecurity Australia will consider any other measures suggested by stakeholders that provide an equivalent level of phytosanitary protection.

Appendices

Appendix A Initiation and categorisation for pests of mangoes from Pakistan

Key to Table A

Initiation (columns 1 – 3) identifies the pests of mangoes that have the potential to be on mangoes produced in Pakistan using commercial production and packing procedures.

Pest categorisation (columns 4 - 7) identifies which of the pests with the potential to be on mangoes are quarantine pests for Australia and require pest risk assessment.

The steps in the initiation and categorisation processes are considered sequentially, with the assessment terminating at the first 'No' for columns 3, 5 or 6 or 'Yes' for column 4.

Details of the method used in this IRA are given in Section 2: Method for pest risk analysis.

Note: Synonyms are only provided in the pest categorisation table when the current scientific name differs from that provided by Pakistan or when supporting literature is found under a different scientific name. For lists of synonyms for potential pests of quarantine concern, refer to Appendix B.

Table A Initiation and pest categorisation

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
ARTHROPODS						
ACARI (mites)						
Aceria mangiferae (Sayed, 1946) [Acari: Eriophyidae]	Yes (Khan 1970)	No. This species primarily affects vegetative and reproductive buds of mango trees; and has been implicated as a vector of mango malformation (Mahgoob 2006). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Brevipalpus obovatus Donnadieu, 1875 [Acari: Tenuipalpidae]	Yes (CIE 1988)	No. These species feed on the leaves and stems of a variety of trees (Bastianel *et al.* 2006). *Brevipalpus phoenicis* has also been found in citrus fruits imported into New Zealand (Manson 1967); however, it is not known to be associated with	Assessment not required	Assessment not required	Assessment not required	No
Brevipalpus phoenicis (Geijskes, 1939) [Acari: Tenuipalpidae]	Yes (Sarwar 2006)		Assessment not required	Assessment not required	Assessment not required	No

[7] In this pest categorisation the potential for economic consequences is assessed in relation to the pest's likelihood to meet the ISPM 5 definition of a quarantine pest. Namely, that the pest is potentially economically important. Consequently, any pest which is considered a minor pest or a pest which is not known to be economically important is not considered further.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		mango fruits.				
Oligonychus coffeae (Nietner, 1861) [Acari: Tetranychidae]	Yes (EPPO 2006)	No. These species attack foliage, particularly the underside of leaves focusing on areas adjacent to veins (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Oligonychus mangiferus (Rahman & Sapra, 1940) [Acari: Tetranychidae]	Yes (Migeon and Dorkeld 2006)		Assessment not required	Assessment not required	Assessment not required	No
Panonychus ulmi (Koch, 1836) [Acari: Tetranychidae]	Yes (Khan *et al.* 1997)	Yes. This species feeds on the fruits of a number of plant species (Filajdic *et al.* 1995).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Polyphagotarsonemus latus (Banks, 1904) [Acari: Tarsonemidae]	Yes (Zaman 1987)	No. This species causes malformation of terminal leaves and buds and premature abortion of flowers (Denmark 1980). Not known to occur on fruit.	Assessment not required	Assessment not required	Assessment not required	No
Tetranychus neocaledonicus (Andre, 1933) [Acari: Tetranychidae]	Yes (Migeon and Dorkeld 2006)	No. This mite is polyphagous in nature (Gutierrez and van Zon 1973) and is not found on fruits.	Assessment not required	Assessment not required	Assessment not required	No
Typhlodromus asiaticus Evans, 1953 [Acari: Phytoseiidae]	Yes (Morton 1987)	No. This species causes malformation-like symptoms that typically occur on leaves and buds (Singh *et al.* 1961). Not known to occur on fruit.	Assessment not required	Assessment not required	Assessment not required	No
Tyrophagus putrescentiae (Schrank, 1781) [Acari: Acaridae]	Yes (Morton 1987)	No. This species feed on moulds and are common only where mould and fungi can flourish (Bennett 2003). The species is unlikely to be associated with commercially produced mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
COLEOPTERA (beetles, weevils)						
Acanthophorus serraticornis (Olivier, 1795) [Coleoptera: Cerambycidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a stem borer that attacks the roots and trunk of mango trees (Srivastava 1997). Not known	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		to be associated with fruit.				
Alcides frenatus Faust, 1894 [Coleoptera: Curculionidiae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a boring insect that bores leaf midribs and twigs (Sen 1917). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Amblyrrhinus poricollis Schönherr, 1826 [Coleoptera: Curculionidiae]	Yes (Qureshi and Mohiuddin 1982)	No. Adults are associated with leaves (Qureshi and Mohiuddin 1982). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Anegleis cardoni (Weise, 1892) [Coleoptera: Coccinellidae]	Yes (Rahim and Hashmi 1984)	No. This is a predatory species that is a potential biological control agent for sugarcane leaf hopper, *Pyrilla perpusilla* (Rahim and Hashmi 1984). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Apion pakistanensis Alam. [Coleoptera: Apionidae]	Yes (Qureshi and Mohiuddin 1982)	No. Members of this genus are wood borers (Oni 1990). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Aulacophora foveicollis (Lucas, 1849) [Coleoptera: Chrysomelidae]	Yes (Wadhero *et al.* 1998)	No. Larvae of this species are soil pests that attack plant roots and stems (CABI 2007). Adults feed on flowers and leaves (Al-Ali *et al.* 1982). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Batocera rubus (Linneaus, 1758) [Coleoptera: Cerambycidae]	Yes (Qureshi and Mohiuddin 1982)	No. These species are stem borers that attack the trunk and branches of a tree (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Batocera rufomaculata (De Geer, 1775) [Coleoptera: Cerambycidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Belinota prasina (Thunberg, 1789) [Coleoptera: Buprestidae]	Yes (Qureshi and Mohiuddin 1982)	No. Larvae of this species are stem borers (Srivastva 1997; Qureshi and Mohiuddin 1982). Adults are nectivorous and not associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Deporaus marginatus (Pascoe, 1883) [Coleoptera: Curculionidiae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a leaf cutting weevil that can, in severe cases, cause defoliation (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Desmidophorus hebes (Fabricius, 1781) [Coleoptera: Curculionidiae]	Yes (Qureshi and Mohiuddin 1982)	No. Larvae of this species are primarily a soil feeding pests (Pandit *et al.* 1986). Adult oviposit in stems (Morimoto and Kojima 2006). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Diaprepes abbreviatus (Hustache, 1929) [Coleoptera: Curculionidiae]	Yes (Peña and Mohyuddin 1997)[8]	No. This weevil feeds on foliage (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Hypocryphalus mangiferae (Stebbing) Coleoptera: Curculionidae]	Yes (Masood *et al.* 2010a)	Yes. At high population levels, this beetle maycontaminate fruit consignments. It is small and highly mobile (Masood *et al.* 2010a). Mango bark beetles, *Hypocryphalus mangiferae*, have been detected at the US border contaminating crates of yam (*Discorea* spp.) destined for New York and Pennsylvania from Brazil (Haack 2001).	Yes (Walker 2008)[9]	Yes. Mango bark beetle, and *Ceratocystis manginecans*, are established in areas with a wide range of climatic conditions (Wood 1982; Masood *et al.* 2010a) and can spread independently or by human activities. Therefore, mango bark beetle, and *Ceratocystis manginecans,* have the potential for establishment and spread in Australia.	Yes. This species is known to vector *Ceratocystis manginecans*, the causal agent of mango sudden death syndrome (Masood *et al.* 2010a). This disease is severe and is responsible for a 43% reduction of mango production over 12 years in Oman (Al-Sadi *et al.* 2010).	Yes
Hypomeces squamosus (Fabricius, 1792) [Coleoptera: Curculionidae]	Yes (Hashmi and Tashfeen 1994)	No. Adults of this species are foliage feeders and larvae feed on roots; not associated with fruits (CABI 2007).	Assessment not required	Assessment not required	Assessment not required	No

[8] Peña and Mohyuddin (1997) provided a generic list of pests with their distribution in various regions; they considered India and Pakistan to be a single region. If a pest was present in one of these countries they mentioned its presence for both countries. There is often no other information available to confirm these species are present in Pakistan.

[9] This species is present in Australia and not under official control. In this risk assessment the species is not assessed for its potential as a quarantine pest, but is considered further for its role in vectoring the causal agents of mango sudden death syndrome.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Monolepta limbata (Olivier, 1808) [Coleoptera: Chrysomelidae]	Yes (Qureshi and Mohiuddin 1982)	No. Species of this genus cause leaf galls (Kathiresan 2003). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Myllocerus dentifer (Fabricius, 1792) [Coleoptera: Curculionidae]	Yes (Rizvi *et al.* 2004)	No. Species of *Myllocerus* are foliage feeding weevils that chew irregular holes in leaves (Srivastava 1997). *M. discolor* has also been recorded feeding on inflorescences (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Myllocerus discolor Schoenherr, 1826 [Coleoptera: Curculionidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Myllocerus sabulosus (Marshall, 1916) [Coleoptera: Curculionidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Myllocerus undecimpustulatus (Faust, 1891) [Coleoptera: Curculionidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Rhynchaenus mangiferae Marshall, 1915 [Coleoptera: Curculionidae]	Yes (Peña and Mohyuddin 1997)[8]	No. Adults of this species are leaf miners which feed on foliage (Kannan and Rao 2006). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Sinoxylon anale Lesne, 1897 [Coleoptera: Bostrichidae]	Yes (Gul and Chaudhry 1991)	No. These species are powder post beetles that bore into the stems and trunks of various trees (Gul and Bajwa 1999). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Sinoxylon conigerum Gerstäcker, 1855 [Coleoptera: Bostrichidae]	Yes (EPPO 2006)		Assessment not required	Assessment not required	Assessment not required	No
Sinoxylon crassum Lesne, 1897 [Coleoptera: Bostrichidae]	Yes (Gul and		Assessment not	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
	Chaudhry 1991)		required			
Sternochetus frigidus (Fabricius, 1787) [Coleoptera: Curculionidiae]	No[10]	Assessment not required	Assessment not required	Assessment not required	Assessment not required	No
Sternochetus mangiferae (Fabricius, 1775) [Coleoptera: Curculionidiae]	No [11]	Assessment not required	Assessment not required	Assessment not required	Assessment not required	No
Tadius laticollis Faust, 1898 [Coleoptera: Erirhinidae]	Yes (Qureshi and Mohiuddin 1982)	No. Associated with bark (Qureshi and Mohiuddin 1982). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Xyleborus perforans (Wollaston, 1857) [Coleoptera: Scolytidae]	Yes (CIE 1973a)	No. This species bores into the stems and trunks of woody hosts (CABI 2007). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Xylosandrus crassiusculus (Motschulsky, 1866) [Coleoptera: Scolytidae]	Yes (Khuhro *et al.* 2005a)	No. This is a species of boring beetle that attacks stems, trunks, branches and roots of woody hosts (Khuhro *et al.* 2005b). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
DIPTERA (flies)						
Atherigona orientalis Schiner, 1868 [Diptera: Muscidae]	Yes (Chughtai *et al.* 1985)	Yes. This specis lays eggs in either the epicarp or the esocarp of ripening fruit (Peña *et al.* 1998). Larvae	Yes (AICN 2007)	Assessment not required	Assessment not required	No

[10] Records for presence of *S. frigidus* in Pakistan (Hashmi and Tashfeen 1994) were based on specimens from Dhaka, formerly of East Pakistan, now Bangladesh. CABI (2007) has updated the distribution of this pest and changed the status of this pest in Pakistan—as invalid record for Pakistan. Additionally, the current distribution of this species is confined to south-east Asia, extending as far as the eastern Indian states that border Bangladesh: Assam, Manipur, Meghalaya, Tripura and West Bengal (CABI 2007).

[11] Records for presence of *S. mangiferae* in Pakistan (Hashmi and Tashfeen 1994) appear to be based on a single specimen from imported mangoes in 1916. CABI (2007) has updated the distribution of this pest and changed the status of this pest in Pakistan—as invalid record for Pakistan.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		develop in the fruit before emerging to pupate in the soil (Peña *et al.* 1998). Not known to be associated with fruit.				
Bactrocera correcta (Bezzi, 1916) [Diptera: Tephritidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. Fruit flies lay eggs inside ripening fruit (Srivastava 1997). The puncture in the fruit made by oviposition is inconspicuous (Srivastava 1997). Harvesting at an early stage of maturity may result in a low intensity of infection (Srivastava 1997), which could evade detection.	No records found	Yes. This species has a wide geographic range that includes many areas with similar climates to Australia (CABI 2007). This species also has a wide host range from several plant families (Tsuruta *et al.* 1997).	Yes. At the farm level fruit flies are estimated to cause losses of $200 million per annum in Pakistan (Stonehouse *et al.* 1998). The overall estimated loss in mango production annually is 15% (Stonehouse *et al.* 1998).	Yes
Bactrocera cucurbitae (Coquillett, 1899) [Diptera: Tephritidae]	Yes (Qureshi and Mohiuddin 1982)	No. *Bactrocera cucurbitae* adult flies have been observed to 'roost' in mango trees where they feed on honey dew produced by aphids and mealybugs (Lall and Singh 1969; Dhillon *et al.* 2005)[12].	Assessment not required	Assessment not required	Assessment not required	No
Bactrocera diversa (Colluillett, 1904) [Diptera: Tephritidae]	Yes (Jabbar-Khan and Jabbar-Khan 1987)	No. Although Srivastava (1997) quoted that *B. diversa* attacks mango, the primary reference (Batra 1953) stated that this pest is recorded from various fruit orchards but breeds only in the flowers of cucurbits. This pest does not breed in fruit orchards but enters them for shade and shelter (Batra 1964).	Assessment not required	Assessment not required	Assessment not required	No
Bactrocera dorsalis (Hendel, 1912) [Diptera: Tephritidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. Fruit flies lay eggs inside ripening fruit (Srivastava 1997). The puncture in the fruit made by oviposition is inconspicuous	No records found	Yes. This species has a wide host range spanning eight plant families (Carroll *et al.* 2004). It also has a wide distribution in areas with	Yes. At the farm level fruit flies are estimated to cause losses of $200 million per annum in Pakistan (Stonehouse *et al.*	Yes

[12] Previous policy has listed this species as associated with mango fruit. Further consideration and review of the available literature has found that there are no records of *B. cucurbitae* adults laying eggs on, or larvae developing within, mango fruits. Consequently, this species is not considered to be on the import pathway.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		(Srivastava 1997).		similar climates to those found in Australia (Carroll *et al.* 2004).	1998). The overall estimated loss in mango production annually is 15% (Stonehouse *et al.* 1998).	
Bactrocera zonata (Saunders, 1841) [Diptera: Tephritidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. Fruit flies lay eggs inside ripening fruit (Srivastava 1997). The puncture in the fruit made by oviposition is inconspicuous (Srivastava 1997).	No records found	Yes. This species has a wide geographic range that includes many areas with similar climates to Australia (CABI 2007). Additionally, the species has a wide host range (Stonehouse *et al.* 2002).		Yes
Dasineura amaramanjarae Grover, 1965 [Diptera: Cecidomyiidae]	Yes (Qureshi and Mohiuddin 1982)	No. Larvae of this midge are found inside buds; the feeding of the larvae prevents the buds from opening and producing fruit (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Erosomyia indica Grover & Prasad, 1966 [Diptera: Cecidomyiidae]	Yes (Peña and Mohyuddin 1997)[8]	No. Larvae develop inside newly formed fruits causing premature fruit drop (Srivastava 1997). Fruit falls from the tree prior to ripening and therefore, this species is not on the pathway.	Assessment not required	Assessment not required	Assessment not required	No
Procontarinia matteiana Kieffer & Cecconi, 1906 [Diptera: Cecidomyiidae]	Yes (Peña and Mohyuddin 1997)[8]	No. Eggs are laid in young leaves where larvae feed and grow causing galls to form (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
HEMIPTERA (aphids, leafhoppers, mealybugs, psyllids, scales, true bugs, whiteflies)						
Aleurocanthus woglumi Ashby, 1915 [Hemiptera: Aleyrodidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species affects foliage (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Amrasca splendens Ghauri, 1967 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]	No. This species feeds and lay eggs on tender leaves (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Amritodus atkinsoni Lethierry, 1889 [Hemiptera: Cicadellidae]	Yes (Qureshi and	No. Mango hoppers suck the sap of leaves, shoots and inflorescences	Assessment not	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
	Mohiuddin 1982)	(Srivastava 1997). As the species attack inflorescences they may affect fruit set but are not associated with the fruit itself (Srivastava 1997).	required			
Amritodus brevistylus Viraktamath, 1976 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]		Assessment not required	Assessment not required	Assessment not required	No
Antestiopsis cruciata (Fabricius, 1775) [Hemiptera: Pentatomidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. This species feeds on the fruit of a number of species (Waller *et al.* 2007; Butani 1993).	No records found	Yes. This species has hosts, including mango (Qureshi and Mohiuddin 1982), that are present and widespread in Australia (Irulandi *et al.* 2003).	No. This species is a minor pest in Pakistan (Qureshi and Mohiuddin 1982).	No
Aonidiella aurantii (Maskell, 1879) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	Yes. These species of scale insects commonly occur on fruit and foliage of various species (Peña and Mohyuddin 1997).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Aonidiella citrina (Coquillett) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		Yes (AICN 2007)	Assessment not required	Assessment not required	No
Aonidiella orientalis (Newstead, 1894) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		Yes (AICN 2007)	Assessment not required	Assessment not required	No
Aphis gossypii Glover, 1877 [Hemiptera: Aphididae]	Yes (Ahmad *et al.* 2003)	No. This species sucks sap from foliage; they secrete honeydew which encourages the growth of sooty moulds (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Apsylla cistellata (Buckton, 1892) [Hemiptera: Psyllidae]	Yes (Singh 2000)	No. This species causes galls to form in the leaf axils; shoots affected by the species generally dry up (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Aspidiotus destructor Signoret, 1869 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	No. This scale occurs on the underside of leaves causing yellowing and wilting (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Aulacaspis rosae (Bouché, 1833) [Hemiptera: Diaspididae]	Yes (Ben-Dov *et al.* 2007)	No. *Aulacaspis rosae* occurs primarily on the foliage of roses (Ozbek and Calmasur 2005). Not	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		known to be associated with fruit.				
Aulacaspis tubercularis Newstead, 1906 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	Yes. Occurs on foliage and fruits; females become sedentary laying eggs under their protective covering (Cunningham 1989).	Yes (Cunningham 1989; Johnson and Parr 1999)	Assessment not required	Assessment not required	No
Bagrada hilaris (Burmeister, 1835) [Hemiptera: Pentatomidae]	Yes (Mahar 1974)	No. This species affects the buds and growing points of a number of crops (Singh *et al.* 2006). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Busoniomimus manjunathi Viraktamath & Viraktamath, 1985 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]	No. Mango hoppers suck the sap of leaves, shoots and inflorescences (Srivastava 1997). As the species attacks inflorescences it may affect fruit set but is not associated with the fruit itself (Srivastava 1997).	Assessment not required	Assessment not required	Assessment not required	No
Ceroplastes actiniformis Green, 1896 [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)	No. *Ceroplastes* species are scale insects that commonly occur on leaves, leaf stalks and shoots (Srivastava 1997). *Ceroplastes floridensis* and *C. rubens* are associated with leaves (Peña and Mohyuddin 1997). *Ceroplastes rubens* is considered to be on the import pathway as it occurs on fruit (USDA 2006).	Assessment not required	Assessment not required	Assessment not required	No
Ceroplastes floridensis Comstock, 1881 [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Ceroplastes rubens Maskell, 1893 [Hemiptera: Coccidae]	Yes (Peña and Mohyuddin 1997)[8]		Yes (AICN 2007)	Assessment not required	Assessment not required	No
Chrysomphalus aonidum (Linnaeus, 1758) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	Yes. This is a scale insect which is known to occur on fruit of host species (Broughton 2007).	Yes (Broughton 2007)	Assessment not required	Assessment not required	No
Coccus discrepans (Green, 1904) [Hemiptera: Coccidae]	Yes (Ben-Dov *et al.* 2007)	No. Scales are found on the upper and lower leaf surfaces (Peña and Mohyuddin 1997) and also on stems (Peña 1993). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Coccus hesperidum Linnaeus, 1758 [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Coccus viridis (Green, 1889) [Hemiptera: Coccidae]	Yes (Sarwar 2006)		Assessment not required	Assessment not required	Assessment not required	No
Drosicha mangiferae (Stebbing, 1902) [Hemiptera: Margarodidae]	Yes (Karar *et al.* 2009)	No. These species suck sap from leaves, shoots and inflorescences (Srivastava 1997). These species may also occur on peduncles but are not associated with fruit (Srivastava 1997).	Assessment not required	Assessment not required	Assessment not required	No
Drosicha stebbingi (Green, 1902) [Hemiptera: Margarodidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Dysdercus koenigii (Fabricius, 1775) [Hemiptera: Pyrrhocoridae]	Yes (Rizwan-ul-Haq *et al.* 2005)	No. This species has previously been found on fruit (Butani 1993); however, due to its highly mobile nature, size and feeding habits it is considered unlikely to be present on the export pathway[13].	Assessment not required	Assessment not required	Assessment not required	No
Dysmicoccus brevipes (Cockerell, 1893) [Hemiptera: Pseudococcidae]	Yes (Khan *et al.* 1998)	Yes. Occurs on foliage and fruit of host plants (CABI 2007).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Ferrisia virgata (Cockerell, 1893j) [Hemiptera: Pseudococcidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. Associated with shoots, stems, leaves and fruit (USDA 2006).	Yes (AICN 2007); Not present in WA (DAFWA 2003)	Yes. This species is already present in Queensland and the Northern Territory (AICN 2007). It is absent from Western Australia (DAFWA 2003).	Yes. This species is a well known and widespread plant pest that damages numerous plant species (Gullan *et al.* 2003). Additionally, the species may transmit plant viruses (Gullan *et al.* 2003).	Yes[WA]
Formicococcus robustus (Ezzat & McConnell, 1956) [Hemiptera: Pseudococcidae]	Yes (Moghaddam 2006)	No. Species of the genus *Formicociccus* affect plant roots; not associated with fruit (Wang 1985).	Assessment not required	Assessment not required	Assessment not required	No
Halys dentata (Pathak 1991)	Yes (CABI 2007)	No. This species sucks sap from several tree species (Dhiman and	Assessment not	Assessment not required	Assessment not required	No

[13] This species was considered in the 2004 draft of the Import Risk Analysis for fresh mango fruit from India and was assessed to have an unrestricted risk rating of negligible. Consequently, this species has not been considered further.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
[Hemiptera: Pentatomidae]		Yadav 2004). It has been recorded to occur externally on fruits (DPP 2001); however, it is unlikely that this species would be present on the importation pathway because of its large size and highly mobile behaviour.	required			
Hemiberlesia lataniae (Signoret, 1869) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	Yes. These species of scale insect feed on foliage and fruits (Peña 1993; CABI 2007).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Hemiberlesia rapax (Comstock, 1881) [Hemiptera: Diaspididae]	Yes (CABI 2007)		Yes (AICN 2007)	Assessment not required	Assessment not required	No
Icerya aegyptiaca Douglas, 1890 [Hemiptera: Margarodidae]	Yes (Qureshi and Mohiuddin 1982)	No. Species of the genus *Icerya* feed on foliage and small stems (Mohammad-Ali 1962; Peña and Mohyuddin 1997; Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Icerya minor Green, 1908 [Hemiptera: Margarodidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Icerya pulchra (Leonardi, 1907) [Hemiptera: Margarodidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Icerya purchasi Maskell, 1879 [Hemiptera: Margarodidae]	Yes (EPPO 2006)		Assessment not required	Assessment not required	Assessment not required	No
Icerya seychellarum (Westwood, 1855) [Hemiptera: Margarodidae]	Yes (Ben-Dov *et al.* 2007)		Assessment not required	Assessment not required	Assessment not required	No
Idioscopus anasuyae Viraktamath & Viraktamath, 1985 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]	No. Mango hoppers suck the sap of leaves, shoots and inflorescences (Peña and Mohyuddin 1997; Srivastava 1997). As the species attack inflorescences they may affect fruit set; however, they are not associated with the fruit itself (Srivastava 1997).	Assessment not required	Assessment not required	Assessment not required	No
Idioscopus clypealis (Lethierry, 1889) [Hemiptera: Cicadellidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Idioscopus decoratus Virktamath, 1976 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]		Assessment not required	Assessment not required	Assessment not required	No
Idioscopus jayshriae Virktamath & Viraktamath, 1985 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]		Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Idioscopus nagpurensis (Pruthi, 1930) [Hemiptera: Cicadellidae]	Yes (Mohyuddin and Mahmood 1993)		Assessment not required	Assessment not required	Assessment not required	No
Idioscopus nitidulus (Walker, 1870) [Hemiptera: Cicadellidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Idioscopus spectabilis Virktamath, 1976 [Hemiptera: Cicadellidae]	Yes (Peña and Mohyuddin 1997)[8]		Assessment not required	Assessment not required	Assessment not required	No
Labioproctus poleii (Green, 1922) [Hemiptera: Margarodidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species occurs on the trunk, branches and leaves of a number of host species (Ghose 1965). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Lepidosaphes gloverii (Packard, 1869) [Hemiptera: Diaspididae]	Yes (Ben-Dov *et al.* 2007)	Yes. Species of *Lepidosaphes* feed on stem, leaf and fruit (USDA 2006). *Lepidosaphes tapleyi* has been recorded on mango fruit entering the UK from Pakistan (DEFRA 2008).	Yes (Ben-Dov *et al.* 2007)[14]	Assessment not required	Assessment not required	No
Lepidosaphes pallidula (Williams, 1969) [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		Yes (AFD 2007)	Assessment not required	Assessment not required	No
Lepidosaphes tapleyi Williams, 1960 [Hemiptera: Diaspididae]	Yes (Watson 2007; DEFRA 2008)		No records found	Yes. This species is widespread in South-East Asia and Africa (Watson 2007). There are similar environments in Australia that would be suitable for its establishment and spread.	No. Watson (2007) reports this species causing isolated damage in guava in the 1960s and 1970s. Recent reviews of this species consider it to be a minor pest (e.g. Swailem 1974).	No
Leptocorisa acuta (Thunberg, 1783) [Hemiptera: Alydidae]	Yes (EPPO 2006)	No. This species feeds on the leaves of mango trees but over-winters on other species (Lal and Mukharji 1975). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No

[14] This species is absent from WA. However, as no specific measures are currently in place to prevent the entry of this species into WA from other states in Australia where it is present, it does not meet the definition of a quarantine pest and is not considered further in this report.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Lindingaspis ferrisi McKenzie, 1950 [Hemiptera: Diaspididae]	Yes (Mohyuddin and Mahmood 1993)	No. These species of scale insects affect foliage (Peña 1993). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Lindingaspis floridana Ferris, 1942 [Hemiptera: Diaspididae]	Yes (Ben-Dov *et al.* 2007)		Assessment not required	Assessment not required	Assessment not required	No
Maconellicoccus hirsutus (Green, 1908) [Hemiptera: Pseudococcidae]	Yes (Ujjan and Shahzad 2007)	Yes. This species has been intercepted on mango fruits in the USA (USDA 2006).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Macrosiphum euphorbiae (Thomas, 1878) [Hemiptera: Aphididae]	Yes (Hassan *et al.* 1993)	Yes. This species feeds on leaves and fruits (CABI 2007).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Milviscutulus mangiferae (Green, 1889) [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. This scale is commonly found on leaves, fruit and branches of mango trees (Peña and Mohyuddin 1997).	Yes[15] (AICN 2007)	Assessment not required	Assessment not required	No
Nezara viridula (Linnaeus, 1758) [Hemiptera: Pentatomidae]	Yes (Ahmad and Onder 1989)	Yes. This species feeds on stem, leaf, inflorescences and fruit (USDA 2006).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Nipaecoccus filamentosus (Cockerell, 1893) [Hemiptera: Pseudococcidae]	Yes (Qureshi and Mohiuddin 1982)	No. Species of this genus of mealybug infest stems, petioles and foliage (Ghosh and Ghosh 1985). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Nipaecoccus nipae (Maskell, 1893) [Hemiptera: Pseudococcidae]	Yes (Ben-Dov *et al.* 2007)		Assessment not required	Assessment not required	Assessment not required	No
Nipaecoccus viridis (Newstead, 1894) [Hemiptera: Pseudococcidae]	Yes (CABI 2007)		Assessment not required	Assessment not required	Assessment not required	No

[15] This pest species is absent from Western Australia; however, it does not meet the definition of being under official control and cannot be considered further.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Otinotus oneratus (Walker, 1858) [Hemiptera: Membracidae]	Yes (Ahmed *et al.* 2004a)	No. This species infests the stems of a number of plant species (Ali and Rane 1998). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Oxyrhachis serratus (Ahmad & Abrar 1976) [Hemiptera: Membracidae]	Yes (Rizvi *et al.* 2002)	No. Species of *Oxyrhachis* affect the stems, branches and leaf pedicels of plants (Misra *et al.* 2003). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Oxyrhachis tarandus Fabricius, 1798 [Hemiptera: Membracidae]	Yes (Rizvi *et al.* 2002)		Assessment not required	Assessment not required	Assessment not required	No
Parasaissetia nigra (Nietner, 1861) [Hemiptera: Coccidae]	Yes (Mahdihassan 1976)	Yes. This species can occur on fruits (EPPO 2006).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Parlatoria cinerea Hadden, 1909 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)	Yes. *Parlatoria crypta* and *P. pseudaspidiotus* have been found in mango consignments from Pakistan to the UK (DEFRA 2008). Other members of the genus, including *P. cinerea*, *P. oleae* and *P. pergandii*, affect foliage and stems (Peña 1993).	Assessment not required	Assessment not required	Assessment not required	No
Parlatoria crypta McKenzie, 1943 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		No records found	Yes. This scale is a pest on plants from 23 families, including many that are grown commercially in Australia (Ben-Dov *et al.* 2007).	Yes. *Parlatoria crypta* is a serious pest of mangoes in Pakistan (Mohyuddin and Mahmood 1993).	Yes
Parlatoria oleae (Colvée, 1880) [Hemiptera: Diaspididae]	Yes (Muzaffar 1974)		Assessment not required	Assessment not required	Assessment not required	No
Parlatoria pergandii Comstock, 1881 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Parlatoria pseudaspidiotus Lindinger, 1905 [Hemiptera: Diaspididae]	Yes (Qureshi and Mohiuddin 1982)		Yes (APPD 2010); Not present in WA (DAFWA 2003)	Yes. This species is already established in the eastern states of Australia (APPD 2010).	Yes. This species is a significant pest of orchids (Balachowsky 1953) but also occurs on a number of other host species.	Yes[WA]
Parthenolecanium persicae (Fabricius, 1776) [Hemiptera: Coccidae]	Yes (CABI 2007)	No. This species of scale infests foliage and stems (CABI 2007). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pinnaspis strachani (Cooley, 1899) [Hemiptera: Diaspididae]	Yes (Chapin and Ahmad 1966)	No. This is a scale insect that affects foliage (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Planococcoides robustus Ezzat & McConnell, 1956 [Hemiptera: Pseudococcidae]	Yes (Mohyuddin and Mahmood 1993)	No. This species is a root mealybug that is not associated with fruits (Puttarudriah and Eswaramurthy 1976).	Assessment not required	Assessment not required	Assessment not required	No
Planococcus citri (Risso, 1813) [Hemiptera: Pseudococcidae]	Yes (Rasheed *et al.* 1986)	Yes. This species occurs on fruits, leaves and stems of host species. It secretes honeydew, which promotes growth of sooty mould fungi (CABI 2007).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Planococcus ficus (Signoret, 1875) [Hemiptera: Pseudococcidae]	Yes (Cox 1989)	No[16]. It has been recorded on mango trees (Cox 1989); however, there is no published record on this mealybug supporting its association with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pseudaonidia trilobitiformis (Green, 1896) [Hemiptera: Diaspididae]	Yes (Ben-Dov *et al.* 2007)	Yes. This species affects foliage, stems and fruit (USDA 2006; Peña 1993).	Yes (Watson 2007)	Assessment not required	Assessment not required	No
Pseudococcus longispinus (Targioni Tozzetti, 1867) [Hemiptera: Pseudococcidae]	Yes (Peña and Mohyuddin 1997)[8]	Yes. This species of scale is found on fruits and leaves of mango (Peña and Mohyuddin 1997).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Pulvinaria polygonata Cockerell, 1905 [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)	No. These scale insects affect foliage (Srivastava 1997; Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pulvinaria psidii Maskell, 1893 [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Pyrilla perpusilla Walker, 1851 [Hemiptera: Lophopidae]	Yes (Rahim and Hashmi 1984)	No. This species infests foliage and exudes honeydew, which promotes the growth of sooty mould (CABI 2007). Not known to be associated	Assessment not required	Assessment not required	Assessment not required	No

[16] This species was initially considered as on the fruit pathway in the 2004 draft Import Risk Analysis for fresh mango fruit from India; however, further research has shown it is not associated with mango fruits and does not warrant further consideration. It was not considered on the import pathway in the provisional final or final Import Risk Analysis for fresh mango fruit from India.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		with fruit.				
Rastrococcus invadens Williams, 1986 [Hemiptera: Pseudococcidae]	Yes (Ben-Dov *et al.* 2007)	Yes. These species are found on leaves, flowers and fruit of mango (Peña 2004).	No records found	Yes. This species occurs on members of several plant families (Tobih *et al.* 2002). It is also known to spread through contaminated materials (Tobih *et al.* 2002).	Yes. This species is a serious pest of mango and a variety of other fruit and ornamental plants (Tobih *et al.* 2002). In addition to the direct damage caused by the species, honeydew produced by the insects promotes growth of sooty moulds (Tobih *et al.* 2002).	Yes
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	Yes (Qureshi and Mohiuddin 1982)		No records found	Yes. This pest has several hosts including mango, citrus, coffee and cashew (Maynard *et al.* 2004). These hosts are widely spread throughout the PRA area.	Yes. *Rastrococcus spinosus* is a pest of economic significance on mango and citrus in West Africa (Williams 1986), and on mango in Pakistan (Mahmood *et al.* 1983).	Yes
Saissetia coffeae (Walker, 1852) [Hemiptera: Coccidae]	Yes (CIE 1973b)	Yes. *Saissetia privigna* has been detected in mango fruit consignments entering the UK from Pakistan (DEFRA 2008). Other member of the genus, including *Saissetia coffeae* and *S. oleae*, affect foliage and stems of host plants (Peña and Mohyuddin 1997; CABI 2007).	Assessment not required	Assessment not required	Assessment not required	No
Saissetia oleae (Olivier, 1791) [Hemiptera: Coccidae]	Yes (CIE 1973c)		Assessment not required	Assessment not required	Assessment not required	No
Saissetia privigna De Lotto, 1965 [Hemiptera: Coccidae]	Yes (Muzaffar and Ahmad 1977)		No records found	Yes. This species occurs on a variety of plants in India, Kenya, Malaysia, Sri Lanka and Tanzania (Muzaffar and Ahmad 1977). There are similarities in the natural and urban environments in these countries to those in Australia, suggesting the species is likely to establish and spread in Australia.	No: On mango, this species has been noted as a minor pest in Israel (Germain *et al.* 2010) and a rare pest of mangoes in Pakistan (Muzaffar and Ahmad 1977). This species has also been recorded on coffee and olives where economic damage was not noted (Muzaffar and Ahmad 1977).	No
Spilostethus pandurus (Scopoli, 1763) [Hemiptera: Lygaeidae]	Yes (Ahmad *et al.* 1976)	No. This species is a polyphagous pest that is usually associated with pasture crops (Kapoor *et al.* 1982). Adults may feed externally on the fruit; however, because of their mobility they are not expected to stay	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		on the commodity during harvest.				
Vinsonia stellifera (Westwood, 1871) [Hemiptera: Coccidae]	Yes (Qureshi and Mohiuddin 1982)	No. This is a scale insect that affects foliage (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
HYMENOPTERA (wasps, ants)						
Camponotus compressus Fabricius, 1787 [Hymenoptera: Formicidae]	Yes (Mahdihassan 1979)	No. This species is usually found in association with aphids (Collingwood *et al.* 1997); it is not known to be associated with fruits.	Assessment not required	Assessment not required	Assessment not required	No
ISOPTERA (termites)						
Coptotermes heimi (Wasmann) [Isoptera: Rhinotermitidae]	Yes (Badshah *et al.* 2004)	No. Termites feed on the cellulose found in woody matter and frequently attack branches, stems and roots (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Heterotermes indicola (Wasmann, 1902) [Isoptera: Rhinotermitidae]	Yes (Badshah *et al.* 2004)	No. Termites feed on the cellulose found in woody matter and frequently attack branches, stems and roots (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Microtermes obesi Holmgren, 1913 [Isoptera: Termitidae]	Yes (Shahid 1991)	No. Termites feed on the cellulose found in woody matter and frequently attack branches, stems and roots (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Odontotermes assmuthi Holmgren, 1913 [Isoptera: Termitidae]	Yes (Manzoor and Akhtar 2002)	No. Termites feed on the cellulose found in woody matter and frequently attack branches, stems and roots (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Odontotermes gurdaspurensis Holmgren & Holmgren, 1917 [Isoptera: Termitidae]	Yes (Shahid 1991)		Assessment not required	Assessment not required	Assessment not required	No
Odontotermes horai Roonwal & Chhotani, 1962 [Isoptera:	Yes (Ahmed *et al.*		Assessment not	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Termitidae]	2004b)		required			
Odontotermes lokanandi Chatterjee & Thakur, 1967 [Isoptera: Termitidae]	Yes (Sattar *et al.* 2008)		Assessment not required	Assessment not required	Assessment not required	No
Odontotermes obesus (Rambur, 1842) [Isoptera: Termitidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
Odontotermes wallonensis (Wasmann, 1902) [Isoptera: Termitidae]	Yes (Peña and Mohyuddin 1997)[8]		Assessment not required	Assessment not required	Assessment not required	No
Trinervitermes biformis (Wasmann, 1902) [Isoptera: Termitidae]	Yes (Qureshi and Mohiuddin 1982)	No. Termites feed on the cellulose found in woody matter and frequently attack branches, stems and roots (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
LEPIDOPTERA (moths, butterflies)						
Acherontia styx Westwood, 1847 [Lepidoptera: Sphingidae]	Yes (Kamaluddin and Haque 2000)	No. This species feeds on foliage and young shoots (CABI 2007). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Agrius convolvuli (Linnaeus, 1758) [Lepidoptera: Sphingidae]	Yes (CIE 1983)	No. This species feeds on foliage and can cause complete defoliation in severe cases (CABI 2007). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Anarsia lineatella Zeller, 1839 [Lepidoptera: Gelechiidae]	Yes (EPPO 2006)	No. Species of this genus are stem borers (Daane *et al.* 1993). *Anarsia lineatella* is known to bore into stonefruits and was considered to be on the import pathway for stonefruit from the US. However, records of the pest occurring on mango s show that only the pith and inner bark of tender twigs and plant shoots are affected by the species (Butani 1993). *Anarsia lineatella* is known as a “mango shoot borer” for this reason	Assessment not required	Assessment not required	Assessment not required	No
Anarsia melanoplecta Meyrick, 1914 [Lepidoptera: Gelechiidae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		(Srivastava 1997; Butani 1993).				
Cadra cautella (Walker, 1863) [Lepidoptera: Pyralidae]	Yes (Huque 1972)	No. This species is a storage pest of dried mango and a number of other foods; not associated with fresh fruit (Khan *et al.* 1999).	Assessment not required	Assessment not required	Assessment not required	No
Characoma nilotica (Rogenhofer, 1882) [Lepidoptera: Noctuidae]	Yes (Habib 1983)	No. This species feeds on inflorescences preventing fruit set (Habib 1983).	Assessment not required	Assessment not required	Assessment not required	No
Chlumetia transversa (Walker, 1863) [Lepidoptera: Noctuidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a shoot borer that kills new stems by boring into them and feeding on young leaves and inflorescences (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Conogethes punctiferalis (Guenée, 1854) [Lepidoptera: Pyralidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. This species feeds on inflorescences and fruits of mango (Srivastava 1997). Larvae bore into fruits, damaging the seeds (Srivastava 1997).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Cricula trifenestrata Helfer, 1837 [Lepidoptera: Saturniidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species feeds on foliage and can cause complete defoliation of mango trees in severe cases (Ali and Karim 1991). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Dasychira mendosa (Hübner, 1823) [Lepidoptera: Lymantriidae]	Yes (Zaman and Karimullah 1987)	No. This species is a pest of foliage (Rani and Sridhar 2004). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Deanolis sublimbalis Snellen,	No[17]	Assessment not required	Assessment not	Assessment not required	Assessment not required	No

[17] Peña and Mohyuddin (1997) provided a generic list of mango pests with their distribution throughout the world. However, they considered India and Pakistan as a single region and if a pest was present in one of these countries they mentioned its presence in both countries. Peña and Mohyuddin (1997) stated that *D. sublimbalis* is present in India and Pakistan; however, the list provided by

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
1899 [Lepidoptera: Pyralidae]			required			
Dudua aprobola (Meyrick, 1886) [Lepidoptera: Tortricidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species feeds on the inflorescences of a number of plants reducing fruit set (Verghese and Jayanthi 1999). Larvae feed on leaves which they web together to form a shelter (Meijerman and Ulenburg 2011).	Assessment not required	Assessment not required	Assessment not required	No
Eudocima fullonia (Clerck, 1764) [Lepidoptera: Noctuidae]	Yes (Waterhouse 1993)	Yes. Larvae of this moth feed on foliage and pupate inside a folded leaf (Srivastava 1997). Adults are large fruit piercing moths which imbibe juices from fleshy fruits at night (Fay 2005); they are not associated with the import pathway.	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Gatesclarkeana erotias (Meyrick, 1905) [Lepidoptera: Tortricidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a shoot borer; not associated with fruit (Srivastava 1997). Larvae construct shelters by sticking together leaves of host plants (Fletcher 1921).	Assessment not required	Assessment not required	Assessment not required	No
Helicoverpa armigera (Hübner, 1805) [Lepidoptera: Noctuidae]	Yes (Gogi *et al.* 2006)	No. This species feeds on inflorescences and immature fruits leading to poor fruit set (Bharati *et al.* 2007).	Assessment not required	Assessment not required	Assessment not required	No
Indarbela quadrinotata Walker, 1856 [Lepidoptera: Metarbelidae]	Yes (Qureshi and Mohiuddin 1982)	No. The caterpillars of this species bore into the trunk of trees forming galleries; not associated with fruit (Srivastava 1997).	Assessment not required	Assessment not required	Assessment not required	No

Pakistan (Qureshi and Mohuyddin 1982) did not include *Deanolis sublimbalis*. Further investigation indicated that *Deanolis sublimbalis* is not present in Pakistan (Waterhouse 1998; Krull 2004; Krull and Basedow 2006; Moore 2006). Therefore, *Deanolis sublimbalis* is not considered further.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Lamida moncusalis Walker, 1859 [Lepidoptera: Pyralidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species eats leaves and tender shoots of plants in the Anacardiaceae family (Rao *et al.* 2002). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Lymantria lunata (Stoll, 1782) [Lepidoptera: Lymantriidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species feeds primarily on foliage (Islam *et al.* 1988).	Assessment not required	Assessment not required	Assessment not required	No
Lymantria marginata Walker, 1855 [Lepidoptera: Lymantriidae]	Yes (Peña and Mohyuddin 1997)[8]	No. This species attacks foliage and can cause complete defoliation in extreme cases (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Melanitis leda ismene (Cramer, 1775) [Lepidoptera: Nymphalidae]	Yes (Dale 1994)	No. Adults of this species can feed on fallen, rotten fruit; larvae feed exclusively on monocots (Braby 2000); not associated with commercially produced mango fruits.	Assessment not required	Assessment not required	Assessment not required	No
Orthaga exvinacea (Hampson, 1891) [Lepidoptera: Pyralidae]	Yes (Peña and Mohyuddin 1997)[8]	No. This species is a leaf webber that consumes foliage and makes large silken webs in which pupation takes place; not associated with fruit (Srivastava 1997).	Assessment not required	Assessment not required	Assessment not required	No
Parasa lepida (Cramer, 1799) [Lepidoptera: Limacodidae]	Yes (Qureshi and Mohiuddin 1982)	No. This pest feeds on the foliage of host plants (Jeyabalan *et al.* 1996). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Penicillaria jocosatrix Guenée, 1952 [Lepidoptera: Noctuidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is considered to be a shoot borer which also consumes foliage (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pericallia ricini (Fabricius, 1775) [Lepidoptera: Arctiidae]	Yes (Tayyab *et al.* 2006)	No. This pest feeds on foliage of host plants (Chockalingam and Krishnan 1984). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Rapala iarbus (Fabricius, 1787) [Lepidoptera: Lycaenidae]	Yes (Qureshi and Mohiuddin 1982)	No. Rapala airbus primarily feeds on foliage and inflorescences of Sapindales and Fabales, as well as mango (Robinson *et al.* 2011). The larvae are not recorded as feeding on fruit and are not associated with the import pathway.	Assessment not required	Assessment not required	Assessment not required	No
Scirpophaga excerptalis (Walker, 1863) [Lepidoptera: Pyralidae]	Yes (Khan and Baloch 1971)	No. This species feeds on stems, leaves and growing points of plants; not associated with fruit (CABI 2007).	Assessment not required	Assessment not required	Assessment not required	No
Selepa celtis Moore, 1858 [Lepidoptera: Noctuidae]	Yes (Qureshi and Mohiuddin 1982)	No. This species is a foliage feeder that may infest a high percentage of leaves on host trees (Bajpai *et al.* 2003). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Spilosoma obliqua Walker, 1865 [Lepidoptera: Arctiidae]	Yes (Khattak *et al.* 1991)	No. This species feeds primarily on foliage (Peña and Mohyuddin 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Stathrobrota simplex (Walsingham, 1891) [Lepidoptera: Cosmopterigidae]	Yes (Chamberlain 1993)	No. This species is primarily a pest of cotton and affects inflorescences (Balan *et al.* 1985). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Strepsicrates rhothia (Meyrick, 1910) [Lepidoptera: Tortricidae]	Yes (Ahmad 1972)	No. This species is a foliage pest that may also affect inflorescences reducing fruit set (Ahmad 1972).	Assessment not required	Assessment not required	Assessment not required	No
Thalassodes dissita Walker, 1861 [Lepidoptera: Geometridae]	Yes (Peña and Mohyuddin 1997)[8]	No. These species feed primarily on foliage and flowers; not associated with fruit (Peña and Mohyuddin 1997; Kannan and Rao 2003).	Assessment not required	Assessment not required	Assessment not required	No
Thalassodes quadraria Guenée, 1858 [Lepidoptera: Geometridae]	Yes (Qureshi and Mohiuddin 1982)		Assessment not required	Assessment not required	Assessment not required	No
ORTHOPTERA (grasshoppers, crickets, katydids)						
Gryllus viator Kirby, 1906	Yes (Qureshi and	No. This species feeds on plant leaves and stems (Gangwere and	Assessment not	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
[Orthoptera: Gryllidae]	Mohiuddin 1982)	Spiller 1995). Not known to be associated with fruit.	required			
Tarbinskiellus portentosus (Lichtenstein, 1796) [Orthoptera: Gryllidae]	Yes (Saeed *et al.* 2000)	No. This species feeds on plant leaves and stems (Gangwere and Spiller 1995). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
THYSANOPTERA (thrips)						
Anaphothrips sudanensis Trybom, 1911 [Thysanoptera: Thripidae]	Yes (Siddiqui *et al.* 2005)	No. This species feeds on the surface of leaves, buds and flowers causing black spots and wilting (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Caliothrips indicus (Bagnall, 1913) [Thysanoptera: Thripidae]	Yes (Afzal *et al.* 2002)	No. This species is a foliage feeder and is not associated with fruits (Sahu and Shaw 2005).	Assessment not required	Assessment not required	Assessment not required	No
Haplothrips ganglbaueri Schmutz, 1913 [Thysanoptera: Phlaeothripidae]	Yes (Ananthakrishnan and Thangavelu 1976)	No. This species feeds on the surface of leaves, buds and flowers causing black spots and wilting (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Megalurothrips distalis (Karny, 1913) [Thysanoptera: Thripidae]	Yes (Varatharajan *et al.* 1992)	No. This species feeds on the surface of leaves, buds and flowers causing black spots and wilting (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Rhipiphorothrips cruentatus Hood, 1919 [Thysanoptera: Thripidae]	Yes (Qureshi and Mohiuddin 1982)	Yes. This species affects foliage causing dark spots and scars from feeding activity (Srivastava 1997). It is also known to feed on mango fruits (Lee and Wen 1982).	No records found	Yes. This thrips is present in Afghanistan, Bangladesh, China, India, Mayanmar, Pakistan, Oman and Thailand (CABI 2007). There are similar environments in parts of Australia that would be suitable for the establishment and spread of this species.	Yes. An important pest of not only mango but other hosts including table grapes. In grapes it is known to cause considerable damage by retarding the development of shoots and flowers and attacking the leaves (Bournier 1976).	Yes

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Scirtothrips dorsalis Hood, 1919 [Thysanoptera: Thripidae]	Yes (Syed *et al.* 1995)	Yes. Feeding of this species occurs on leaves, buds and fruit resulting in malformation of vegetative and reproductive parts (Lee and Wen 1982; Srivastava 1997).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Selenothrips rubrocinctus (Giard, 1901) [Thysanoptera: Thripidae]	Yes (Sarwar 2006)	No. This thrips feeds on foliage by piercing leaves and scraping out the leaf tissue (Srivastava 1997). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Thrips hawaiiensis (Morgan, 1913) [Thysanoptera: Thripidae]	Yes (Reynaud *et al.* 2008)	Yes. Both *T. hawaiiensis* and *T. tabaci* feed by sucking sap from the leaves and fruit of mango trees (Lee and Wen 1982; Morishita 2005). *T. palmi* is not known to affect fruit but is commonly found on buds (Peña and Mohyuddin 1997).	Yes (AICN 2007)	Assessment not required	Assessment not required	No
Thrips palmi Karny, 1925 [Thysanoptera: Thripidae]	Yes (Rosenheim *et al.* 1990)		Assessment not required	Assessment not required	Assessment not required	No
Thrips tabaci Lindeman, 1888 [Thysanoptera: Thripidae]	Yes (Attique and Ahmad 1990)		Yes (AICN 2007)	Assessment not required	Assessment not required	No
CHLOROPHYTA						
Cephaleuros virescens (Kunze) Karsten, 1891 [Trentepohliales: Trentepohliaceae]	Yes (Tariq 1991)	No. This species causes rust-coloured spots and white crusts on the foliage of the plant (Kwee and Chong 1994). In severe cases the disease can spread to the bark and branches and invade the cortical tissues (Kwee and Chong 1994). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
PATHOGENS						
BACTERIA						
Pseudomonas syringae pv. *syringae* van Hall [Pseudomonadales:	Yes (Siddique *et al.* 1988)	No. This species causes necrotic lesions on inflorescences, buds and leaves reducing fruit set (Cazorla *et*	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Pseudomonadaceae]		*al.* 2006). Not known to be associated with fruit.				
Rhizobium radiobacter (Beijerinck & van Delden) Young *et al.* [Rhizobiales: Rhizobiaceae]	Yes (Al-Momani *et al.* 1998)	No. This species is associated with root and stem (Bradbury 1986).	Assessment not required	Assessment not required	Assessment not required	No
Xanthomonas campestris pv. *mangiferae-indicae* (Patel, Moniz & Kulkarni) Robbs *et al.* [Xanthomonadales: Xanthomonadaceae]	Yes (Khan and Mirza 1995)	Yes. This species causes lesions on foliage and fruit; infected fruit produces bacteria-laden exudate that may spread the infection (Johnson *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
FUNGI						
Alternaria alternata (Fr.) Keissler (synonym: *Alternaria tenuis* Nees[18] [Anamorphic Pleospraceae]	Yes (Iqbal *et al.* 2006a)	Yes. These species cause post-harvest fruit rot in mangoes; conidia penetrate fruit and develop intercellularly before the hyphae become latent prior to fruit ripening (Abd-Elmegid *et al.* 1971; Ploetz *et al.* 1998).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Alternaria tenuissima (Kunze) Wiltshire [Anamorphic Pleospraceae]	Yes (Khan and Ahmad 1998)		Yes (APPD 2010)	Assessment not required	Assessment not required	No
Aspergillus niger Tiegh. var. *niger* [Eurotiales: Trichocomaceae]	Yes (Javaid *et al.* 2006)	Yes. Both species are common on mango fruits. *Aspergillus niger* var. *niger* causes light brown lesions on harvested fruit and *A. terreus* causes stem end rot (Johnson *et al.* 1989; Patel *et al.* 1985).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Aspergillus terreus Thom, [Eurotiales: Trichocomaceae]	Yes (Manzoor *et al.* 2004)		Yes (APPD 2010)	Assessment not required	Assessment not required	No
Athelia rolfsii (Curzi) C.C. Tu & Kimbr. [Atheliales: Atheliaceae]	Yes (Iqbal *et al.* 2001)	No. This species is a soil-borne disease affecting young plants; not known to be associated with fruits	Assessment not required	Assessment not required	Assessment not required	No

[18] This species forms part of the Mango decline disease complex (also known as Sudden death phenomenon, Mango wilt disease, Sudden mango decline disease, Sudden decline, Mango sudden death syndrome and Mango sudden decline). The Mango decline disease complex has become an emerging problem of mango orchards internationally since the late 1990's (Khanzada *et al.* 2005). This, and other contributing, species have been considered separately in this assessment to ensure differences in distribution (presence or absence in Pakistan and Australia), pathway association and potential for establishment are adequately addressed. Where appropriate, economic consequences for a species takes into account its importance as a member of this disease causing complex. Further information on the Mango decline disease complex can be found in Appendix C.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		(Ploetz and Prakash 1997).				
Beltraniella portoricensis (F. Stevens) Piroz. & S.D. Patil [Xylariales: Hyponectriaceae] (synonym: *Ellisiopsis gallesiae* Bat. & Nascim.)	Yes (Pirozynski 1963)	No: This species is a saprophyte associated with leaf litter (Heredia *et al.* 2002; Shanthi and Vittal 2010a; Shanthi and Vittal 2010b; Duong *et al.* 2008). There is no evidence that this pathogen is associated with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Botryosphaeria dothidea (Moug.) Ces. & De Not. [Dothideales: Botryosphaeriaceae] (synonym: *Dothiorella dominicana* Petr. & Cif.	Yes (Ahmad 1978)	Yes. *Botryosphaeria dothidea* causes stem end rot in harvested mangoes (Plan *et al.* 2002).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Botryosphaeria ribis Grossenb. & Duggar [Dothideales: Botryosphaeriaceae]	Yes (Quraishi and Jamal 1970)	No. *Botryosphaeria ribis* causes tip-dieback and is not known to be associated with fruits or seeds (Richardson 1990; Akhtar and Alam 2002).	Assessment not required	Assessment not required	Assessment not required	No
Capnodium ramosum Cooke [Capnodiales: Capnodiaceae]	Yes (GSAD 2004)	Yes. This species causes sooty mould to grow over the foliage and fruit of infected plants (Sharma and Badiyala 1991; Ahmed *et al.* 1991; Akhtar and Alam 2002).	Yes (DAFWA 2003)	Assessment not required	Assessment not required	No
Ceratocystis fimbriata[19] Ellis and Halst.[11] [Microascales: Ceratocystidaceae]	Yes (van Wyk *et al.* 2007)	No. This species has been recorded as a causal agent of mango sudden decline disease (van Wyk *et al.* 2007). This disease causes dieback of branches and eventual death of the plant (Iqbal *et al.* 2007).	Assessment not required	Assessment not required	Assessment not required	No
Ceratocystis manginecans van Wyk *et al.*[11] [Microascales:	Yes (van Wyk *et al.*	No. *Ceratocystis manginecans* has been recorded as a causal agent of	Assessment not	Assessment not required	Assessment not required	No

[19] The taxonomy of *Ceratocystis fimbriata* has been reviewed and is now known to be a complex of many species, each with a distinct host range and geographic distribution (CABI 2007). Further information on its taxonomy and role in the Mango decline disease complex can be found in Appendix C.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Ceratocystidaceae]	2007)	mango sudden decline disease (van Wyk *et al*. 2007). The species is not known to be associated with fruit and is not considered to be on the fruit pathway. However, *C. manginecans* is known to be vectored by mango bark beetle (Masood *et al*. 2009). For further details on the beeltes association with the import pathway see the risk assessment for mango bark beelte.	required			
Ceratocystis paradoxa (Dade) C. Moreau [Microascales: Ceratocystidaceae]	Yes (CMI 1987)	Yes. When associated with mango fruits it can cause early ripening (Cherian and Varghese 2002).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Ciliochorella mangiferae Syd. [Anamorphic Pezizomycotina]	Yes (Farr and Rossman 2011)	No. This species has been found on dead leaves of mango (Subramanian and Ramakrishnan 1956); it is not associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Cladosporium cladosporioides (Fresen.) GA De Vries Synonym: *Hormodendrum cladosporioides* (Fresen.) Sacc. [Capnodiales: Davidiellaceae]	Yes (Maqbool *et al*. 1997)	Yes. This species cause stem end rot of mango fruits (Johnson *et al*. 1991).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Coccomyces vilis Syd., P. Syd. & E.J. Butler [Rhytismatales: Rhytismataceae]	Yes (Watson 1971)	No. This species causes leaf spot in mango (Cannon and Minter 1984). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Cochliobolus hawaiiensis Alcorn [Pleosporales: Pleosporaceae]	Yes (Khan and Ahmad 1998)	No. These species cause leaf spots and other foliar diseases on a number of plants (CABI 2007). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Cochliobolus lunatus R.R. Nelson & Haasis [Pleosporales: Pleosporaceae]	Yes (Rajput *et al*. 2005)		Assessment not required	Assessment not required	Assessment not required	No
Cochliobolus tuberculatus Sivan. [Pleosporales: Pleosporaceae]	Yes (Sivanesan 1990)		Assessment not required	Assessment not required	Assessment not required	No
Coleophoma cylindrospora (Desm.) Hohn. [Dothideales:	Yes (Ahmad *et al*.	No: This fungus is associated with leaves and leaf litter (Masilamani and	Assessment not	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Incertae sedis]	1997)	Muthumary 1995; Sieber-Canavesi and Sieber 1993). No evidence this pathogen is associated with mango fruit.	required			
Coleophoma mangiferae S. Ahmed [Dothideales: Incertae sedis]	Yes (Ahmad *et al.* 1997)	No: The genus is associated with leaves (Wu *et al.* 1996). There is no evidence that this species is associated with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Colletotrichum capsici (Syd.) E.J. Butler & Bisby [Incertae sedis: Glomerellaceae]	Yes (Shahzad 2000)	Yes. These species cause fruit spots and lesions; infections may be symptomless at the time of harvest and only apparent upon ripening (Ploetz *et al.* 1998).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Colletotrichum gloeosporioides[20] (Penz.) Penz. & Sacc. [Phyllachorales: Hypocreomycetidae]	Yes (Shahzad 2000)		Yes (APPD 2010)	Assessment not required	Assessment not required	No
Colletotrichum mangiferae Kelker [Incertae sedis: Glomerellaceae]	Yes (Farr and Rossman 2011)		No records found	Yes. Species of this genus are often found growing on fruits of a variety of plant species (CABI 2007).	No. This species has been recorded on mango and other host species (Farr and Rossman 2011). However, it is not recorded as having an economically significant impact on its host species.	No
Coniothyrium olivaceum Bonord. [Pleosporales: Incertae sedis] (synonym: *Microsphaeropsis olivacea* (Bonard.) Hohn.)	Yes (Ahmad *et al.* 1997)	No: This species causes leaf spotting (Hammouda 1991), and is associated with buds, leaf scars and internodes (Royse and Ries 1978). This species can be used as a biocontrol agent for peach canker (Royse and Ries 1978). There is no evidence that this pathogen is associated with mango	Assessment not required	Assessment not required	Assessment not required	No

[20] The species, *Colletotrichum gloeosporioides*, has been recently described as a species complex (Phoulivong *et al.* 2010). It is thought to include at least 14 species (Damm *et al.* 2010; Phoulivong *et al.* 2010). Further taxonomic revision is currently underway which may provide additional information on the taxonomic relationship within the species complex. Current information available from Pakistan suggests only three species are associated with mango in Pakistan.

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		fruit.				
Cytoplea mangiferae S. Ahmad [Pleosporales: Didymosphaeriaceae]	Yes (Ahmad *et al.* 1997)	No: This genus is known as saprophytic (Poon and Hyde 1998). This pathogen is not known to be associated with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Cytosphaera mangiferae Died. [Anamorphic Pezizomycotina]	Yes (Johnson and Hyde 1992)	Yes. This species causes stem end rot of harvested mango fruits (Johnson *et al.* 1992).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Didymella mangiferae Bat. [Incertae sedis: Pleosporales]	Yes (Farr and Rossman 2011)	No. This species affects leaves causing necrosis (Farr and Rossman 2011). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Dothiorella ladharensis S. Ahmad [Botryosphaeriales: Botryosphaeriaceae]	Yes (Ahmad *et al.* 1997)	Yes: The genus is associated with stem-end rot of mango fruit and can infect fruit directly through wounds (Johnson *et al.* 1991). These pathogens are spread by graft and can cause early fruit fall, fruitlet abortion and can cause severe losses post-harvest (Johnson *et al.* 1991).	No records found	Yes. This pathogen is present in Pakistan (Ahmad *et al.* 1997). There are similar environments in parts of Australia that would be suitable for the establishment and spread of this species.	No. This species has been recorded on mango (Farr and Rossman 2011). However, it is not recorded as having an economically significant impact.	No
Erysiphe cichoracearum Jacz. [Erysiphales: Erysiphaceae]	Yes (Bhutta *et al.* 1995)	No. This species is a powdery mildew that affects leaves, stems and flowers; it is not associated with fruit (CABI 2007).	Assessment not required	Assessment not required	Assessment not required	No
Erythricium salmonicolor (Berk. & Broome) Burds. [Corticiales: Corticiaceae]	Yes (CABI 2007)	No. This pathogen causes a wood disease called pink disease (Ploetz *et al.* 1998). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Fracchiaea heterogenea Sacc. [Coronophorales: Nitschkiaceae]	Yes (Ahmad *et al.* 1997)	No: This species has been found on dead branches of mango (Farr and Rossman 2011); not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Fusarium mangiferae Britz *et al.* [Hypocreales: Nectriaceae]	Yes (Iqbal *et al.* 2006b)	Yes. Conidia survive on the fruit surface but have not been detected in the flesh or seed (Youssef *et al.* 2007).	No[21]	Yes. This species is under official control in the Northern Territory. This suggests that the species is suited for establishment and spread in Australia.	Yes. Mango malformation is considered one of the most important diseases of mango (Youssef *et al.* 2007).	Yes
Fusarium oxysporum Schltdl.:Fr.[11] [Hypocreales: Nectriaceae]	Yes (Iqbal *et al.* 2006a)	No. This species causes black root rot and is not associated with fruits (Kwee and Chong 1994).	Assessment not required	Assessment not required	Assessment not required	No
Fusarium pallidoroseum (Cooke) Sacc. [Hypocreales: Nectriaceae]	Yes (Iqbal *et al.* 2006a)	Yes. This species is part of the mango-malformation complex (Ploetz *et al.* 1998) and contaminate fruit with conidia.	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Fusarium subglutinans (Wollenw. & Reinking) P.E. Nelson *et al.* [Hypocreales: Nectriaceae]	Yes (Akhtar and Alam 2002)	Yes. This species is part of the mango-malformation complex (Ploetz *et al.* 1998) and contaminate fruit with conidia.	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Ganoderma applanatum (Pers.) Pat. [Polyporales: Ganodermataceae]	Yes (Steyaert 1975)	No. This species occurs on wood of various tree species (Banerjee and Saekae 1956). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Geotrichum candidum Link Synonym: *Oospora mali* Kidd & Beaumont [Saccharomycetales: Dipodascaceae]	Yes (Rafiq *et al.* 1995)	Yes. This species causes post-harvest fruit diseases in mango (Badyal and Sumbali 1990).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Gibberella intricans Wollenw. [Hypocreales: Nectriaceae]	Yes (GSAD 2004)	No. *Gibberella intricans* is a soil-borne pathogen that causes wilt of mango (Dwivedi *et al.* 2003). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Gibberella zeae (Schwein.) Petch [Hypocreales: Nectriaceae]	Yes (Bhutta 1998)	No. This species causes malformation of inflorescences	Assessment not	Assessment not required	Assessment not required	No

[21] This species has been detected in the Northern Territory of Australia. It is currently the subject of an ongoing eradication campaign (IPPC 2010).

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		preventing fruit development (Chattopadhyay and Nandi 1977).	required			
Gyrothrix podosperma (Corda) Rabenh. 1844 [Incertae sedis]	Yes (Farr and Rossman 2011)	No. This species is saprophytic (Allegrucci *et al.* 2005). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Hexagonia discopoda Pat. & Har. [Polyporales: Polyporaceae]	Yes (Ahmad *et al.* 1997)	No: This species is a wood rot fungi (Dass and Teyegaga 1996). This pathogen is not known to be associated with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Lasiodiplodia theobromae (Pat.) Griffon & Maubl.[11] [Botryosphaeriales: Botryosphaeriaceae]	Yes (Khanzada *et al.* 2005)	Yes. This fungus infects fruit through the peduncle and pedicel; it is known to spread in harvested fruit by physical contact or by exudates from decaying fruit (Ploetz *et al.* 1998).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Leptosphaeria sacchari Breda de Haan [Pleosporales: Leptosphaeriaceae]	Yes (Croft 2000)	No. This species causes leaf spot on mango (Farr and Rossman 2011). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Macrophomina phaseolina (Tassi) Goid. [Botryosphaeriales: Botryosphaeriaceae]	Yes (Bhutta *et al.* 1995)	Yes. This species is commonly found on mature mango fruits (Sinha *et al.* 2003).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Nattrassia mangiferae (Syd. & P. Syd.) Crous, Slippers & A.J.L. Phillips [Botryosphaeriales: Botryosphaeriaceae]	Yes (Farr and Rossman 2011)	Yes. This species causes post-harvest diseases of mango fruits including soft brown rot and stem end rot (Saaiman and Smith 1997).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Nectria haematococca Berk. & Broome [Hypocreales: Nectriaceae]	Yes (Khan and Ahmad 1998)	No. This species causes black root rot and stem lesions (Kwee and Chong 1994). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Neofusicoccum mangiferae (Syd. & P. Syd.) Crous, Slippers & A.J.L. Phillips [Botryosphaeriales: Botryosphaeriaceae]	Yes (Ahmad *et al.* 1997)	Yes: This species causes small brown lesions on fruit that lead to mango fruit rot (Ni *et al.* 2010). This pathogen is found on stems and can cause dieback of trees (Johnson *et*	Yes (Phillips and Alves 2009)	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
		al. 1992). This pathogen is also associated with fruit rot of avocado (Ni *et al.* 2009).				
Oidium mangiferae Berthet, [Erysiphales: Erysiphaceae]	Yes (Akhtar and Alam 2000)	Yes. This fungus occurs on inflorescences, leaves and fruits (Akhtar and Alam 2002).	Yes (Farr and Rossman 2011)	Assessment not required	Assessment not required	No
Patellariopsis clavispora (Berk. & Broome) Dennis [Helotiales: Dermateaceae]	Yes (Farr and Rossman 2011)	No. This species is found on decorticated wood (Farr and Rossman 2011); not known to be associated with mango fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pestalotiopsis mangiferae (Henn.) Steyaert [Xylariales: Amphisphaeriaceae]	Yes (Panhwar 2005)	Yes. *Pestalotiopsis mangiferae* primarily causes grey leaf spot but may also infect fruit causing grey spots and necrotic areas (Ploetz *et al.* 1998).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Pestalotiopsis versicolor (Spegazzini) Styaert [Xylariales: Amphisphaeriaceae]	Yes (Ahmad 1969)	No. *Pestalotiopsis versicolour* causes leaf spots and is not known to occur on fruits (Kwee and Chong 1994).	Assessment not required	Assessment not required	Assessment not required	No
Phellinus gilvus (Schwein.) Pat. [Hymenochaetales: Hymenochaetaceae]	Yes (Ahmad *et al.* 1997)	No: The genus is associated with the stem causing white pocket rot and severe plant disease such as canker and heart rot (Jo *et al.* 2009).	Assessment not required	Assessment not required	Assessment not required	No
Phoma glomerata (Corda) Wollenweb & Hochapfel [Incertae sedis: Pleosporales]	Yes (Mirza *et al.* 2004)	No. This species causes foliar spots and necrotic patches on leaves (Prakash and Singh 1977). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Phoma mangiferae S. Ahmad [Pleoporales: Incertae sedis]	Yes (Ahmad *et al.* 1997)	No: This fungus is a secondary pathogen associated with the fruit (Diedhiou *et al.* 2007).	Assessment not required	Assessment not required	Assessment not required	No
Phomopsis mangiferae S. Ahmad [Diaporthales: Diaporthaceae]	Yes (Punithalingam 1993)	Yes. This species causes stem end rot of harvested mango fruits (Johnson *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Rhizoctonia solani JG Kuhn [Ceratobasidiales: Ceratobasidiaceae]	Yes (Manzoor *et al.* 2004)	No. This species causes root rot and damping off; it is not associated with fruit (Ploetz and Prakash 1997).	Assessment not required	Assessment not required	Assessment not required	No
Rhizopus stolonifer (Ehrenb.:Fr.) Vuill. [Mucorales: Mucoraceae] (synonym: *Rhizopus nigricans* Ehrenb.)	Yes (Manzoor *et al.* 2004)	Yes. This species causes small pale spots on fruit (Johnson *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Schizophyllum commune Fr. [Agaricales: Schizophyllaceae]	Yes (Ahmad *et al.* 1997)	No: This fungus is a saprophyte associated with fallen dead branches and trees (Ohm *et al.* 2010).	Assessment not required	Assessment not required	Assessment not required	No
Sclerotinia sclerotiorum (Lib.) de Bary [Helotiales: Sclerotiniaceae]	Yes (Bhutta *et al.* 1995)	Yes. This species causes mould to grow on fruit as well as cankers on stems and lesions on leaves (CABI 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Setosphaeria rostrata K.J. Leonard [Pleosporales: Pleosporaceae]	Yes (Ahmad and Ilyas 1994)	No. This fungus causes leaf blight (Sawant and Raut 1994). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Tripospermum acerium (Syd.) Speg. [Capnodiales: Capnodiaceae]	Yes (GSAD 2004)	Yes. This species causes a black mildew to grow over the foliage and fruit of infected plants (Ploetz and Prakash 1997; Akhtar and Alam 2002).	No records found	Yes. This species is a sooty mould that coats fruits and other plant surfaces (Nameth *et al.* 2003). Sooty moulds occur on a number of plant species (Nameth *et al.* 2003).	No. This species is a sooty mould, which is considered to be a weak pathogen or secondary invader and is normally considered to be a cosmetic or aesthetic problem (Nameth *et al.* 2003).	No
Tryblidaria pakistanica (E. Müll. & S. Ahmad) Kutorga & D. Hawksw. [Patellariales: Patellariaceae]	Yes (Farr and Rossman 2011)	No. This species occurs on branches (Farr and Rossman 2011); it is not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Verticillium albo-atrum Reinke & Berthold [Incertae sedis: Plectosphaerellaceae]	Yes (Javed *et al.* 1998)	No. These species cause *Verticillium* wilt, which causes necrosis of patches of the trees canopy; they are not known to affect fruit (Ploetz and Prakash 1997).	Assessment not required	Assessment not required	Assessment not required	No
Verticillium dahliae Kleb. [Incertae sedis: Plectosphaerellaceae]	Yes (Bhutta *et al.* 1997)		Assessment not required	Assessment not required	Assessment not required	No
STRAMINOPILA						

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Phytophthora nicotianae Breda de Haan [Peronosporales: Peronosporaceae]	Yes (Saleem *et al.* 1993)	Yes. These species are best known as the causal agents of wilt, crown rot and root rot; however, they have also been found on mango fruit (Ploetz and Prakash 1997; CABI 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	No
Phytophthora palmivora (E.J. Butler) E.J. Butler [Peronosporales: Peronosporaceae]	Yes (Aslam *et al.* 1995)		Yes (APPD 2010)	Assessment not required	Assessment not required	No
Pythium vexans de Bary [Pythiales: Pythiaceae]	Yes (Lodhi 2007)	No. This species is the cause of root rot and seedling wilt (Kwee and Chong 1994). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
NEMATODES						
Aphelenchus avenae Bastian, 1865 [Rhabditida: Aphelenchoididae]	Yes (Islam *et al.* 2006)	No. Species of *Aphelenchus* are soil-borne and are *usually* associated with diseased plant tissue where they feed upon fungi (Evans *et al.* 1993). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Aphelenchus eremitus Thorne, 1961 [Rhabditida: Aphelenchoididae]	Yes (Maqbool 1992)		Assessment not required	Assessment not required	Assessment not required	No
Basiria graminophila Siddiqi, 1959 [Rhabditida: Tylenchulidae]	Yes (Khan and Shaukat 2005)	No. This species is soil-borne and is not associated with fruit (Khan and Shaukat 2005).	Assessment not required	Assessment not required	Assessment not required	No
Ditylenchus clarus Thorne. &. Malek. 1968 [Rhabditida: Anguinidae]	Yes (Farshori 1995)	No. This species is an ecto-parasite of stems and leaves of a number of plant species; infestation may, in rare cases, be internal (Luc *et al.* 1990).	Assessment not required	Assessment not required	Assessment not required	No
Helicotylenchus digonicus Perry, 1959 [Rhabditida: Haplolaimidae]	Yes (Khan 2005)	No. Species of *Helicotylenchus* are ecto- and semi-endo- root parasites (Evans *et al.* 1993). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Helicotylenchus dihystera (Cobb) Sher, 1961 [Rhabditida: Haplolaimidae]	Yes (Pathan *et al.* 2004)		Assessment not required	Assessment not required	Assessment not required	No
Helicotylenchus indicus Siddiqi 1963 [Rhabditida: Haplolaimidae]	Yes (Khan *et al.* 2005)		Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Helicotylenchus mangiferensis Elmiligy 1970 [Rhabditida: Haplolaimidae]	Yes (Khan *et al.* 2005)		Assessment not required	Assessment not required	Assessment not required	No
Helicotylenchus multicinctus (Cobb) Golden, 1956 [Rhabditida: Haplolaimidae]	Yes (Khan and Shaukat 2005)		Assessment not required	Assessment not required	Assessment not required	No
Helicotylenchus obliquus Maqbool & Shahina, 1986 [Rhabditida: Haplolaimidae]	Yes (Maqbool and Shahina 1988)		Assessment not required	Assessment not required	Assessment not required	No
Hemicriconemoides gaddi Chitwood & Birchfield, 1957 [Rhabditida: Criconematidae]	Yes (Farshori 1995)	No. These species are root ecto-parasites of a number of woody plant hosts (Evans *et al.* 1993). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Hemicriconemoides mangiferae Siddiqi, 1961 [Rhabditida: Criconematidae]	Yes (Khan *et al.* 2005)		Assessment not required	Assessment not required	Assessment not required	No
Hoplolaimus californicus Sher, 1963 [Rhabditida: Hoplolaimidae]	Yes (Maqbool and Ghazala 1988)	No. These species are migratory root endo- and ecto-parasites; not associated with fruits (Evans *et al.* 1993).	Assessment not required	Assessment not required	Assessment not required	No
Hoplolaimus indicus Sher, 1963 [Rhabditida: Hoplolaimidae]	Yes (Islam *et al.* 2006)		Assessment not required	Assessment not required	Assessment not required	No
Hoplolaimus seinhorsti Luc, 1958 [Rhabditida: Hoplolaimidae]	Yes (Maqbool and Ghazala 1988)		Assessment not required	Assessment not required	Assessment not required	No
Meloidogyne incognita (Kofoid & White) Chitwood, 1949 [Rhabditida: Meloidogynidae]	Yes (Khan and Shaukat 2005)	No. These species are root endo-parasites, usually forming galls in infested roots; not associated with fruit (Evans *et al.* 1993).	Assessment not required	Assessment not required	Assessment not required	No
Meloidogyne javanica (Treub) Chitwood, 1949 [Rhabditida: Meloidogynidae]	Yes (Khan *et al.* 2005)		Assessment not required	Assessment not required	Assessment not required	No
Merlinius brevidens (Allen) Siddiqi 1970 [Rhabditida: Dolichodridae]	Yes (Farshori 1995)	No. This species is a soil dwelling pest of a number of crops (Luc *et al.* 1990). Not known to be associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus brachyurus (Godfrey) Filipjev & Schuurmans Stekhoven, 1941 [Rhabditida: Haplolaimidae]	Yes (Khan 2005)	No. Species of *Pratylenchus* are migratory root endo-parasites often associated with root rot fungi (Evans *et al.* 1993). Not known to be	Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Pratylenchus penetrans (Cobb) Filipjev & Schuurmans Stekhoven, 1941 [Rhabditida: Haplolaimidae]	Yes (Khan 2005)	associated with fruit.	Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus thornei Sher & Allen, 1953 [Rhabditida: Haplolaimidae]	Yes (Khan 2005)		Assessment not required	Assessment not required	Assessment not required	No
Pratylenchus zeae Graham, 1951 [Rhabditida: Haplolaimidae]	Yes (Farshori 1995)		Assessment not required	Assessment not required	Assessment not required	No
Quinisulcius capitatus (Allen) Siddiqi, 1971 [Rhabditida: Dolochodoridae]	Yes (Farshori 1995)	No. These species are migratory root ecto-parasites; not associated with fruit (Evans *et al.* 1993).	Assessment not required	Assessment not required	Assessment not required	No
Rotylenchulus reniformis Linford & Oliveira, 1940 [Rhabditida: Hoplolaimidae]	Yes (Shahina and Musarrat 2006)	No. This species is a semi-endo-root parasite; not associated with fruits (Luc *et al.* 1990).	Assessment not required	Assessment not required	Assessment not required	No
Tylenchorhynchus annulatus (Cassidy) Golden, 1971 [Rhabditida: Dolochodoridae]	Yes (Khan 2005)	No. These species are migratory root ecto-parasites; not associated with fruit (Evans *et al.* 1993).	Assessment not required	Assessment not required	Assessment not required	No
Tylenchorhynchus mashhoodi Siddiqi & Basir, 1959 [Rhabditida: Dolochodoridae]	Yes (Farshori 1995)		Assessment not required	Assessment not required	Assessment not required	No
Xiphinema americanum Cobb, 1913 [Dorylaimina: Longidoridae]	Yes (Nasira and Maqbool 1994)	No. These species are long lived migratory root ecto-parasites; not associated with fruit (Luc *et al.* 1990).	Assessment not required	Assessment not required	Assessment not required	No
Xiphinema basiri Siddiqi, 1959 [Dorylaimina: Longidoridae]	Yes (Khan and Shaukat 2005)		Assessment not required	Assessment not required	Assessment not required	No
Xiphinema brevicolle Lordello & Da Costa, 1961 [Dorylaimina: Longidoridae]	Yes (Pathan *et al.* 2004)		Assessment not required	Assessment not required	Assessment not required	No
Xiphinema insigne Loos, 1949 [Dorylaimina: Longidoridae]	Yes (Lamberti *et al.* 1987)		Assessment not required	Assessment not required	Assessment not required	No
Xiphinema pachtaicum (Tulaganov) Kirjanova, 1951 [Dorylaimina: Longidoridae]	Yes (Farshori 1995)		Assessment not required	Assessment not required	Assessment not required	No

Scientific name	Present in Pakistan	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences[7]	Pest risk assessment required
Xiphinema radicola Goodey, 1936 [Dorylaimina: Longidoridae]	Yes (Farshori 1995)		Assessment not required	Assessment not required	Assessment not required	No
UNKNOWN ETIOLOGY						
Unnamed Phytoplasma (as detected by Kazmi *et al.* 2007).	Yes (Kazmi *et al.* 2007)	No: Phytoplasmas are confined to the phloem tissues of the tree (Kazmi *et al.* 2007) and are not known to be associated with fruit. Whether the phytoplasma is pathogenic is yet to be confirmed.	Assessment not required	Assessment not required	Assessment not required	No

Appendix B: Additional quarantine pest data

Quarantine pest	*Bactrocera correcta* (Bezzi 1916)
Synonyms	*Chaetodacus correctus* Bezzi 1916; *Dacus bangaloriensis* Agarwal & Kapoor 1983; *Dacus dutti* Kapoor 1971; *Strumeta paratuberculatus* Philip 1950; *Dacus correctus* (Bezzi, 1916).
Common name(s)	Guava fruit fly
Main hosts	Hosts include: *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Psidium guajava* (guava), *Prunus persica* (peach), *Syzygium jambos* (rose-apple), *Terminalia catappa* (Indian almond), *Ziziphus jujuba* (jujube). Other recorded hosts include *Aegle marmelos* (Indian bael), *Carissa carandas* (karanda), *Citrus* spp., *Coffea canephora* (robusta coffee), *Eugenia uniflora* (Surinam cherry), *Ricinus communis* (castor-oil plant) and *Santalum album* (sandalwood) (White and Elson-Harris 1992).
Distribution	India, Nepal, Pakistan, Sri Lanka, Thailand and the United States (individuals trapped in California, but population does not appear to have become established) (White and Elson-Harris 1992). In India, this pest often occurs with serious pest species such as *B. dorsalis* and *B. zonata* (Kapoor 1989).
Quarantine pest	*Bactrocera dorsalis* (Hendel, 1912)
Synonyms	*Dacus dorsalis* Hendel, 1912; *Bactrocera conformis* Doleschall, 1858 (preocc.); *Bactrocera ferrugineus* (Fabricius, 1805); *Chaetodacus dorsalis* (Hendel, 1912); *Chaetodacus ferrugineus* (Fabricius, 1805); *Chaetodacus ferrugineus dorsalis* (Hendel, 1912); *Chaetodacus ferrugineus okinawanus* Shiraki, 1933; *Dacus ferrugineus* Fabricius, 1805; *Dacus ferrugineus* var. *dorsalis* Fabricius, 1805; *Dacus ferrugineus okinawanus* (Shiraki, 1933); Musca ferruginea Fabricius, 1794 (preocc.); Strumeta dorsalis (Hendel, 1912); Strumeta ferrugineus (Fabricius, 1805).
Common name(s)	Oriental fruit fly
Main hosts	*Bactrocera dorsalis* occurs on a wide range of fruit crops including *Aegle marmelos* (golden apple), *Anacardium occidentale* (cashew nut), *Annona* spp., *Areca catechu* (betelnut palm), *Artocarpus* spp., *Averrhoa carambola* (carambola), *Capsicum* spp. (bell pepper), *Carica papaya* (papaw), *Chrysophyllum cainito* (caimito), *Citrus* spp., *Clausena lansium*, *Coffea arabica* (arabica coffee), *Cucumis* spp., *Dimocarpus longan* (longan tree), *Diospyros kaki* (persimmon), *Ficus racemosa* (cluster tree), *Flacourtia indica* (governor's plum), *Lycopersicon esculentum* (tomatoes) *Malpighia glabra* (acerola), *Malus* spp. (apple), *Mangifera* spp. (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (spanish cherry), *Momordica charantia* (bitter gourd), *Muntingia calabura* (Jamaica cherry), *Musa* spp. (banana), *Nephelium lappaceum* (rambutan), *Persea americana* (avocado), *Prunus* spp. (stonefruit), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Pyrus* spp. (pear), *Spondias purpurea* (red mombin), *Syzygium* spp. (lilly-pilly), *Terminalia catappa* (Singapore almond) and *Ziziphus* spp. (jujube) (CABI 2007; EPPO 2006).
Distribution	Native *B. dorsalis* is restricted to mainland Asia (except the peninsula of southern Thailand and West Malaysia), as well as Taiwan and its adventive population in Hawaii (Drew and Hancock 1994). CABI (2007) also includes California and Florida, USA, in the distribution because the fly is repeatedly trapped there in small numbers. This species is a serious pest of a wide range of fruit crops in Taiwan, southern Japan, China and in the northern areas of the Indian subcontinent (CABI 2007). In Asia, *B. dorsalis* is recorded from Bangladesh (IIE 1994); Bhutan, Cambodia, China (Drew and Hancock 1994), Guam (Waterhouse 1993), Laos, Myanmar (Drew and Hancock 1994), Nauru (Waterhouse 1993), Nepal, Pakistan, Sri Lanka, Thailand, United States (Hawaii) and Vietnam (Drew and Hancock 1994).
Quarantine pest	*Bactrocera zonata* (Saunders, 1842)
Synonyms	*Dasyneura zonatus* Saunders, 1841; *Dacus ferrugineus* var. *mangiferae* Cotes, 1893; *Rivellia persicae* Bigot, 1890; *Chaetodacus zonatus* (Saunders, 1841); *Dacus zonatus* (Saunders, 1842); *Dacus mangiferae* Cotes, 1893; *Dacus persicae* (Bigot, 1890); *Dacus zonatus* (Saunders, 1842); *Strumeta zonata* (Saunders, 1842); *Dasyneura zonata* Saunders, 1842; *Dacus persicus* (Bigot, 1890); *Strumeta zonatus* (Saunders, 1842).
Common name(s)	Peach fruit fly; guava fruit fly

Main hosts	*Bactrocera zonata* has been recorded on 32 host plants, including peach, guava, mango, fig, dates, okra and tomato (Alzubaidy 2000). It has also been recorded from wild host plants of the families Euphorbiaceae, Lecythidaceae and Rhamnaceae (Duyck *et al.* 2004). Hosts include: *Mangifera indica* (mango), *Prunus persica* (peach) and *Psidium guajava* (guava). Secondary hosts include: *Aegle marmelos* (bael tree), *Annona squamosa* (sugar apple), *Careya arborea* (slow match tree), *Carica papaya* (papaya, pawpaw), *Citrus* spp., *Cydonia oblonga* (quince), *Ficus carica* (fig), *Grewia asiatica* (phalsa), *Luffa* spp. (loofah), *Malus domestica* (apple), *Malus pumila* (paradise apple), *Momordica charantia* (bitter gourd), *Phoenix dactylifera* (date-palm), *Punica granatum* (pomegranate) and *Terminalia catappa* (Indian almond) (White and Elson-Harris 1992).
Distribution	Originating in tropical Asia, *B. zonata* has spread to other regions of the world including Africa and the Arab world. It currently occurs in Bangladesh, Egypt, India, Laos, Mauritius, Moluccus Islands, Myanmas, Pakistan, Reunion Island, Sri Lanka, Thailand and Vietnam (Alzubaidy 2000).
Quarantine pest	*Parlatoria crypta* (McKenzie, 1943)
Synonyms	*Palatoria morrisoni* McKenzie, 1943; *Parlatoria* sp. Ghauri, 1962.
Common name(s)	Mango white scale
Main hosts	*Parlatoria crypta* is a highly polyphagous species that has been recorded on a range of hosts including *Asparagus*, *Azadirachta*, *Bauhinia*, *Carissa*, *Cassia*, *Citrus*, *Clerodendrum*, *Cocos*, *Cordia*, *Cordylia*, *Diospyros*, *Ethretia*, *Eriobotrya*, *Euronymus*, *Ficus*, *Grewia*, *Hibiscus*, *Jasminum*, *Laurus*, *Mallotus*, *Malus*, *Mangifera*, *Melia*, *Morus*, *Musa*, *Nerium*, *Olea*, *Phoenix*, *Podocarpus*, *Rosa* and *Ziziphus* (Watson 2007).
Distribution	Afghanistan, Eritrea, India (Andhra Pradesh, Bihar, Delhi, Karnataka, Punjab and Uttar Pradesh) (Ben-Dov *et al.* 2007; Watson 2007), Iran, Iraq, Niger, Nigeria, Oman, Pakistan, Saudi Arabia, Sudan, West Malaysia and Yemen (Watson 2007).
Quarantine pest	*Parlatoria pseudaspidiotus* Lindinger, 1905
Synonyms	*Aonidia pseudaspidiotus* Cockerell, 1922; *Genaparlatoria mangiferae* MacGillivray, 1921; *Genaparlatoria pseudaspidiotus* MacGillivray, 1921; *Leucaspis mangiferae* Wester, 1920; *Parlatorea mangiferae* Lindinger, 1908; *Parlatoria mangiferae* Marlatt, 1908; *Parlatoria pseudaspidiotus* Ferris, 1936; *Parlatoria pseudaspidiotus* Merrill, 1953; *Pinnaspis pseudaspidiotus* Reyne, 1961
Common name(s)	Vanda scale
Main hosts	*Parlatoria pseudaspidiotus* occurs on members of three plant families: Anacardiaceae, Euphorbiaceae and Orchidaceae (Watson 2007). Important host genera include *Aerides*, *Caryopteris*, *Cymbidium*, *Dendrobium*, *Euphorbia*, *Mangifera*, *Plumeria*, *Trichoglottis* and *Vanda* (Watson 2007).
Distribution	While the origin of *Parlatoria pseudaspidiotus* is unknown, the species primarily occurs in tropical areas and possibly glasshouses elsewhere (Watson 2007). The species is widespread in Asia and can also be found in the Caribbean, the Pacific, Central America and northern South America (Watson 2007). The species has been recorded in Germany and is known to occur in glasshouses in Italy (Watson 2007).
Quarantine pest	*Ferrisia virgata* (Cockerell, 1893j)
Synonyms	*Dactylopius segregatus* Cockerell, 1893; *Dactylopius virgatus* Cockerell, 1893; *Dactylopius virgatus farinosus* Cockerell, 1893; *Dactylopius virgatus humilis* Cockerell, 1893; *Dactylopius ceriferus* Newstead, 1894; *Dactylopius talini* Green, 1896; *Dactylopius dasylirii* Cockerell, 1896; *Dactylopius setosus* Hempel, 1900; *Pseudococcus virgatus* Kirkaldy, 1902; *Dactylopius magnolicida* King, 1902; *Pseudococcus magnolicida* (Cockerell, 1902p); *Pseudococcus virgatus farinosus* (Cockerell, 1902p); *Pseudococcus dasylirii* (Fernald, 1903b); *Pseudococcus segregatus* (Fernald, 1903b); *Pseudococcus virgatus humilis* (Fernald, 1903b); *Dactylopius virgatus madagascariensis* Newstead, 1908; *Pseudococcus marchali* Vayssière, 1912; *Pseudococcus virgatus madagascariensis* (Lindinger, 1913); *Pseudococcus bicaudatus* Keuchenius, 1915; *Ferrisiana virgata* (Takahashi, 1929a); *Heliococcus malvastrus* McDaniel, 1962; *Ferrisiana setosus* (Ali, 1970a).
Common name(s)	Striped mealybug

Main hosts	*Ferrisia virgata* is one of the most highly polyphagous mealybugs known, attacking plant species belonging to some 160 genera in over 70 families (Ben-Dov *et al.* 2007; CABI 2007). Many of the host species belong to the Leguminosae and Euphorbiaceae families. Hosts of economic importance include: *Anacardium occidentale* (cashew), *Ananas comosus* (pineapple), *Annona cherimola* (custard apple), *Brassica oleracea* (cauliflower), *Cajanus cajan* (pigeon pea), *Citrus* spp., *Coffea* spp. (coffee), *Corchorus* spp. (jute), *Elaeis guineensis* (African oil palm), *Glycine max* (soybean), *Gossypium* spp. (cotton), *Litchi chinensis* (lychee), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manihot esculenta* (cassava, tapioca), *Musa × paradisiaca* (banana), *Persea americana* (avocado), *Piper nigrum* (black pepper), *Psidium guajava* (guava), *Solanum melongena* (aubergine, eggplant), *Theobroma cacao* (cocoa) and *Vitis vinifera* (wine grape) (CABI 2007).
Distribution	*Ferrisia virgata* has spread to all zoogeographical regions, mainly in the tropics, but often extends well into the temperate regions (CABI 2007). It is widely distributed in Africa, Asia, North, Central and South America and Oceania regions. Early geographical records of *F. virgata* need to be verified due to misidentification of *F. malvastra* (Ben-Dov 1994). Present in Australia (Ben-Dov *et al.* 2007), not in WA (DAFWA 2006). In Asia, *F. virgata* is recorded from Bangladesh, British Indian Ocean Territory, Brunei Darussalam, Cambodia, China (Guangdong, Hong Kong, Taiwan) (CABI 2007), India (Andhra Pradesh, Goa, Kerala, Orissa, Punjab, Rajasthan, Tripura (CABI 2007), Assam, Bihar, Karnataka, Madhya Pradesh, Maharashtra, Tamil Nadu, Uttar Pradesh, West Bengal (Ben-Dov *et al.* 2007), Indonesia, Japan, Laos, Malaysia, Myanmar, Pakistan, Philippines, Saudi Arabia, Singapore, Sri Lanka, Thailand, United Arab Emirates, Vietnam and Yemen (CABI 2007).
Quarantine pest	*Rastrococcus invadens* Williams, 1986
Synonyms	n/a
Common name(s)	Mango mealybug
Main hosts	*Rastrococcus invadens* attacks plant species belonging to 48 genera in 27 families, including *Mangifera indica* (mango) (Ben-Dov *et al.* 2007). Agounké *et al.* (1988) listed 45 species of host plants from 22 families attacked by *R. invadens* in West Africa; and Biassangama *et al.* (1991) listed 23 species from Central Africa. Since then, over 100 host plant species have been found in Africa, particularly where populations of this insect are abundant on the primary host, mango (CABI 2007)
Distribution	Bangladesh, Benin, Bhutan, China (Hong Kong), Congo, Côte d'Ivoire, Gabon, Ghana, India (Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Orissa, Sikkim, Uttar Pradesh) (Ben-Dov *et al.* 2007), Indonesia, Malaysia, Nigeria, Pakistan, Philippines, Sierra Leone, Singapore, Sri Lanka, Thailand, Togo and Vietnam (Ben-Dov *et al.* 2007; Williams 2004).
Quarantine pest	*Rastrococcus spinosus* (Roboinson, 1918)
Synonyms	*Phenacoccus spinosus* Robinson, 1918; *Puto spinosus* (Robinson); Ceroputo spinosus (Robinson).
Common name(s)	Philippine mango mealybug
Main hosts	*Anacardium occidentale* (cashew), *Antidesma nitidum*, *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Calophyllum* sp., *Citrus* sp.,*Cocos nucifera* (coconut), *Ficus ampelas*, *Garcinia mangostana* (mangosteen), *Heveabrasiliensis* (rubber tree), *Lansium domesticum* (langsat), *Mangifera indica* (mango),*Mangifera odorata* (kuwini), *Nypa fruticans* (mangrove palm), *Plumeria robusta*, *Psidiumguajava* (guava), *Syzygium aqueum* (water apple) and *Tabernaemontana* spp. (Ben-Dov *et al.* 2007).
Distribution	Bangladesh, Brunei, India, Indonesia, Cambodia, Laos, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand and Viet Nam (Ben-Dov *et al.* 2007).
Quarantine pest	*Rhipiphorothrips cruentatus* Hood, 1919
Synonyms	*Rhipiphorothrips karna* Ramakrishnan, 1928
Common name(s)	Mango thrips, Grapevine thrips
Main hosts	*Anacardium occidentale* (cashew nut), *Annona squamosa* (sugarapple), *Mangifera indica* (mango), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Rosa rugosa* (Rugosa rose), *Syzygium cumini* (black plum), *Syzygium samarangense* (water apple or wax apple), *Terminalia catappa* (Singapore almond), *Vitis vinifera* (grapevine) (CABI 2007), *Areca catechu* (areca nut) (More *et al.* 2003), *Jatropha curcas* (Rani and Sridhar 2002), *Eugenia malaccensis* (malay apple) (Wen 1989) and *Rosa indica* var. *iceberg* (Aslam *et al.* 2001).
Distribution	Afghanistan, Bangladesh, China, India, Myanmar, Oman, Pakistan, Sri Lanka, Taiwan and Thailand (CABI 2007).
Quarantine pest	*Fusarium mangiferae* Britz, M.J., Wingf. and Marasas
Synonyms	n/a

Common name(s)	Mango malformation
Main hosts	*Mangifera indica* L.
Distribution	Present in Egypt, India (Britz *et al.* 2002; Ploetz *et al.* 2002) Israel, Malaysia, South Africa and USA. Detected in Australia (Northern Territory) in 2007 and is now under official control (DPIFM 2008)
Quarantine pest	*Hypocryphalus mangiferae* (Stebbing)
Synonyms	*Cryphalus inops* Eichhoff, *Cryphalus robustus* Eichhoff,,*Cryphalus subclyindricus* Schedl, *Hypocryphalus mangiferae* Eggers, *Hypocryphalus opacus* Schedl, and *Hypothenemus grisues* Blackburn (Walker 2008).
Common name(s)	Mango bark beetle
Main hosts	*Mangifera indica* (Atkinson 2011; Masood *et al.* 2010a; Walker 2008).
Distribution	Present in Brazil, Oman and Pakistan (Masood *et al.* 2010a), Australia, Barbados, Brazil, Costa Rica, Dominican Republic, Honduras, Malaysia, Mexico, Panama, Puerto Rico, USA, and Venezuela (Atkinson 2011).
Quarantine pest	*Ceratocystis manginecans*[22] M. van Wyk, A. Adawi & M.J. Wingf.
Synonyms	n/a
Common name(s)	Mango sudden death syndrome (MSDS)
Main hosts	*Acacia mangium, Acacia crassicarpa, Hypocryphalus mangifera,* and *Mangifera indica* (Tarigan *et al.* 2010).
Distribution	Present in Indonesia (Tarigan *et al.* 2010), Oman and Pakistan (van Wyk *et al.* 2007)

[22] This species has been assessed in this risk analysis as it may be vectored by the manago bark beetle contaminating fruit consignments. It is not known to be associated with fruit.

Appendix C: Mango Sudden Death Syndrome (MSDS)

Mango sudden death syndrome (MSDS) is the term given to different phases of a declining disease of mango i.e. dieback, quick dieback and sudden death. MSDS is caused by a combination of both biotic and abiotic factors (Kazmi *et al*. 2007). Biotic factors include a complex of various fungal pathogens and abiotic factors include water stress, high temperatures, sun scald and high humidity (Kazmi *et al*. 2005). MSDS was first reported from Oman in 1998 and subsequently from Pakistan in 2005 (Malik *et al*. 2005). A similar disease causing serious die-back of mango known as 'seca' has been known since the 1930s in Brazil (Al-Adawi *et al.* 2006).

Fungi associated with MSDS in Pakistan

Several fungi have been reported from mango trees showing MSDS symptoms in Pakistan (Table 1). Of the pathogens identified *Ceratocystis fimbriata* is present in India and Taiwan, and *Fusarium oxysporum* and *Lasiodiplodia theobromae* are present in India, the Philippines and Taiwan and were assessed in previous pest risk assessments to import mango to Australia from those countries. *Nattrassia mangiferae* is present in Australia and subsequently does not meet the definition of a quarantine pest.

Table 1: Fungi associated with MSDS symptoms

Pathogen	Distribution	References	Status in Australia
Alternaria alternata	**Pakistan**	Kazmi *et al.* 2007	Present (APPD 2010)
Ceratocystis fimbriata	Oman	Al-Adawi *et al.* 2006	
	Pakistan	Fateh *et al.* 2006; Kazmi *et al.* 2007; Malik *et al.* 2009	Present (Walker *et al.* 1988)
	Latin America (Brazil)	Baker *et al.* 2003	
Ceratocystis manginecans	Oman	van Wyk *et al.* 2007; Al-Sadi *et al.* 2010	
	Pakistan	van Wyk *et al.* 2007	Not known to occur
Ceratocystis omanensis	Oman	Al-Adawi *et al.* 2006; Al-Subhi *et al.* 2006	
Fusarium oxysporum	**Pakistan**	Fateh *et al.* 2006	Present (APPD 2010)
Lasiodiplodoa theobromae	Oman	Al-Adawi *et al.* 2006	
	Pakistan	Kazmi *et al.* 2007; Fateh *et al.* 2006; Khanzada *et al.* 2004	Present (APPD 2010)
Nattrassia mangiferae	**Pakistan**	Fateh *et al.* 2006	Present (APPD 2010)

Ceratocystis fimbriata, *Ceratocystis omanesis* and *Lasiodiplodia theobromae* have been consistently isolated from MSDS affected trees in Oman (Al-Adawi *et al*. 2006). Mango seedlings inoculated with *Ceratocystis fimbriata* developed gummosis and extensive lesions. Lesions also developed on plants inoculated with *C. omanensis* and *L. theobromae*, but mean lesion length was significantly longer on stems inoculated with *C. fimbriata* compared with *C. omanensis* or *L. theobromae*, demonstrating that *C. fimbriata* is the primary causal organism of MSDS in Oman (Al-Adawi *et al*. 2006). *Ceratocystis omanensis* has not been detected in Pakistan.

Ceratocystis fimbriata

The taxonomy of *Ceratocystis fimbriata* has been reviewed and the species is now thought to be a complex of many species, each with a distinct host range and geographic distribution (CABI 2007). Harrington (2000) proposed differentiation of the *C. fimbriata* complex based on geographic clades; a North American, a Latin American and an Asian clade (Harrington 2000). Both rDNA and allozyme analyses support these three major clades (Baker *et al.* 2003; Harrington 2000; Johnson *et al*. 2005). DNA-based techniques have made it possible to recognise distinct taxa that might otherwise have been assigned to *C. fimbriata*. For example, a fungus causing a serious wilt disease of *Acacia mearnsii* was initially identified as *C. fimbriata* (Morris *et al*. 1993) but has now been described as *Ceratocystis albifundus*. Similarly, *C. pirilliformis* from *Eucalyptus* in Australia (Barnes *et al*. 2003) represents a species considered to be a member of this complex.

The pathogen responsible for mango decline in Oman and Pakistan was initially identified as *Ceratocystis fimbriata* (Al-Adawi *et al*. 2006; Malik *et al.* 2005). However, based on DNA-based techniques, *C. fimbriata* causing this disease in Pakistan was recently described as *C. manginecans* (van Wyk *et al*. 2007). In Oman, *Ceratocystis manginecans* and another speices, *C. omanensis* are known to cause the disease (Al-Adawi *et al*. 2006). When mango seedlings were inoculated with *Ceratocystis manginecans*, seedlings produced wilt symptoms, oozing gum and vascular necrosis and discolouration (Al-Sadi *et al*. 2010). These symptoms are consistent with symptoms of mango decline disease found in the field (Al-Adawi *et al*. 2006). The mycelium blocks the vascular system and causes the subsequent death of the plant (Al-Sadi *et al*. 2010).

Ceratocystis fimbriata has been identified as causing a die-back of mango known as 'seca' in Brazil (Al-Adawi *et al.* 2006). However, recent studies indicate that the disease in Brazil is not caused by either *C. fimbriata, C. manginecans* or *C. omanensis*, but rather by another novel species in this complex (van Wyk *et al*. 2007).

Disease symptoms

The dieback phase of MSDS, also known as slow decline of mango, causes a gradual drying of twigs from the top of the canopy downward. Trees remain alive but become less productive. Quick dieback, the next phase of MSDS, can cause mango trees to weaken and lose vigour. The leaves of infected trees become chlorotic and experience severe leaf drop. The tree-trunk exudes gum of different colours and on removal of the bark, the branches reveal browning of the vascular tissue.

The final and most serious phase of MSDS is sudden death of mango. As the name suggests, this disease can lead to the rapid death of the tree. The leaves of affected trees droop and turn leathery and greenish-brown whilst remaining attached to the tree. The tree trunk frequently exudes gum and on removal of the bark, the trunk shows dark brown streaks in the xylem tissue. In infected plants, the twigs and branches show internal discoloration. Brown streaks in the vascular regions are visible upon splitting the twigs lengthwise (Figure 1). Different fungi have been reported from trees infected by different phases of MSDS including *Lasiodiplodia theobromae, Ceratocystis fimbriata*, *Nattrasia mangifera* and *Fusarium oxysporum* (Fateh *et al*. 2006). *Lasiodiplodia theobromae* is only known to be a cause of the dieback and quick dieback phases (Khanzada *et al*. 2004). However, studies conducted in Oman reveal that *Lasiodiplodia theobromae* may act as a secondary pathogen that colonizes the lesions produced by *C. fimbriata* (Al-Adawi *et al.* 2006).

Figure 1: Symptoms of mango sudden death syndrome

a) dieback of branches on a mango tree; b) mango plant showing sequential death of branches; (c) and (d) heavy gummosis on the main trunk; (e) mango branch showing splitting of the bark; (f) gum oozing from the split bark and (g) browning of vascular tissues (Khanzada *et al.* 2004).

Pathway

The following pathways were considered for the entry of MSDS into Australia:

Fruit:

Ceratocystis species (*C. fimbriata* and *C. manginecans*) associated with MSDS are not on the fruit importation pathway as the pathogens cause branch dieback, gummosis, bark splitting, floral necrosis and eventual death of the plant (Iqbal *et al*. 2007; Al-Subhi *et al.* 2006). The causal agents have never been isolated from healthy trees, only from trees with characteristic symptoms (Kazmi *et al*. 2007). Plant death occurs six months following symptom expression (Al-Subhi *et al.* 2006), causing a wholesale decline in the productivity of the plant.

Despite the large number of publications from major mango exporting countries on this economically important disease, there are no references of fruit symptoms or records that fruits form on infected plants. It is considered that the movement of fruit is not a pathway for entry of *Ceratocystis fimbriata* and *C. manginecans* as there are no records of these pathogens infecting fruit.

Ceratocystis species (*C. fimbriata* and *C. manginecans*) are soil-borne (Van Wyk *et al*., 2007; Malik *et al*. 2009) and enter the plant through wounds or injuries. The fungi block the vascular system of infected plants causing wilting and subsequent death of the plant (Al-Sadi *et al*. 2010). *Ceratocystis* species produce symptoms on various parts of the plant as the disease progresses. For example, rotting of the main root and canker development are observed in roots zone; gummosis and canker formation on the collar region and the main stem; and gummosis and drying of twigs and branches and bark spliting/cracking on the main limbs and trunk (Masood *et al*. 2010b).

Propagative material:

Ceratocystis fimbriata is thought to have been introduced to Oman and Pakistan from Brazil on infected mango nursery stock, or soil accompanying the plants (van Wyk *et al*. 2007). Infected propagative material is considered to be one of the highest risk pathways for the entry of the pathogen complex causing MSDS. An import policy review has been conducted on the nursery stock import pathway and conditions specific to mango sudden death syndrome are now listed on the import conditions database for any new propagative material entering Australia.

Vectors:

Mango bark beetle (*Hypocryphalus mangiferae*) is considered to be the primary vector of the causal agents of MSDS (Masood *et al.* 2010a). The beetles act as a wounding agent and facilitate the dispersal of spores of the pathogen complex of MSDS (Al-Adawi *et al*. 2006). The beetle is frequently associated with diseased mango trees (Masood *et al*. 2008) and is also known to colonize dead parts of infected trees (Al Adawi *et al.* 2006; Masood *et al.* 2009), as well as playing a significant role in the spread of the pathogens to healthy trees (Masood *et al*. 2010a). The mango bark beetle becomes contaminated with fungal propagules on its body during feeding on diseased trees (Masood *et al.* 2009) and can subsequently vector the pathogen (Masood *et al*. 2010a).

The bark beetles are active from May to August in Pakistan (Masood *et al*. 2009) and may contaminate harvested mango consignments during this period. Mango bark beetles have been detected at the US border contaminating crates of yam (*Discorea* spp.) destined for New York and Pennsylvania from Brazil (Haack 2001). This suggests that the beetles may be able to contaminate mango consignments and act as an entry pathway for the introduction of the pathogen complex causing MSDS.

Appendix D Biosecurity framework

Australia's biosecurity policies

The objective of Australia's biosecurity policies and risk management measures is the prevention or control of the entry, establishment or spread of pests and diseases that could cause significant harm to people, animals, plants and other aspects of the environment.

Australia has diverse native flora and fauna and a large agricultural sector, and is relatively free from the more significant pests and diseases present in other countries. Therefore, successive Australian Governments have maintained a conservative, but not a zero-risk, approach to the management of biosecurity risks. This approach is consistent with the World Trade Organization's (WTO's) Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement).

The SPS Agreement defines the concept of an 'appropriate level of protection' (ALOP) as the level of protection deemed appropriate by a WTO Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory. Among a number of obligations, a WTO Member should take into account the objective of minimising negative trade effects in setting its ALOP.

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

Consistent with the SPS Agreement, in conducting risk analyses Australia takes into account as relevant economic factors:

- the potential damage in terms of loss of production or sales in the event of the entry, establishment or spread of a pest or disease in the territory of Australia
- the costs of control or eradication of a pest or disease and
- the relative cost-effectiveness of alternative approaches to limiting risks.

Roles and responsibilities within Australia's quarantine system

Australia protects its human[23], animal and plant life or health through a comprehensive quarantine system that covers the quarantine continuum, from pre-border to border and post-border activities.

Pre-border, Australia participates in international standard-setting bodies, undertakes risk analyses, develops offshore quarantine arrangements where appropriate, and engages with our neighbours to counter the spread of exotic pests and diseases.

At the border, Australia screens vessels (including aircraft), people and goods entering the country to detect potential threats to Australian human, animal and plant health.

[23] The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine.

The Australian Government also undertakes targeted measures at the immediate post-border level within Australia. This includes national co-ordination of emergency responses to pest and disease incursions. The movement of goods of quarantine concern within Australia's border is the responsibility of relevant state and territory authorities, which undertake inter- and intra-state quarantine operations that reflect regional differences in pest and disease status, as a part of their wider plant and animal health responsibilities.

Roles and responsibilities within the Department

The Australian Government Department of Agriculture, Fisheries and Forestry is responsible for the Australian Government's animal and plant biosecurity policy development and the establishment of risk management measures. The Secretary of the Department is appointed as the Director of Animal and Plant Quarantine under the *Quarantine Act 1908* (the Act).

The Biosecurity Services Group (BSG) within the Department takes the lead in biosecurity and quarantine policy development and the establishment and implementation of risk management measures across the biosecurity continuum, and:

- through Biosecurity Australia, conducts risk analyses, including IRAs, and develops recommendations for biosecurity policy as well as providing quarantine policy advice to the Director of Animal and Plant Quarantine
- through the Australian Quarantine and Inspection Service, develops operational procedures, makes a range of quarantine decisions under the Act (including import permit decisions under delegation from the Director of Animal and Plant Quarantine) and delivers quarantine services
- coordinates pest and disease preparedness, emergency responses and liaison on inter- and intra-state quarantine arrangements for the Australian Government, in conjunction with Australia's state and territory governments.

Roles and responsibilities of other government agencies

State and territory governments play a vital role in the quarantine continuum. The BSG works in partnership with state and territory governments to address regional differences in pest and disease status and risk within Australia, and develops appropriate sanitary and phytosanitary measures to account for those differences. Australia's partnership approach to quarantine is supported by a formal Memorandum of Understanding that provides for consultation between the Australian Government and the state and territory governments.

Depending on the nature of the good being imported or proposed for importation, Biosecurity Australia may consult other Australian Government authorities or agencies in developing its recommendations and providing advice.

As well as a Director of Animal and Plant Quarantine, the Act provides for a Director of Human Quarantine. The Australian Government Department of Health and Ageing is responsible for human health aspects of quarantine and Australia's Chief Medical Officer within that Department holds the position of Director of Human Quarantine. Biosecurity Australia may, where appropriate, consult with that Department on relevant matters that may have implications for human health.

The Act also requires the Director of Animal and Plant Quarantine, before making certain decisions, to request advice from the Environment Minister and to take the advice into account when making those decisions. The Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) is responsible under the *Environment Protection and Biodiversity Conservation Act 1999* for assessing the environmental impact associated with proposals to import live species. Anyone proposing to import such material should contact DEWHA directly for further information.

When undertaking risk analyses, Biosecurity Australia consults with DEWHA about environmental issues and may use or refer to DEWHA's assessment.

Australian quarantine legislation

The Australian quarantine system is supported by Commonwealth, state and territory quarantine laws. Under the Australian Constitution, the Commonwealth Government does not have exclusive power to make laws in relation to quarantine, and as a result, Commonwealth and state quarantine laws can co-exist.

Commonwealth quarantine laws are contained in the *Quarantine Act 1908* and subordinate legislation including the Quarantine Regulations 2000, the Quarantine Proclamation 1998, the Quarantine (Cocos Islands) Proclamation 2004 and the Quarantine (Christmas Island) Proclamation 2004.

The quarantine proclamations identify goods, which cannot be imported, into Australia, the Cocos Islands and or Christmas Island unless the Director of Animal and Plant Quarantine or delegate grants an import permit or unless they comply with other conditions specified in the proclamations. Section 70 of the Quarantine Proclamation 1998, section 34 of the Quarantine (Cocos Islands) Proclamation 2004 and section 34 of the Quarantine (Christmas Island) Proclamation 2004 specify the things a Director of Animal and Plant Quarantine must take into account when deciding whether to grant a permit.

In particular, a Director of Animal and Plant Quarantine (or delegate):

- must consider the level of quarantine risk if the permit were granted, and
- must consider whether, if the permit were granted, the imposition of conditions would be necessary to limit the level of quarantine risk to one that is acceptably low, and
- for a permit to import a seed of a 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
- may take into account anything else that he or she knows is relevant.

The level of quarantine risk is defined in section 5D of the *Quarantine Act 1908*. The definition is as follows:

> 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, the Cocos Islands or Christmas Island; 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.

The Quarantine Regulations 2000 were amended in 2007 to regulate keys steps of the import risk analysis process. The Regulations:

- define both a standard and an expanded IRA,
- identify certain steps, which must be included in each type of IRA,
- specify time limits for certain steps and overall timeframes for the completion of IRAs (up to 24 months for a standard IRA and up to 30 months for an expanded IRA),
- specify publication requirements,
- make provision for termination of an IRA, and
- allow for a partially completed risk analysis to be completed as an IRA under the Regulations.

The Regulations are available at www.comlaw.gov.au.

International agreements and standards

The process set out in the *Import Risk Analysis Handbook 2007 (update 2009)* is consistent with Australia's international obligations under the SPS Agreement. It also takes into account relevant international standards on risk assessment developed under the International Plant Protection Convention (IPPC) and by the World Organisation for Animal Health (OIE).

Australia bases its national risk management measures on international standards where they exist and when they achieve Australia's ALOP. Otherwise, Australia exercises its right under the SPS Agreement to apply science-based sanitary and phytosanitary measures that are not more trade restrictive than required to achieve Australia's ALOP.

Notification obligations

Under the transparency provisions of the SPS Agreement, WTO Members are required, among other things, to notify other members of proposed sanitary or phytosanitary regulations, or changes to existing regulations, that are not substantially the same as the content of an international standard and that may have a significant effect on trade of other WTO Members.

Risk analysis

Within Australia's quarantine framework, the Australian Government uses risk analyses to assist it in considering the level of quarantine risk that may be associated with the importation or proposed importation of animals, plants or other goods.

In conducting a risk analysis, Biosecurity Australia:

- identifies the pests and diseases of quarantine concern that may be carried by the good
- assesses the likelihood that an identified pest or disease or pest would enter, establish or spread
- assesses the probable extent of the harm that would result.

If the assessed level of quarantine risk exceeds Australia's ALOP, Biosecurity Australia will consider whether there are any risk management measures that will reduce quarantine risk to achieve the ALOP. If there are no risk management measures that reduce the risk to that level, trade will not be allowed.

Risk analyses may be carried out by Biosecurity Australia's specialists, but may also involve relevant experts from state and territory agencies, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), universities and industry to access the technical expertise needed for a particular analysis.

Risk analyses are conducted across a spectrum of scientific complexity and available scientific information. An IRA is a type of risk analysis with key steps regulated under the Quarantine Regulations 2000. Biosecurity Australia's assessment of risk may also take the form of a non-regulated analysis of existing policy or technical advice to AQIS. Further information on the types of risk analysis is provided in the *Import Risk Analysis Handbook 2007 (update 2009)*.

Glossary

Term or abbreviation	Definition
Absorbed dose	Quantity of radiating energy (in gray) absorbed per unit of mass of a specified target (FAO 2009).
Additional declaration	A statement that is required by an importing country to be entered on a Phytosanitary Certificate and which provides specific additional information on a consignment in relation to regulated pests (FAO 2009).
Appropriate level of protection	The level of protection deemed appropriate by the Member establishing a sanitary or phytosanitary measure to protect human, animal or plant life or health within its territory (WTO 1995).
Area	An officially defined country, part of a country or all or parts of several countries (FAO 2006).
Biosecurity Australia	A prescribed agency, within the Australian Government Department of Agriculture, Fisheries and Forestry, responsible for recommendations for the development of Australia's biosecurity policy.
Certificate	An official document which attests to the phytosanitary status of any consignment affected by phytosanitary regulations (FAO 2006).
Consignment	A quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single Phytosanitary Certificate (a consignment may be composed of one or more commodities or lots) (FAO 2006).
Contaminating pest	A pest that is carried by a commodity and, in the case of plants and plant products, does not infest those plants or plant products (FAO 2009).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO 2006).
Endangered area	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss (FAO 2006).
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO 2006).
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO 2006).
Fresh	Living; not dried, deep-frozen or otherwise conserved (FAO 2006).
Fruits and vegetables	A commodity class for fresh parts of plants intended for consumption or processing and not for planting (FAO 2006).
Host range	Species capable, under natural conditions, of sustaining a specific pest or other organism (FAO 2006).
Import Permit	Official document authorising importation of a commodity in accordance with specified phytosanitary import requirements (FAO 2006).
Import Risk Analysis	An administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection (FAO 2006).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations (FAO 2006).
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced, or used (FAO 2006).
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment (FAO 2006).
Introduction	The entry of a pest resulting in its establishment (FAO 2006).
International Standard for Phytosanitary Measures	An international standard adopted by the Conference of FAO [Food and Agriculture Organization], the Interim Commission on phytosanitary measures or the Commission on phytosanitary measures, established under the IPPC (FAO 2006).
Lot	A number of units of a single commodity, identifiable by its homogeneity of composition, origin etc., forming part of a consignment (FAO 2006).
Mango fruit waste	May include mango skin, pulp, flesh and/or seed.
Monophagous	Only one known host.
National Plant Protection Organisation	Official service established by a government to discharge the functions specified by the IPPC (FAO 2006).

Term or abbreviation	Definition
Official control	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 (FAO 2006).
Parasitoid	An insect parasitic only in its immature stages, killing its host in the process of its development, and free living as an adult (FAO 2006).
Pathway	Any means that allows the entry or spread of a pest (FAO 2006).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2006).
Pest categorisation	The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest (FAO 2006).
Pest Free Area	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2006).
Pest free place of production	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2006).
Pest free production site	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this conditions is begin officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production (FAO 2006).
Pest Risk Analysis (agreed interpretation)	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (FAO 2006).
PRA area	Area in relation to which a Pest Risk Analysis is conducted (FAO 2006).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences (FAO 2009).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2006).
Phytosanitary Certificate	Certificate patterned after the model certificates of the IPPC (FAO 2006).
Phytosanitary measure (aggred interpretation)	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2006).
Phytosanitary regulation	Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2006).
Polyphagous	Feeding on a relatively large number of host plants from different plant families.
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 (FAO 2006).
Regulated article	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 transportation is involved (FAO 2006).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Spread	Expansion of the geographical distribution of a pest within an area (FAO 2006).
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Systems approach(es)	The integration of different pest risk management measures, at least two of which act independently, and which cumulatively achieve the appropriate level of protection against regulated pests (FAO 2006).
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk management measures.

References

Abd-Elmegid MKE, Gaafar K, Necola N (1971) *Alternaria* spot of mango in A.R.E. *Agricultural Research Review* 49: 123–135.

AFD (Australian Faunal Directory) (2007) Nomenclatural and distributional database. Australian Biological Resources Study and the Australian Government Department of the Environment, Water, Heritage and the Arts. http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/afd/index.html Accessed 27 April 2007.

Afzal M, Ahmad T, Bashir MH (2002) Relative toxicity of different insecticides against whitefly, *Bemisia tabaci* (Genn.) and black thrips, *Caliothrips indicus* on NM-92 mung bean, *Vigna radiata* (L.). *Pakistan Journal of Agricultural Sciences* 39: 224–225.

Agounke D, Agricola U, Bokonon-Ganta HA (1988) *Rastrococcus invadens* Williams (Hemiptera: Pseudococcidae), a serious exotic pest of fruit trees and other plants in West Africa. *Bulletin of Entomological Research* 78: 695–702.

Ahmad I, Islamullah M, Afzal M (1976) Comparative functional morphology of the alimentary organs of lygaedid-coreoid species (Heteroptera: Pentatomomorpha: Trichophora) of Pakistan, with reference to phylogeny. *Pakistan Journal of Zoology* 8: 47–64.

Ahmad I, Onder F (1989) Life table technique with reference to population studies in some trichophoran bugs (Hemiptera: Pentatomomorpha) of cash crops in Pakistan and Turkey. *Proceedings of Pakistan Congress of Zoology* 9: 211–215.

Ahmad M, Arif MI, Denholm I (2003) High resistance of field populations of the cotton aphid *Aphis gossypii* Glover (Homoptera: Aphididae) to pyrethroid insecticides in Pakistan. *Journal of Economic Entomology* 96: 875–878.

Ahmad M, Ilyas MB (1994) Leaf spot disease of sugarcane caused by *Drechslera halodes*. *Pakistan Journal of Phytopathology* 6: 69–70.

Ahmad MK (1972) Scientific notes on the biology and life history of *Strepsicrates rhothia* Meyr. (Tortricidae, Lepidoptera), a pest of guava in Karachi. *Pakistan Journal of Zoology* 4: 223–225.

Ahmad S, Iqbal SH, Khalid AN (1997) *Fungi of Pakistan*. Mycological Society of Pakistan, 248 pages.

Ahmad S (1969) Fungi of West Pakistan. *Biological Society of Pakistan Monograph* 5: 1–110.

Ahmad S (1978) Ascomycetes of Pakistan, part ii. *Biological Society of Pakistan Monograph* 8: 1–144.

Ahmed A, Suhail A, ul-Abdin Z, Iftikhar S, Zahoor K (2004a) Biodiversity of insects associated with sugarcane crop in Faisalabad. *Pakistan Entomologist* 26: 65–69.

Ahmed HU, Hossain MM, Alam SMK, Huq MI, Hossain M (1991) Efficacy of different fungicides in controlling anthracnose and sooty mould of mango. *Bangladesh Journal of Agricultural Research* 16: 74–78.

Ahmed S, Akbar W, Riaz MA (2004b) Effect of crop rotation and intercropping on subterranean termites in wheat at Faisalabad. *Pakistan Entomologist* 26: 25–30.

AICN (Australian Insect Common Names) (2007) Nomenclature database. CSIRO Entomology and the Australian Government Department of Agriculture, Forestry and Fisheries. http://www.ento.csiro.au/aicn/ Accessed 27 April 2007.

Akhtar KP, Alam SS (2000) Powdery mildew of mango: a review. *Pakistan Journal of Biological Sciences* 3: 1119–1122.

Akhtar KP, Alam SS (2002) Assessment keys for some important diseases of mango. *Pakistan Journal of Biological Sciences* 5: 246–250.

Al-Adawi AO, Deadman ML, Al-Rawahi AK, Al-Maqbali YM, Al-Jahwari AA, Al-Saadi BA, Al-Amri IS and Wingfield MJ (2006) Aetiology and causal agents of mango sudden decline disease in the Sultanate of Oman. *European Journal of Plant Pathology* 116: 247–254.

Al-Ali AS, Al-Neamy IK, Alwan MS (1982) On the biology and host preference of *Aulacophora foveicollis* Lucas (Coleoptera, Galerucidae). *Zeitschrift fur Angewandte Entomologie* 94: 82–86.

Ali MI, Karim MA (1991) Notes on the biology, behaviour and biocontrol agents of mango defoliator *Cricula trifenestrata* (Lepidoptera: Saturniidae). *Bangladesh Journal of Entomology* 1: 83–87.

Ali SS, Rane AE (1998) Record of cow bug *Otinotus oneratus* (Walker) on rose in India. *Insect Environment* 4: 50.

Allegrucci N, Cazau MC, Cabello MN, Arambarri AM (2005) Analysis of microfungal communities on *Scutia buxifolia* (Rhamnaceae) leaf litter from eastern Buenos Aires Province, Argentina. *Darwiniana* 43: 1–9.

Allwood AL, Chinajariyawong A, Drew RAI, Hamacek EL, Hancock DL, Hengsawad C, Jipanin JC, Jirasurat M, Kong Krong C, Kritsaneepaiboon S, Leong CTS, Vijaysegaran S (1999) Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology*, *Supplement* 7: 1–92.

Al-Momani F, Rashid N, Riazuddin S (1998) Occurrence and distribution of crown gall disease in some plants of Pakistan. *Bangladesh Journal of Botany* 27: 47–50.

Al-Sadi AM, Al-Ouweisi FA, Al-Shariani NK, Al-Adawi AO, Kaplan EJ, Deadman ML (2010) Histological changes in mango seedlings following infection with *Ceratocystis manginecans*, the cause of mango decline. *Journal of Phytopathology* 158: 738–743.

Al-Subhi AM, Al-Adawi AO, Van Wyk M, Deadman ML, Wingfield MJ (2006) *Ceratocystis omanensis,* a new species from diseased mango trees in Oman. *Mycological Research* 110: 237–245.

Alzubaidy M (2000) Economic importance and control/eradication of peach fruit fly, *Bactrocera zonata*. *Arab Journal Plant Protection* 18: 139–142.

Amin M, Malik AU, Mazhar MS, Din IU, Khalid MS, Ahmad S (2008) Mango fruit desapping in relation to time of harvesting. *Pakistan Journal of Botany* 40: 1587–1593.

Ananthakrishnan TN, Thangavelu K (1976) The cereal thrips *Haplothrips ganglbaueri* Schmutz with particular reference to the trends of infestation on *Oryza sativa* and the weed *Echinochloa crusgalli*. *Proceedings of the Indian Academy of Sciences B* 83: 196–201.

APPD (Australian Plant Pest Database) (2010) Plant Health Australia. http://www.planthealthaustralia.com.au/APPD/queryForm.asp. Accessed September 2010.

AQIS (2010) AQIS Methyl Bromide Fumigation Standard Version 1.4. Australian Quarantine and Inspection Service. http://www.daff.gov.au/data/assets/pdf_file/0010/734464/mbr-standard.pdf. Accessed March 2010.

Aslam M, Jatoi MY, Shaheen FA (2001) Influence of environmental factors on *Rhipiphorothrips cruentatus* Hood (Thysanoptera: Heliothripidae) feeding on *Rosa indica* var. 'Iceberg' (Rosaceae). *Journal of Biological Sciences* 1: 289–290.

Aslam M, Majid K, Ali S, Akhtar AS (1995) Root/stem rot of okra caused by *Phytophthora palmivora* (Butler) Butler: a new report from Pakistan. *Pakistan Journal of Phytopathology* 7: 217.

Atkinson TH (2011) Bark and Ambrosia Beetle Database. http://www.barkbeetles.info. Accessed 24 February 2011.

Attique MR, Ahmad Z (1990) Investigation of *Thrips tabaci* Lind. as a cotton pest and the development of strategies for its control in Punjab. *Crop Protection* 9: 469–473.

Badshah HF, Salihah Z, Saljoqi AUR, Shakur M (2004) Toxic effects of Ak (*Calotropis procera*) plant extracts against termites (*Heterotermes indicola* and *Coptotermes heimi*) Isoptera: Rhinotermitidae. *Pakistan Journal of Biological Sciences* 7: 1603–1606.

Badyal K, Sumbali G (1990) Market diseases of mango. *Indian Journal of Mycology and Plant Pathology* 20: 281.

Bajpai R, Choudhary BS, Nayak D (2003) Infestation of *Selepa celtis* on canola. *Indian Journal of Tropical Biodiversity* 11: 106–107.

Baker CJ, Harrington TC, Kraus U and Alfenas AC (2003) Genetic variability and host specialization in the Latin American clade of *Ceratocystis fimbriata*. *Phytopathology* 93: 1274–1284.

Bakhsh K, Ishtiaq Hassan I, Akhter MS (2006) Profitability and cost in growing mango orchards. *Journal of Agriculture and Social Sciences* 2: 46–50.

Balachowsky AS (1953) Les cochenilles de France, d'Europe, du Nord de l'Afrique et du bassin Méditerranéen : vii. Monographie des Coccoïdea, Diaspidinae – iv. *Actualités Scientifiques et Industrielles*, *Entomologie Appliquée* 1202: 723–929.

Balan JS, Singh G, Naresh JS (1985) First record of *Pyroderces simplex* Walsingham (Lepidoptera: Momphidae) infesting cotton in Haryana. *International Journal of Tropical Agriculture*, 1: 259.

Banerjee S, Saekae A (1956) Formation of sporophores of *Ganoderma lucidum* (Leyss.) Karst, and *Ganoderma applanatum* (Pers.) Pat. in culture. *Indian Journal of Mycological Research* 2: 80–82.

Barnes I, Roux J, Wingfield MJ, Old KM, Dudzinski M (2003) *Ceratocystis pirilliformis*, a new species from *Eucalyptus nitens* in Australia. *Mycologia* 95: 865–871.

Bastianel M, de Oliveira AC, Cristofani M, Filho OG, Freitas-Astua J, Rodrigues V, Astua-Monge G, Machado MA (2006) Inheritance and heritability of resistance to citrus leprosis. *Phytopathology* 96: 1092–1096.

Batra HN (1953) Biology and control of *Dacus diversus* Goquillett and *Carpomyia versuriana* Costa and important notes on other fruit flies in India. *Indian Journal of Agricultural Sciences* 23: 87–112.

Batra HN (1964) Value of clensel as a chemical attractant and preliminary studies on population fluctuations and movements of fruit flies in the orchards. *Indian Journal of Agricultural Sciences* 34: 28–37.

Ben-Dov Y (1994) *A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance.* Intercept Limited, Andover.

Ben-Dov Y, Miller DR, Gibson GAP (2007) ScaleNet: a database of scale insects of the world. United States Department of Agriculture. Available online at: http://www.sel.barc.usda.gov/scalenet/scalenet.htm Accessed 27 April 2007.

Bennett SM (2003) Sore product insects. http://www.the-piedpiper.co.uk/th7.htm Accessed 30 March 2010.

Bharati SM, Gundannavar KP, Giiraddi RS, Hilli JS, Kamanna BC, Budhihal RA (2007) Mango: a new record for *Helicoverpa armigera* (Hubner). *Current Science* 92: 1033.

Bhutta AR (1998) Seed borne fungal pathogens associated with maize seeds in Pakistan. *Pakistan Journal of Phytopathology* 10: 105–107.

Bhutta AR, Bhatti MHR, Nizamani SM, Ahmad I (1997) Studies on effect of seed-borne fungi on germination of sunflower. *Helia* 20: 35–42.

Bhutta AR, Rahber-Bhatti MH, Ahmad SI, Ahmad I (1995) Prevalence and incidence of sunflower diseases in Pakistan. *Pakistan Journal of Phytopathology* 7: 135–139.

Biassangama A, Fabres G, Moussa JB (1991) The presence in Congo of *Gyranusoidea tebygi* (Hymenoptera: Encyrtidae), parasitoid of *Rastrococcus invadens* (Hom.: Pseudococcidae). *Bulletin de la Société Entomologique de France* 96: 209–211.

Biosecurity Australia (2006) Policy for the importation of fresh mangoes (*Mangifera indica* L.) from Taiwan. Biosecurity Australia, Canberra.

Biosecurity Australia (2008) Final import risk analysis report for fresh mango fruit from India. Biosecurity Australia, Canberra

Blood PR (1996) Pakistan: a country study. Federal Research Division Library of Congress. Washington.

Boardman MC (2010) The Second Green Revolution. http://thesecondgreenrevolution.blogspot.com/2010_06_01_archive.html. Accessed February 2011.

Botha J, Reeves A, Hardie D (2004) Melon fruit fly (*Bactrocera cucurbitae*) with reference to other fruit fly species of importance to the cucurbit industry. Department of Agriculture Western Australia Factsheet No. 5/2004, Perth. http://www.agric.wa.gov.au/pls/portal30/docs/FOLDER/IKMP/PW/INS/PP/HORT/FS005_2004.PDF Accessed April 2007.

Bournier A (1976) Grape insects. *Annual Review of Entomology* 22: 355–376.

Bradbury JF (1986) *Guide to plant pathogenic bacteria.* CAB International Mycological Institute, Slough.

Braby MF (2000) Butterflies of Australia: their identification, biology and distribution. CSIRO Publishing, Collingwood, Victoria, Australia.

Britz H, Steenkamp ET, Coutinho TA, Wingfield BD, Marasas WFO, Wingfield MJ (2002) Two new species of *Fusarium* sect *Liseola* associated with mango malformation. *Mycologia* 94: 722–730.

Broughton S (2007) Farmnote 243: Scale in citrus. Department of Agriculture and Food, Government of Western Australia. http://www.agric.wa.gov.au/objtwr/imported_assets/content/hort/fn/cp/citrusfruits/fn2007_citrusscale_sbroughton.pdf. Accessed February 2011.

Burger HC, Ulenberg SA (1990) Quarantine problems and procedures. In Rosen D (ed) *Armoured scale insects, their biology, natural enemies and control*: *world crop pests vol. 4b* 313–327. Elsevier, Amsterdam.

Buriro AS (2006) Managing mango insect pests in Pakistan. Paper presented at the workshop on mango research, development and extension in Pakistan and Australia, 28–31 March, 2006, Multan, Pakistan. http://www.aciar.gov.au/node/775. Accessed 27 April 2007.

Bustos ME, Enkerlin W, Reyes J, Toledo J (2004) Irradiation of mangoes as post harvest quarantine treatment for fruit flies (Diptera: Tephritidae). *Journal of Economic Entomology* 97: 286–292.

Butani DK (1993) *Mango: pest problems.* Periodical Expert Book Agency, Delhi.

CABI (2007) Crop protection compendium. Cab International, Wallingford, UK. http://www.cabicompendium.org/cpc/home.asp Accessed 27 April 2007.

Cannon PF, Minter DW (1984) *IMI descriptions of fungi and bacteria: Coccomyces vilis, 80, sheet 792.* International Mycological Institute, CAB International, Wallingford, UK.

Carroll LE, Norrbom AL, Dallwitz MJ, Thompson FC (2004) *Pest fruit flies of the world: larvae.* Version: 13th April 2005. http://delta-intkey.com Accessed 27 April 2007.

Carver M, Gross GF and Woodward TE (1991) Hemiptera. In Naumann ID (eds) *Insects of Australia* pp. 429–509. Melbourne University Press, Carlton, Victoria.

Cazorla FM, Arrebola E, Olea F, Velasco L, Hermoso JM, Perez-Garcia A, Tores JA, Farre JM, de Vicente A (2006) Field evaluation of treatments for the control of the *Bacterial apical necrosis* of mango (*Mangifera indica*) caused by *Pseudomonas syringae* pv. *syringae*. *European Journal of Plant Pathology* 116: 279–288.

Chamberlain DJ (1993) *Sathrobota* (*Pyroderces*) *simplex* Walsingham (Lepidoptera: Cosmopterygidae): a secondary pest of cotton in Pakistan. *International Journal of Pest Management* 39: 19–22.

Chapin EA, Ahmad R (1966) A new species off Coccinellid [*Pseudoscymnus simmondsi*] feeding on scale insects [*Pinnaspis strachani* (Cooley)] in West Pakistan. *Entomophaga* 11: 213–215.

Chattopadhyay NC, Nandi B (1977) Degradation of cellulose and lignin in malformed mango inflorescence by *Fusarium moniliforme* var. *subglutinans*. *Acta Phytopathologica Academiae Scientiarum Hungaricae* 12: 283–287.

Cherian TT, Varghese M (2002) *Thielaviopsis paradoxa* (de Seynes) V. Hohnel infection and early ripening of fruits. *Journal of Mycopathological Research* 40: 49–50.

Chockalingam S, Krishnan M (1984) Influence of foliage age on food utilization in the final instar larva of a monophagous and a polyphagous insect pest. *Journal of Advanced Zoology* 5: 1–9.

Chughtai GH, Khan S, Baloch UK (1985) A new record of infestation of melon fruits by an anthomyiid fly in Indus River Beach areas of D.I. Khan. *Pakistan Journal of Zoology* 17: 165–168.

CIE (Commonwealth Institute of Entomology) (1973a) *Distribution maps of plant pests, no. 320.* CAB International, Wallingford, UK.

CIE (Commonwealth Institute of Entomology) (1973b) *Distribution maps of plant pests, no. 318.* CAB International, Wallingford, UK.

CIE (Commonwealth Institute of Entomology) (1973c) *Distribution maps of plant pests, no. 24.* CAB International, Wallingford, UK.

CIE (Commonwealth Institute of Entomology) (1983) Distribution *maps of plant pests, series A, no. 449.* CAB International, Wallingford, UK.

CIE (Commonwealth Institute of Entomology) (1988) *Distribution maps of plant pests, series A, no. 128.* CAB International, Wallingford, UK.

CMI (Commonwealth Mycological Institute) (1987) *Distribution maps of plant pests, no. 142.* 5th edn. CAB International, Wallingford, UK.

Collingwood CA, Tigar BJ, Agosti D (1997) Introduced ants in the United Arab Emirates. *Journal of Arid Environments* 37: 505–512.

Corcoran RJ, Waddell BC (2003) *Ionizing energy treatments for quarantine disinfestation*. Horticulture Australia Limited, Sydney, Australia.

Cox JM (1989) The mealybug genus *Planococcus* (Homoptera: Pseudococcidae). *Bulletin of the British Museum of Natural History (Entomology)* 58: 1–78.

Croft BJ (2000) Ring spot. In: Rott P, Bailey RA, Comstock JC, Croft BJ, Saumtally AS (eds) Aguide to sugarcane diseases 167–169. CIRAD and ISSCT, Montpellier, France.

Cunningham I (1989) Pests. In *Mango pests and disorders* 10–19. Department of Primary Industries, Queensland.

Daane KM, Yokota GY, Dlott JW (1993) Dormant-season sprays affect the mortality of peach twig borer (Lepidoptera: Gelechiidae) and its parasitoids. *Journal of Economic Entomology* 86: 1679–1685.

DAFWA (2003) Draft WA pest list for arthropods, pathogens and nematodes. Provides by the Department of Agriculture, Government of Western Australia, August 2003. [Unpublished internal document].

DAFWA (2006) *An annotated catalogue of insect and allied species of economic significance or of potential export quarantine concern for Western Australian primary and related industries: perennial draft report (March update).* Department of Agriculture and Food, Western Australia.

Dahiya KK, Lakra RK (2001) Seasonal occurrence and succession of thrips, *Rhipiphorothrips cruentatus* Hood in important horticultural crops of Haryana. *Crop Research (Hisar)* 21: 112–114.

Dale D (1994) Insect pests of the rice plant and their biology and ecology. In Heinrichs EA (ed) *Biology and management of rice insects.* Wiley Eastern Limited and International Rice Research Institute.

Damm U, Baroncelli R, Cai L, Kubo Y, O'Connell R, Weir B, Yoshino K, Cannon PF (2010) *Colletotrichum*: species, ecology and interactions. IMA Fungus 1(2): 161–165.

Dass C, Teyegaga A (1996) A growth suppression of some wood-decay and other fungi by *Bacillus subtilis*. *Australian Journal of Botany* 44: 705–712.

DEFRA (2008) *UK Plant Health interceptions.* Department of Environment, Food and Rural Affairs. http://www.defra.gov.uk/planth/interc.htm. Accessed 12 August 2008.

Denmark HA (1980) Broad mite, *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae) on *Pittosporum*. *Entomology Circular: Division of Plant Industry, Florida Department of Agriculture and Consumer Services,* 213: 2 pp.

Dhillon MK, Singh R, Naresh JS, Sharma HC (2005) The melon fruit fly, *Bactrocera cucurbitae*: A review of its biology and management. *Journal of Insect Science* 5: 40–56.

Dhiman SC, Yadav YK (2004) Studies on parasitoids of *Halys dentatus* Fabr. (Heteroptera: Pentatomidae) and their bio-control efficacy. *Annals of Plant Protection Sciences* 12: 263–266.

Diedhiou PM, Mbaye N, Drame A, Samb PI (2007) Alteration of post harvest diseases of mango *Mangifera indica* through production practices and climatic factors. *African Journal of Biotechnology* 6(9): 1087–1094.

DPIFM (2008) *Mango malformation disease fact sheet.* Department of Primary Indusry, Fisheries and Mines. http://www.nt.gov.au/dpifm/Content/File/p/Plant_Pest/mango_malformation.pdf Accessed 27 April 2008.

DPP (2001) *Pest list provided by the Directorate of Plant Protection in India to Dr Sharan Singh on his visit to India.* Directorate of Plant Protection, Quarantine and Storage, Ministry of Agriculture, India.

Drew RAI, Hancock DL (1994) The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research*, *Supplement* 2: 1–68.

Duong LM, McKenzie EHC, Lumyong S, Hyde KD (2008) Fungal succession on senescent leaves of *Castanopsis diversifolia* in Doi Suthep-Pui National Park, Thailand. *Fungal Diversity* 30: 23–36.

Duyck PF, Sterlin JF, Quilici (2004) Survival and development of different life stages of *Bactrocera zonata* (Diptera: Tephritidae) reared at five constant temperatures compared to other fruit fly species. *Bulletin of Entomological Research* 94: 89–93.

Dwivedi BP, Logani R, Dwivedi BK, Shukla DN (2003) Studies on the association of rhizosphere and rhizoplane mycoflora with wilted mango plants (*Mangifera indica* L.). *Bioved* 14: 21–24.

EPPO (2006) *EPPO data sheets.* European and Mediterranean Plant Protection Organization. http://www.eppo.org. Accessed 19 September 2007.

Evans K, Trudgill DL, Webster JM (1993) *Plant parasitic nematodes in temperate agriculture.* CAB International, Wallingford.

FAO (1996) *International standards for phytosanitary measures (ISPM) no. 4: establishment of pest free areas.* Food and Agricultural Organization of the United Nations, Rome.

FAO (1997) *International standards for phytosanitary measures (ISPM) no. 7: export certification systems.* Food and Agricultural Organization of the United Nations, Rome.

FAO (1999) *International standards for phytosanitary measures (ISPM) no. 10: requirements for the establishment of pest free places of production and pest free production sites.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2003) *International standards for phytosanitary measures (ISPM) no. 18: guidelines for the use of irradiation as a phytosanitary measure.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2004a) *International standards for phytosanitary measures (ISPM) no. 11: pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2004b) *Fertilizer use by crop in Pakistan.* Food and Agriculture Organization of the United Nations. http://www.fao.org Accessed 30 October 2010.

FAO (2005) *International standards for phytosanitary measures (ISPM) no. 22: requirements for the establishment of areas of low pest prevalence.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2006) *International standards for phytosanitary measures (ISPM) no. 1: phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2007) *International standards for phytosanitary measures (ISPM): no. 2 framework for pest risk analysis.* Food and Agricultural Organization of the United Nations, Rome.

FAO (2009) *International standards for phytosanitary measures (ISPM) no. 5 glossary of phytosanitary terms.* Food and Agricultural Organization of the United Nations, Rome.

Farr DF, Rossman AY (2011) Fungal Databases, Systematic Mycology and Microbiology Laboratory, ARS, USDA. http://nt.ars-grin.gov/fungaldatabases/. Accessed February 2011.

Farshori M-U (1995) *Letter from Muzammil-Uddin Farshori (Principal Economist, Industrial Liaison Division, Pakistan Council of Scientific and Industrial Research Laboratirues Complex, Karachi) to Long Life Traders, Karachi re: some studies regarding mangoes.*

Fateh FS, Kazmi MR Ahmad I, Ashraf M (2006) *Ceratocystis fimbriata* isolated from vascular bundles of declining mango trees. Pakistan Journal of Botany 38: 1257–1259.

Fateh FS, Kazmi MR, Jabeen A (2009) Different forms of mango sudden-death syndrome. *Science Technology and Development* 28: 34–41.

Fay H (2005) Fruit piercing moth on citrus: a perspective including control developments. Department of primary Industries and Fisheries, Queensland Government.www2.dpi.qld.gov.au/horticulture/5541.html. Accessed February 2011.

Filajdic N, Sutton TB, Walgenbach JF, Unrath CR (1995) The influence of European red mites on intensity of *Alternaria* blotch of apple and fruit quality and yield. *Plant Disease* 79: 683–690.

Fletcher BS (1989a) Life history strategies of tephritid fruit flies. In Robinson AS and Hooper G (eds) *Fruit flies: their biology, natural enemies and control: world crop pests volume 3b* 195–208. Elsevier Science Publishers: Amsterdam.

Fletcher BS (1989b) Movements of tephritid fruit flies. In Robinson AS and Hooper G (eds) *Fruit flies: their biology, natural enemies and control: world crop pests volume 3b* 209–219. Elsevier Science Publishers: Amsterdam.

Fletcher TB (1921) Life histories of Indian insects. Microlepidoptera. *Memoirs of the Department of Agriculture in India* (*Entomological series*) 6: 1–217.

Foldi I (1990) Moulting and scale-cover formation. In Rosen D (ed) *Armoured scale insects, their biology, natural enemies and control*: *world crop pests vol. 4a* 257–265. Elsevier, Amsterdam.

Follett PA (2004) Generic vapour heat treatments to control *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae). *Journal of Economic Entomology* 97: 1263–1268.

Freeman S, Klein-Gueta D, Korolev N, Sztejnberg A (2004) Epidemiology and survival of *F. mangiferae*, the causal agent of mango malformation disease. *Acta Horticulturae* 645: 487–491.

Freeman S, Maimon M, Pinkas Y (1999) Use of GUS transformants of *Fusarium subglutinans* for determining etiology of mango malformation disease. *Phytopathology* 89: 456–461.

FSANZ (2000) *Standard 1.5.3: irradiation of food.* Food Standards Australia and New Zealand. http://www.foodstandards.gov.au/_srcfiles/FSC_Standard_1_5_3_Irrad_v88.pdf Accessed 27 April 2007.

Gangwere SK, Spiller DO (1995) Food selection and feeding behavior in selected *Orthoptera* sen. lat. of the Balearic Islands, Spain. *Journal of Orthoptera Research* 4: 147–160.

Germain JF, Vayssieres JF, Matile-Ferrero D (2010) Preliminary inventory of mangoes trees in Benin. *Entomologia Hellenica* 19: 124–131.

Gharib A (1973) *Parlatoria blanchardi* Targ. (Homoptera: Diaspididae). *Entomologie et Phytopathologie Appliquees* 34: 10–17.

Ghose SK (1965) Control of orange coccid, *Labioproctus polei* Green (Margarodidae: Hemiptera). *Indian Journal of Agricultural Science* 35: 32–38.

Ghosh AB, Ghosh SK (1985) Effect of infestation of *Nipaecoccus vastator* (Maskell) on host plants. *Indian Agriculturist* 29: 141–147.

Gogi MD, Sarfraz RM, Dosdall LM, Arif MJ, Keddie AB, Ashfaq M (2006) Effectiveness of two insect growth regulators against *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) and *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) and their impact on population densities of arthropod predators in cotton in Pakistan. *Pest Management Science* 62: 982–990.

Government of Sindh, Agriculture Department (2011) Pesticide Recommendation for Fruit Crops. http://www.sindhagri.gov.pk/pesticides%20rpt/pest_recom/Pesticide%20Recom%20fruit.pdf. Accessed February 2011.

GSAD (2004) *Diseases of mango and their control.* Government of Sindh Agriculture Department. http://www.sindhagri.gov.pk/mango-disea.html. Accessed 27 April 2007.

Gul H, Bajwa GA (1999) Screening and economics of some pyrethroid insecticides against powder post beetles. *Pakistan Journal of Forestry* 47: 81–88.

Gul H, Chaudhry MI (1991) Efficacy of pyrethroids against powder post beetles attack on fuelwood. *Pakistan Journal of Forestry*, 41: 178–183.

Gullan PJ, Downie DA, Steffan SA (2003) A new pest species of the mealybug genus *Ferrisia* Fullaway (Hemiptera: Pseudococcidae) from the United States. *Annals of the Entomological Society of America* 96: 723–737.

Gutierrez J, van Zon AQ (1973) A comparative study of several strains of the *Tetranychus neocaledonicus* complex and sterilisation tests of males by x-ray. *Entomologia Experimentalis et Applicata* 16: 123–134.

Haack RA (2001) Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985–2000. *Integrated Pest Management Reviews* 6: 253–282.

Habib R (1983) Tamarisk flower-feeder *Characoma nilotica* Rogenh. (Lepidoptera: Noctuidae) a potential pest in Pakistan. *Proceedings of the 1st Pakistan Congress of Zoology, 30 April–1 May, 1980* 307–311. Quaid I Azam University, Islamabad.

Hammouda AM (1991) *Coniothyrium olivaceum* causing leaf spot of tomato—a new record. *Plant Pathology* 41: 306–307.

Harrington TC (2000) Host specialization and speciation in the American wilt pathogen *Ceratocystis fimbriata*. *Fitopatologia Brasileira* 25: 262–263.

Hashmi AA, Tashfeen A (1994) Coleoptera of Pakistan. *Proceedings of Pakistan Congress of Zoology, Vol. 12: Twelfth Pakistan Congress of Zoology held under auspices of the Zoological Society of Pakistan Government College, Lahore, April 1992* 133–170. Zoological Society of Pakistan Government College, Lahore.

Hassan S, Arif M, Defoer T (1993) Epidemiological studies of tomato viruses in Malakand Agency of North West Frontier Province of Pakistan. *Sarhad Journal of Agriculture* 9: 37–43.

Heredia G, Arias RM, Reyes M, Castandea-Ruiz R (2002) New anamorph fungi with rhombic conidia from Mexican tropical forest litter. *Fungal Diversity* 11: 99–107.

Hinds TE (1972) Insect transmission of *Ceratocystis* species associated with aspen cankers. *Phytopathology* 62: 221–225.

Huque H (1972) Application of radio-isotopes and radiation for the control of rice pests. *Japan Pesticide Information* 10: 37–39.

IIE (International Institute of Entomology) (1994) Distribution maps of pests: *Bactrocera dorsalis* (Hendel), series A, map no. 109.

IPPC (2010) *Official pest report: detection of mango malformation disorder in Queensland, Australia.* International Plant Protection Convention https://www.ippc.int/ Accessed 5 November 2010.

Iqbal SM, Ahmad M, Ayub N, Ahmad I (2001) Collar rot of strawberry caused by *Sclerotium rolfsii* in Pakistan. *Pakistan Journal of Phytopathology* 13: 170–171.

Iqbal Z, Dasti AA, Saleem A (2006a) Role of *Fusarium mangiferae* in causation of mango malformation disease. *Journal of Research (Science)*, *Bahauddin Zakariya University*, *Multan*, *Pakistan* 17: 9–14.

Iqbal Z, Rhaman MU, Dasti AA, Saleem A, Zafar Y (2006b) RAPD analysis of *Fusarium* isolates causing 'mango malformaion' disease in Pakistan. *World Journal of Microbiology and Biotechnology* 22: 1161–1167.

Iqbal Z, Saleem EE, Shahbaz M, Ahmad K, Khan ZI, Malik MT, Danish M (2007) Determination of different decline disorders in mango orchards of the Punjab, Pakistan. *Pakistan Journal of Botany* 39(4): 1313–1318.

Irulandi S, Kumar PKV, Sreedharan K (2003) Observations on the incidence and biology of the pentatomid bug, *Antestiopsis cruciata* (Fabricius) (Hemiptera: Pentatomidae) on coffee. *Journal of Coffee Research* 31: 95–98.

Ishaq M, Usman M, Asif M and Khan IA (2004) Integrated pest management of mango against mealybug and fruit fly. *International Journal of Agriculture & Biology* 6: 452–454.

Islam S, Hamid F, Khan A, Poswal MA (2006) Plant parasitic nematodes associated with different crops of Swat and Malakand Agency, under MRDP area (NWFP), Pakistan. *Proceedings of Parasitology* 41: 77–83.

Islam W, Nargis A, Joarder OI (1988) Biology, seasonal occurrence, host range and damage potential of the castor hairy caterpillar, *Euproctis lunata* Walk. (Lymantriidae: Lepidoptera). *Crop Protection* 7: 332–335.

Jabbar-Khan R, Jabbar-Khan MA (1987) *Gastrointestinal myiasis* caused by the maggots of synanthropic flies in human. *Proceedings of Parasitology* 3: 24–27.

Jacobsen CM, Hara AH (2003) Irradiation of *Maconellicoccus hirsutus* (Homoptera: Pseudococcidae) for phytosanitation of agricultural commodities. *Journal of Economic Entomology* 96: 1334–1339.

Javaid A, Shafique S, Shafique S (2006) Fungi associated with stored seeds of *Parthenium hysterophorus* collected from Lahore. *International Journal of Biology and Biotechnology* 3: 551–553.

Javed MS, Abdul-Wahid S, Idrees M, Saleem A (1998) Seed-borne mycoflora of peanut (*Arachis hypogaea*) varieties/genetic stock in Punjab. *Pakistan Journal of Phytopathology* 10: 53–55.

Jeyabalan D, Kumar NS, Murugan K (1996) Dietary influence on the feeding and excretion of *Latoia lepida* (Cramer) (Lepidoptera: Limacodidae). *Insect Environment* 2: 46–47.

Jo W-S, Park S-D, Park S-C, Chang Z-Q, Seo G-S, Uhm J-Y, Jung H-Y (2009) Changes in quality of *Phelinus gilvus* mushroom by different drying methods. *Mycoscience* 50: 70–73.

Johnson G, Muirhead I, Mayers P, Cooke T (1989) Diseases. In *Mango pests and disorders* 1–9. Department of Primary Industries, Queensland.

Johnson GI, Hyde KD (1992) *IMI descriptions of fungi and bacteria: Cytosphaera mangiferae, sheet 1122.* International Mycological Institute, CAB International, Wallingford, UK.

Johnson GI, Mead AJ, Cooke AW, Dean JR (1991) Mango stem end rot pathogens: infection levels between flowering and harvest. *Annals of Applied Biology* 119: 465–473.

Johnson GI, Mead AJ, Cooke AW, Dean JR (1992) Mango stem end rot pathogens: fruit infection by endophytic colonization of the inflorescence and pedicel. *Annals of Applied Biology* 120: 225–234.

Johnson JA, Harrington TC and Engelbrecht CJB (2005) Phylogeny and taxonomy of the North-American clade of the *Ceratocystis fimbriata* complex. *Mycologia* 97: 1067–1092.

Johnson PR, Parr D (1999) *Mango growing in Western Australia.* Bulletin No. 4348, Department of Agriculture, Western Australia. http://www.agric.wa.gov.au/servlet/page?_pageid=449&_dad=portal30&_schema=PORTAL30&p_start_url=/pls/portal30/docs/FOLDER/IKMP/HORT/FN/CP/PAWPAWS/B4348_INDEX.HTM Accessed 27 April 2007.

Kamaluddin S, Haque E (2000) Redescription of *Acherontia styx* Westwood (Lepidoptera: Sphingidae: Acherontiinae) from Pakistan and its systematic position. *Proceedings of Pakistan Congress of Zoology* 20: 117–122.

Kannan M, Rao NV (2003) Effect of meteorological parameters on the population dynamics of leaf and flower feeder on mango (*Mangifera indica* L.). *Insect Environment* 9: 88.

Kannan M, Rao NV (2006) Influence of age and stage of the host plant on insect pests of mango (*Mangifera indica* L.). *International Journal of Agricultural Science* 2: 351–353.

Kapoor KN, Dhamdhere SV, Singh OP, Misra US (1982) Population dynamics of insect pests of pearl millet in Northern Madhya Pradesh. *Indian Journal of Plant Protection* 9: 69–73.

Kapoor VC (1989) Indian sub-continent. In Robinson AS, Hooper G (eds.) *Fruit flies: their biology, natural enemies and control: world crop pests vol. 3a.* Elsevier Science Publishers: Amsterdam.

Karar H, Arif MJ, Sayyed HA, Saeed S, Abbas G, Arshad M (2009) Integrated pest management of mango mealybug (*Drosicha mangiferae*) in mango orchards. *International Journal of Agriculture and Biology* 11: 81–84.

Kathiresan K (2003) Insect foliovory in mangroves. *Indian Journal of Marine Sciences* 32: 237–239.

Kazmi MR, Farooq SI, Fateh FS, Hameed S, Fahmeed F, Ashraf M and Ahmed I (2007) Identification of phytoplasma from mango trees showing sudden death phenomenon through molecular techniques. *Pakistan Journal of Botany* 39: 2153–2157.

Kazmi MR, Fateh FS, Majeed K, Kashkhely AM, Hussain I, Ahmad I and Jabeen A (2005) Incidence and etiology of mango sudden death phenomenon in Pakistan. *Pakistan Journal of Phytopathology* 17: 154–158.

Khan A, Sayed M, Shaukat SS (2005) Nematodes associated with mango in Sindh. *International Journal of Biology and Biotechnology* 2: 917–919.

Khan A, Shaukat SS (2005) A survey of nematodes of pomegranate in lower Sindh, Pakistan. *Sarhad Journal of Agriculture* 21: 699–702.

Khan AA, Avesi GM, Masud SZ, Rizvi SWA (1998) Incidence of mealy bug *Dismycoccus brevipes* (Cockrell) on pineapple. *Turkish Journal of Zoology* 22: 159–161.

Khan AR, Faruki SI, Pramanik MR (1999) The combined efficacy of DipelReg. and Malathion on the development and reproductive potential of the tropical warehouse moth, *Cadra cautella* (Walker), on dried mango. *Entomon* 24: 315–322.

Khan AW (1970) Some very common and highly destructive mites: Acarina in mango buds in West Pakistan. *Science and Industry* 7: 276–279.

Khan MA, Mirza JH (1995) Bacterial leaf spot of mango in Pakistan. *Pakistan Journal of Phytopathology* 7: 204–205.

Khan MQ (2005) Distribution and occurrence of plant parasitic nematodes in Balochistan. *International Journal of Biology and Biotechnology* 2: 157–164.

Khan MQ, Ahmad SI (1998) Seed-borne mycoflora of vegetable seed lots in Northern Areas of Pakistan. *Pakistan Journal of Scientific and Industrial Research* 41: 47–49.

Khan MR, Baloch UK (1971) Incidence of rice borers in the North-West frontier province, Pakistan. *Pakistan Journal of Zoology* 3: 242–243.

Khan SM, Khan MA, Khan MZ (1997) Comparative effect of different acaricide against mites on apple in Swat. *Sarhad Journal of Agriculture* 13: 71–75.

Khanzada MA, Lodhi AM and Shahzad S (2004) *Mango dieback and gummosis in Sindh, Pakistan caused by Lasiodiplodia theobromae.* Plant Health Progress doi:10.1094/PHP-2004-0302-01-DG

Khanzada MA, Lodhi AM, Shahzad S (2005) Chemical control of *Lasiodiplodia theobromae*, the causal agent of mango decline in Sindh. *Pakistan Journal of Botany* 37: 1023–1030.

Khattak SU, Jabbar A, Hussain N (1991) Chemical control of hairy caterpillar, *Diacrisia obliqua* Walk. *Pakistan Journal of Zoology* 23: 149–151.

Khuhro RD, Nizamani SM, Abbasi QD, Rahoo GM, Jiskani MM (2005a) Asian ambrosia beetle: a new insect pest in Sindh Pakistan. *Pakistan Journal of Agriculture*, *Agricultural Engineering*, *Veterinary Sciences* 21: 44.

Khuhro RD, Nizamani SM, Abbasi QD, Solangi GS, Jiskani MM (2005b) Mango tree mortality due to Asian ambrosia beetle, *Xylosandrus crassiusculus* Mot. (Coleoptera: Scolytidae). *Pakistan Journal of Agriculture*, *Agricultural Engineering*, *Veterinary Sciences* 21: 39–42.

Khuhro RD, Nizamani SM, Rizvi NH, Abbasi QD, Buriro AS, Khuhro IU, Kalwar MA (1996) Relative susceptibility of mango varieties against mango thrips, *Rhipiphorothrips cruentatus* Hood at Tandojam [Pakistan]. *Proceedings of the Second International Congress of Entomological Sciences, held in March 19–21, Islamabad, Pakistan*.

Krull S, Basedow T (2006) Studies on the biology of *Deanolis sublimbalis* Snellen (Lepidoptera, Pyralidae) and its natural enemies on mango in Papua New Guinea. *Mitteilung der Deutsched Gesellschaft tsch fuer Allgemeine und Angewandete Entomologie* 15: 273–276.

Krull SME (2004) Studies on the mango-ecosystem in Papua New Guinea with special reference to the ecology of *Deanolis sublimbalis* Snellen (Lepidoptera, Pyralidae) and to the biological control of *Ceroplastes rubens* Maskell (Homoptera, Coccidae). Ph. D. thesis, Institut fur Phytopathologie und Angewandte Zoologie, der Justus-Liebig-Universitat Gieβen, Versuchsstation, Alter Steinbacher Weg 44, D-35394 Gieβen.

Kumar J, Singh US, Beniwal SPS (1993) Mango malformation: one hundred years of research. *Annual Review of Phytopathology* 31: 217–232.

Kwee LT, Chong KK (1994) *Diseases and disorders of mango in Malaysia.* Tropical Press SDN. BHD., Kuala Lumpur.

Lal L, Mukharji SP (1975) Incidence of rice gundhi bug on certain medicinal plants at Varanasi. *Science and Culture* 41: 560–561.

Lall BS, Singh BN (1969) Studies on the biology and control of melon fly, *D. cucurbitae* (Diptera: Teohritidae). *Labdev Journal of Science and Technology* 7B: 148–153.

Lamberti F, Maqbool MA, Shahina F, Agostinelli A (1987) Occurrence of *Xiphinema* species in Pakistan (Nematoda, Dorylaimida). *Nematologia Mediterranea* 15: 145–148.

Lee HS, Wen HC (1982) Seasonal occurrence of and injury caused by thrips and their control on mangoes. *Plant protection Bulletin* 24: 179–187.

Lewis T (1997) Pest thrips in perspective. In Lewis, T. (ed) *Thrips as crop pests.* CAB International, Wallingford.

Lieutier F, Day KR, Battisti A, Gregoire JC, Evans HF (2007) Bark and wood boring insects in living trees in Europe, A Synthesis. Spinger Publishers, Dordrecht, The Netherlands 569 pp.

Lodhi AM (2007) *Taxonomic studies on oomycetous fungi from Sindh*. Ph. D. Thesis, Department of Agriculture, University of Karachi, Pakistan.

Luc M, Sikora RA, Bridge J (1990) *Plant parasitic nematodes in subtropical and tropical agriculture.* CAB International, Wallingford.

Mahar MMM (1974) Carry over and host plants of painted bug, *Bagarada picta* Fabr., (Pentatomidae: Heteroptera): a pest of rabi oilseed crops. *Agriculture Pakistan* 24: 9–10.

Mahdihassan S (1976) A fig tree heavily infested with *Icerya aegyptiaca* (Dougl.). *Bollettino del Laboratorio di Entomologia Agraria' Filippo Silvestri', Portici.* 33: 315–317.

Mahdihassan S (1979) The black ant, *Camponotus* spp. feeding on urea. *Journal of the Bombay Natural History Society* 74: 197–199.

Mahgoob AEA (2006) Susceptibility of some mango varieties to the bud mite *Eriophyes mangiferae* (Sayed) and malformation disease and the relation of mite infestation to malformation disease. *Arab Universities Journal of Agricultural Sciences* 14: 491–507.

Mahmood R, Mohyuddin AI, Kazimi SK (1983) *Rastrococcus spinosus* (Robinson) (Homoptera: Pseudococcidae) and its natural enemies in Pakistan. Proceedings of the 1st Pakistan Congress of Zoology 1980: 291–294.

Malik MT, Akem C, Khan SM, Dasti AA, Kazmi MR Syed SA, Awan MZ, Grewal AG and Khan MI (2009) Detection of *Ceratocystis fimbriata* from soil of the plants affected with mango sudden death disease syndrome in Pakistan. *Pakistan Journal of Phytopathology* 21: 49–55.

Malik MT, Khan SM, Dasti AA and Kazmi MR (2005) First record of *Ceratocystis fimbriata*, causal organism of mango sudden death in Pakistan. *Pakistan Journal of Phytopathology* 17: 187–191.

Manson DCM (1967) Mites of the family Tenuipalpidae and Tetranychidae intercepted entering New Zealand from overseas. *New Zealand Journal of Science* 10: 664–674.

Manzoor F, Akhtar MS (2002) Morphometric variations in termite *Odontotermes assmuthi* Holmgren. *Punjab University Journal of Zoology* 17: 146–161.

Manzoor S, Dawar S, Shaukat SS (2004) Studies on the soil mycoflora of Karachi coast. *International Journal of Biology and Biotechnology* 1: 597–602.

Maqbool A, Shafiq MK, Khan IA, Mahmood F (1997) Prevalence, aetiology, hematology, chemotherapy and control of Deg Nala disease in buffaloes and cattle. *Indian Journal of Dairy Science* 50: 102–106.

Maqbool M, Malik AU, Jabbar A (2007) Sap dynamics and its management in commercial mango cultivars of Pakistan. *Pakistan Journal of Botany* 39: 1565–1574.

Maqbool MA (1992) Pakistan. In Maqbool MA (eds) *Plant nematode problems and their control in the near east region.* FAO Plant Production and Protection Paper 144. http://www.fao.org/docrep/V9978E/v9978e0j.htm#nematology%20in%20pakistan Accessed 27 April 2007.

Maqbool MA, Ghazala P (1988) Observation on some known species of *Hoplolaimus* von Daday, 1905 (Nemata: Hoplolaimidae) from Pakistan. *Pakistan Journal of Nematology* 6: 1–7.

Maqbool MA, Shahina F (1988) Taxonomic studies on some plant parasitic nematodes associated with important crops in Pakistan. *Advances in Plant Nematology* 137–156.

Marasas WFO, Ploetz RC, Wingfield MJ, Steenkamp ET (2006) Mango malformation disease and the associated *Fusarium* species. *Phytopathology* 96: 667–672.

Masilamani S, Muthumary J (1995) Pycnidium ontogeny in *Coleophoma cylindrospora*. *Mycological Research* 99(6): 693–696.

Masood A, Saeed S, Erbilgin N, Jung Kwon Y (2010a) Role of stressed mango host conditions in attraction of and colonization by the mango bark beetle *Hypocryphalus mangiferae* Stebbing (Coleoptera: Curculionidae: Scolytinae) and in the symptom development of quick decline of mango trees in Pakistan. *Entomological Research* 40: 316–327.

Masood A, Saeed S, Iqbal, N, Malik MT, Kazmi MR (2010b) Methodology for the evaluation of symptoms severity of mango sudden death syndrome in Pakistan. *Pakistan Journal of Botany* 42: 1289–1299.

Masood A, Saeed S, Sajjad A (2008) Characterisation and damage patterns of different bark beetle species associated with mango sudden death syndrome in Punjab, Pakistan. *Pakistan Entomologist* 30(2): 163–168.

Masood A, Saeed S, Sajjad A, Ali M (2009) Life cycle and biology of mango bark beetles, *Hypocryphalus mangiferae* (Stebbing), a possible vector of mango sudden death disease in Pakistan. *Pakistan Journal of Zoology* 41: 281–288.

Maynard GV, Hamilton JG, Grimshaw JF (2004) Quarantine: phytosanitary, sanitary and incursion management: an Australian entomological perspective. *Australian Journal of Entomology* 43: 318–328.

Meijerman L, Ulenburg SA (2011) *Dudua aprobola*; Eurasian Tortricidae. Arthropods of Economic Importance. Netherlands Biodiversity Information Facility, http://nlbif.eti.uva.nl/bis/tortricidae.php?menuentry=soorten&id=183. Accessed February 2011.

Migeon A, Dorkeld F (2006) *Spider mites web: a comprehensive database for the Tetranychidae.* http://www.montpellier.inra.fr/CBGP/spmweb. Accessed 27 April 2007.

Millar JG, Daane KM, McElfresh JS, Moreira JA, Malakar-Kuenen R, Guillen M, Bentley WH (2002) Development and optimisation of methods for using sex pheromone for monitoring the mealybug *Planococcus ficus* (Homoptera: Pseudococcidae) in California vine-yards. *Journal of Economic Entomology* 95: 706–714.

Mirza JH, Akhtar N, Bajwa R (2004) Additions to fungi imperfecti of Pakistan. *Mycopathology* 2: 65–66.

Misra S, Reddy CRG, Sivaprasad V, Reddy KD, Chandrashekharaiah (2003) Record of *Oxyrachis tarandus* (Fb) on mulberry in Andhra Pradesh. *Indian Journal of Sericulture* 42: 66.

Moghaddam M (2006) The mealybugs of southern Iran (Hem.: Coccoidea: Pseudococcidae). *Journal of Entomological Society of Iran* 26: 1–11.

Mohammad-Ali S (1962) A new record of *Icerya pulcher* (Leonardi) in India and its identity (Coccoidea). *Indian Journal of Entomology* 23: 151–152.

Mohyuddin AI, Mahmood R (1993) Integrated control of mango Pests in Pakistan. *Acta Horticulturae* 341: 467–483.

Moore A (2006) *Red banded mango caterpillar.* Checklist of Micronesian insects. http://www.guaminsects.net/gisac/index.php?title=Red_banded_mango _caterpillar Accessed 27 April 2007.

More PS, Desai BD, Jalagaonkar VN, Mule RS (2003) Record of pests infesting arecanut, *Areca catechu* Linnaeus and their seasonal incidence. *Indian Journal of Arecanut*, *Spices and Medicinal Plants* 5: 5–8.

Morimoto K, Kojima H (2006) Larva of *Desmidophorus crassus* and the Systematic Position of the Desmidophorini (Coleoptera: Curculionoidea). *Esakia* 46: 89–100.

Morishita M (2005) Seasonal abundance of the western flower thrips, *Flankliniella occidentalis* (Pergande), and onion thrips, *Thrips tabaci* (Lindeman) (Thysanoptera: Thripidae), on weeds in persimmon and mandarin orange orchards. *Japanese Journal of Applied Entomology and Zoology* 49: 195–203.

Morris MJ, Wingfield MJ and De Beer C (1993) Gummosis and wilt of *Acacia mearnsii* in South Africa caused *Ceratocystis fimbriata*. *Plant Pathology* 42: 814–817.

Morton J (1987) Mango. In Morton JF (ed) *Fruits of warm climates* 221–239. http://www.hort.purdue.edu/newcrop/morton/lemon.html. Accessed 27 April 2007.

Muzaffar N (1974) New records. In Ghani MA, Muzaffar N. (eds) *Relations between the parasite-predator complex and the host-plants of scale insects in Pakistan* 69–80. CAB International: Wallingford, UK.

Muzaffar N, Ahmad R (1977) A note on *Saissetia privigna* (Hem.: Coccidae) in Pakistan and the breeding of its natural enemies. *Entomophaga* 22: 45–46.

Nameth S, Chatfield J, Shetlar D (2003) *Sooty molds on trees and shrubs.* Ohio State University Extension Fact Sheet. http://ohioline.osu.edu/hyg-fact/3000/3046.html. Accessed 27 April 2007.

Nasira K, Maqbool MA (1994) Occurrence of virus vector nematodes in Pakistan. *Pakistan Journal of Nematology* 12: 79–85.

Ni HF, Liou RF, Hung TH, Chen RS, Yang HR (2009) First report of a fruit rot disease of Avocado caused by *Neofusicoccum mangiferae*. *Plant Disease* 93(7): 760.

Ni HF, Liou RF, Hung TH, Chen RS, Yang HR (2010) Disease Notes: First report of fruit rot disease of mango caused by *Botryosphaeria dothidea* and *Neofusicoccum mangiferae* in Taiwan. *Plant Disease* 94(1): 128.

Ohm RA, de Jong JF, Lugones LG, Aerts A, Kothe E, Stajich JE, de Vries RP, Record E, Levasseur A, Baker SE, Bartholomew KA, Coutinho PM, Erdmann S, Fowler TJ, Gathman AC, Lombard V, Henrissat B, Knabe N, Kues U, Lilly WW, Lindquist E, Lucas S, Magnusan JK, Piumi F, Raudaskoski M, Salamov A, Schmutz J, Schwarze FWMR, van Kuyk PA, Horton JS, Grigoriev IV, Wosten HAB (2010) Genome sequence of the model mushroom *Schizophyllum commune*. *Nature Biotechnology* 28(9): 957–963.

Oni O (1990) Fruit abortion in a West African hardwood, *Terminalia ivorensis*. *Journal of Tropical Forest Science* 2: 280–285.

Ozbek H, Calmasur O (2005) A review of insects and mites associated with roses in Turkey. *Acta Horticulturae* 690: 167–174.

Pandit NC, Pradhan SK, Chakravorty S (1986) Incidence, host susceptibility and natural population control of large black weevil *Desmidophorus hebes* a new pest of bast fibre crop. *Proceedings of a national symposium on pesticide residues and environmental pollution, Muzaffarnagar, India, 2–4 October, 1985* 233–239.

Panhwar F (2005) *Post-harvest technology of mango fruits, its development, physiology, pathology and marketing in Pakistan.* Digitalverlag GmbH, Germany. http://www.ChemLin.com. Accessed 27 April 2007.

PARC (2011) Mango. Pakistan Agricultural Research Council. http://www.parc.gov.pk/1subdivisions/narccsi/horticul/Mango.html. Accessed February 2011.

Patel JG, Patel ST, Patel SK (1985) Occurrence of stem end rot of mango fruit in Gujarat. *Gujarat Agricultural University Research Journal* 11: 59–60.

Pathan MA, Talpur MA, Jiskani MM, Wagan KH (2004) Studies on plant parasitic nematodes associated with banana in Sindh, Pakistan. *Journal of Asia Pacific Entomology* 7: 249–252.

Peña JE (1993) Pests of mango in Florida. *Acta Horticulturae* 341: 395–406.

Peña JE (2004) Integrated pest management and monitoring techniques for mango pests. *Acta Horticulturae* 645: 151–161.

Peña JE, Mohyuddin AI (1997) Insect pests. In Litz RE (ed) *The mango: botany, production and uses* 327–362. CAB International, Wallingford, UK.

Peña JE, Mohyuddin AI, Wysoki M (1998) A review of the pest management situation in mango agroecosystems. *Phytoparasitica* 26: 1–20.

PHDEB (2005) *Mango marketing strategy.* Pakistan Horticulture Development and Export Board: April 2005. http://www.phdeb.org.pk/MktStrategies/Mango.pdf. Accessed February 2011.

PHDEB (2007) *Information on insect pests of mangoes.* Pakistan Horticulture Development and Export Board: August 2007. http://www.phdeb.org.pk/sec_overview/mango.php. Accessed 27 April 2007.

Phillips AJL, Alves A (2009) Taxonomy, phylogeny, and epitypification of *Melanops tulasnei*, the type species of *Melanops*. *Fungal Diversity* 38: 155–166.

Phoulivong S, Cai L, Chen H, McKenzie EHC, Abdelsalam K, Chukeatirote E, Hyde KD (2010) *Colletotrichum gloeosporioides* is not a common pathogen on tropical fruits. *Fungal Diversity* 44: 33–43.

Pirozynski KA (1963) *Beltrania* and related genera. *Mycological Papers* 90: 1–37.

PIRSA (2009) *Plant quarantine standards: South Australia.* Primary Industry and Resources, South Australia. http://www.phylloxera.com.au/regulation/pdfs/PQS09_full_version.pdf. Accessed 22 July 2010.

Plan MRR, Joyce DC, Ogle HJ, Johnson GI (2002) Mango stem-end rot (*Botryosphaeria dothidea*) disease control by partial-pressure infiltration of fungicides. *Australian Journal of Experimental Agriculture* 42: 625–629.

Ploetz R, Zheng QI, Vazquez A, Abdel Sattar MA (2002) Current status and impact of mango malformation in Egypt. *International Journal of Pest Management* 48: 279–285.

Ploetz RC, Prakash O (1997) Foliar, floral and soilborne diseases. pp. 281–325. *In:* Litz, R. (eds.). The mango. CAB International, Wallington, Oxon, UK.

Ploetz RC, Zentmyer GA, Nishijima WT, Rohrbach KG, Ohr HD (1998) *Compendium of tropical fruit diseases.* The American Phytopathological Society Press, St. Paul, Minnesota.

Poon MOK, Hyde KD (1998) Evidence for the vertical distribution of saprophytic fungi on senescent *Phragmites australis* culms at Mai Po marshes, Hong Kong. *Botanica Marina* 41: 285–292.

Prakash O, Singh UN (1977) Phoma blight: a new disease of mango (*Mangifera indica*). *Plant Disease Reporter* 61: 419–421.

Punithalingam E (1993) *IMI descriptions of fungi and bacteria: Phomopsis mangiferae, sheet 1168.* International Mycological Institute, CAB International, Wallingford, UK.

Puttarudriah M, Eswaramurthy PK (1976) *Planococcoides* sp. nr. *robustus* a mango root mealybug and its control. *Current Research* 5: 205–207.

QDPI&F (2006) *Assessment of mango diseases, pest and production problems in Pakistan*: *workshop and mango orchard survey visit to Pakistan 27 March to 11 April 2006.* Queensland Department of Primary Industries and Fisheries.

Quraishi MA, Jamal SM (1970) Fungi on *Populus nigra* Linn cv. T[h]evestina in West Pakistan. *Pakistan Journal of Forestry* 23: 313–320.

Qureshi SA, Mohiuddin S (1982) Insect pests of mangoes recorded from Pakistan. *Proceedings of the Entomological Society*, *Karachi* 11–12: 19–22.

Rafiq M, Mirza JH, Shakir AS, Akhtar KP (1995) Post-harvest fungal diseases of potato in Faisalabad and their chemical control. *Pakistan Journal of Phytopathology* 7: 44–46.

Rahim A, Hashmi AA (1984) Biological control of *Pyrilla perpusilla* Walker in Sind, Pakistan. *International Pest Control* 26: 124–126.

Rajput MA, Pathan MA, Lodhi AM, Shah GS, Khanzada KA (2005) Studies on seed-borne fungi of wheat in Sindh Province and their effect on seed germination. *Pakistan Journal of Botany* 37: 181–185.

Rani BJ, Sindhar V (2002) Record of insect pests of Jatropha, *Jatropha curcas* Linn.: a medicinal and minor oil seed plant. *Insect Environment* 8: 76–77.

Rani BJ, Sridhar V (2004) Record of arthropod pests on velvet bean, *Mucuna pruriens* var. *utilis* under Bangalore conditions. *Journal of Medicinal and Aromatic Plant Sciences* 26: 505–506.

Rao AR, Naidu VG, Prasad PR (2002) Studies on the biology of cashew shoot and blossom webber (*Lamida moncusalis* Walker). *Indian Journal of Plant Protection* 30: 167–171.

Rasheed S, Mahmood R, Mohyuddin AI (1986) Notes on biology and population trends of *Sumnius renardi* Weise and *Rodolia fumida* Muls. (Coleoptera: Coccinellidae) and their potential as biocontrol agents of *Drosicha stebbingi* Green (Homoptera: Margarodidae). *Proceedings of Pakistan Congress of Zoology* 6: 137–142.

Reynaud P, Balmes V, Pizzol J (2008) *Thrips hawaiiensis* (Morgan, 1913) (Thysanoptera: Thripidae), an Asian pest thrips now established in Europe. *Bulletin OEPP/EPPO Bulletin* 38: 155–160.

Richardson MJ (1990) *An annotated list of seed-borne disease* 4th edn. Department of Agriculture and Fisheries for Scotland, East Craigs, Edinburgh.

Rizvi SA, Ahmad I, Azmi MA, Akhter K (2002) Diversity of *Oxyrhachis* spp. community feeding on leguminous plants in some localities of Karachi. *Proceedings of Pakistan Congress of Zoology* 22: 57–61.

Rizvi SA, Ahmad Z, Naz S (2004) Redescription of *Myllocerus dentifer* (Fabricius) (Coleoptera: Curculionidae), with reference to male and female genitalia from Pakistan. *International Journal of Biology and Biotechnology* 1: 503–506.

Rizwan-ul-Haq M, Sabri MA, Rashid A (2005) Toxicity of nicotinyl insecticides on the haemocytes of red cotton bug, *Dysdercus koenigii* (Fb.) (Pyrrhocoridae: Hemiptera). *Journal of Agriculture and Social Sciences* 1: 239–241.

Robinson GS, Ackery PR, Kitching IJ, Beccaloni GW, Hernández LM (2011) HOSTS - a Database of the World's Lepidopteran Hostplants. Natural History Museum, http://www.nhm.ac.uk/research-curation/research/projects/hostplants/. Accessed February 2011.

Rosenheim JA, Welter SC, Johnson MW, Mau RFL, Gusukuma-Minuto LR (1990) Direct feeding damage on cucumber by mixed-species infestations of *Thrips palmi* and *Frankliniella occidentalis* (Thysanoptera: Thripidae). *Journal of Economic Entomology* 83: 1519–1525.

Royse DJ, Ries SM (1978) The influence of fungi isolated from peach twigs on the pathogenicity of *Cytospora cincta*. *Phytopathology* 68: 603–607.

Saaiman WC, Smith Z (1997) Selective medium for isolating *Nattrassia mangiferae*. *Acta Horticulturae* 455: 587–594.

Saeed A, Saeed M, Yousef M (2000) New species and records of some crickets (Gryllinae: Gryllidae: Orthoptera) from Pakistan. *International Journal of Agriculture and Biology* 2: 175–182.

Saeed S, Masood A, Sajjad A, Zahid DM (2010) Monitoring the dispersal potential of the bark beetle, *Hypocryphalus mangiferae* Stebbing (Scolytidae: Coleoptera) in mango orchards. *Pakistan Journal of Zoology* 42(4): 473–479.

Sahu IK, Shaw SS (2005) Influence of tomato genotypes against *Caliothrips indicus* (Bagnall) with reference to biophysical parameters. *Journal of Soils and Crops* 15: 274–279.

Saleem A, Majeed K, Aslam M, Hamid K, Shahid M, Ali S (1993) New records of *Phytophthora* species causing stem/root rot in brinjal, lucerne and soybean in Pakistan. *Pakistan Journal of Phytopathology* 5: 131–132.

Sarwar M (2006) Occurrence of insect pests on guava (*Psidium guajava*) tree. *Pakistan Journal of Zoology* 38: 197–200.

Sattar A, Misbah ul Haq M, Salihah Z, Khatoon R (2008) Foraging activity of *Microtermes unicolour* Snyder and *Odontotermes lokanandri* Chatterjee and Thakur (Termitidae: Isoptera) in Peshawar, Pakistan. *Sunanaree Journal of Science and Technology* 15: 69–74.

Sawant NV, Raut SP (1994) Pathogenicity and chemical control of leaf blight of mango caused by *Drechslera halodes*: a new report. *Journal of Maharashtra Agricultural Universities* 19: 398–399.

Sen PC (1917) *Alcides frenatus*, a Coleopteran injurious to the mango tree in Bengal. *Bulletin of the Bureau of Agricultural Intelligence and Plant Diseases* 8: 315–316.

Shahid AS (1991) *Studies on fungus growing termites with hypogeal nesting system.* Ph. D. thesis, Department of Zoology, University of the Punjab, Lahore. http://prr.hec.gov.pk/Thesis/1438.pdf. Accessed 27 April 2007.

Shahina F, Musarrat AR (2006) Root-knot and reniform nematodes infecting some ornamental and medicinal plants in Pakistan. *Pakistan Journal of Nematology* 24: 45–48.

Shahzad S (2000) Anthracnose of betelvine in Pakistan. *Pakistan Journal of Botany* 32: 41–44.

Shanthi M, Rajavel DS, Baskaran RKM (2007) Severe incidence of *Rhipiphorothrips cruentatus* (Hood) on *Jatropha curcas* Linn. in Madurai, Tamil Nadu. *Insect Environment* 13: 127.

Shanthi S, Vittal BPR (2010a) Biodiversity of microfungi associated with leaf litter of *Pavetta indica*. *Mycosphere* 1: 23–27.

Shanthi S, Vittal BPR (2010b) Fungi associated with decomposing leaf litter of cashew (*Anacardium occidentale*). *Mycology* 1(2): 121–129.

Sharma IM, Badiyala SD (1991) Relative occurrence of sooty mould on mango varieties in Himachal Pradesh. *Plant Disease Research* 6: 71–74.

Siddique M, Aslam MM, Akhtar MA (1988) Bacterial leaf and stem blight of safflower in Pakistan. *Pakistan Journal of Agricultural Research* 9: 596–597.

Siddiqui MJI, Rana SA, Rana N, Sohail A (2005) Biodiversity of insects in high and low input wheat (*Triticum aestivum*) fields agroecosystems of Punjab. *Pakistan Enotomologist* 27: 25–28.

Sieber-Canavesi F, Sieber TN (1993) Successional patterns of fungal communities in needles of European silver fir (*Abies alba* Mill.). *New Phytologist* 125(1): 149–161.

Singh G (2000) Field resistance in mango varieties against shoot gall. *Acta Horticulturae* 509: 759–763.

Singh GP, Singh NN, Singh AK, Upadhyay RK (2006) Effect of sowing dates on occurrence of painted bug, *Bagrada hilaris* (Burmeister) in mustard. *Crop Research Hisar* 32: 116–117.

Singh LB, Singh SM, Nirvan RS (1961) Studies on mango malformation: i. review, symptoms, extent, intensity and cause. *Hort Advance* 5: 197–217.

Sinha P, Pal RK, Singh CP, Agarwal DK (2003) Storage rot of mango due to *Rhizoctonia bataticola*. *Annals of Plant Protection Sciences* 11: 329–332.

Sivanesan A (1990) *IMI descriptions of fungi and bacteria: Cochliobolus tuberculatus, sheet 1004.* International Mycological Institute, CAB International, Wallingford, UK.

Srivastava RP (1997) *Mango insect pest management* 1st edn. International Book Distributing Co., Lucknow, India.

Steenkamp E, Britz H, Coutinho T, Wingfield B, Marasas W, Wingfield M (2000) Molecular characterization of *Fusarium subglutinans* associated with mango malformation. *Molecular Plant Pathology* 1: 187–193.

Steyaert RL (1975) *IMI descriptions of fungi and bacteria: Ganoderma applanatum, sheet 443*. International Mycological Institute, CAB International, Wallingford, UK.

Stonehouse J, Mahmood R, Poswal A, Mumford J, Baloch KN, Chaudhary ZM, Makhdum AH, Mustafa G, Huggett D (2002) Farm field assessments of fruit flies (Diptera: Tephritidae) in Pakistan: distribution, damage and control. *Crop Protection* 21: 661–669.

Stonehouse JM, Mumford JD, Mustafa G (1998) Economic losses to tephritid fruit flies (Diptera: Tephritidae) in Pakistan. *Crop Protection* 17: 159–164.

Subramanian CV, Ramakhrishnan K (1956) *Ciliochorella* Syndow, *Plagionema* Subram. & Ramakr., and *Shanoria* gen. nov. *Transactions of the British Mycological Society* 39: 314–318.

Swailem SM (1974) On the seasonal occurrence of *Lepidosaphes tapleyi* Williams (Hemiptera-Homoptera: Diaspididae). *Bulletin de la Societe Entomologique d'Egypte* 57: 67–72.

Syed TS, Pathan HH, Abro GH (1995) Comparative efficacy of insecticides against *Scirtothrips dorsalis* Hood, *Earias* spp. and *Pectinophora gossypiella* (Saund.) on cotton. *Proceedings of Pakistan Congress of Zoology* 15: 159–169.

Tarigan M, Roux J, Van Wyk M, Tjahjono B, Wingfield MJ (2010) A new wilt and die-back disease of *Acacia mangium* associated with *Ceratocystis manginecans* and *C. acaciivora sp. nov.* in Indonesia. *South African Journal of Botany* (In Press) (doi: 10.1016/j.sajb.2010.08.006).

Tariq ZK (1991) *Pests on mango: telex from Zafarullah Khan Tariq*. Department of Plant Protection, Pakistan.

Tayyab M, Suhail A, Arshad S, Arshad M (2006) Biodiversity of lepidopterous insects in agro-forest area of Bahawalpur. *Pakistan Entomologist* 28: 5–9.

Tobih FO, Omoloye AA, Ivbijaro MF, Enobakhare DA (2002) Effects of field infestation by *Rastrococcus invadens* Williams (Hemiptera: Pseudococcidae) on the morphology and nutritional status of mango fruits, *Mangifera indica* L. *Crop Protection* 21: 757–761.

Tsuruta K, White I, Bandara HMJ, Rajapakse H, Sundaraperuma SAH, Hahawatta SBMUC, Rajapakse GBJP (1997) A preliminary note on the host-plants of fruit flies of the tribe Dacini (Diptera, Tephritidae) in Sri Lanka. *ESAKIA* 37: 149–160. http://www.lib.kyushu-u.ac.jp/esakia/es37/es370149.pdf. Accessed 27 April 2007.

Ujjan AA, Shahzad S (1997) Pathogenicity of *Metarhizium anisopliae* var. *acridum* strains on pink hibiscus mealy bug (*Maconellicoccus hirsutus*) affecting cotton crop. *Pakistan Journal of Botany* 39: 967–973.

USDA (2006) *Draft document: importation of fresh* Mangifera indica *(mango) fruit from India into the continental United States.* United States Department of Agriculture: Animal and Plant Health Inspection Service. http://www.aphis.usda.gov/newsroom/hot_issues/indian_mango/download/RMindmang.doc. Accessed 27 April.

van Wyk M, Adawi AOA, Khan IA, Deadman ML, Al Jahwari AA, Wingfield BD, Ploetz R, Wingfield MJ (2007) *Ceratocystis manginecans* sp. nov., causal agent of a destructive mango wilt disease in Oman and Pakistan. *Fungal Diversity* 27: 231–230.

Varatharajan R, Singh OD, Sen S (1992) On some flower thrips from Manipur. *Bulletin of Entomology (New Delhi)* 33: 68–73.

Varma A, Raychaudhuri SP, Lele VC, Ram A (1974) Preliminary investigations on epidemiology and control of mango malformation. *Proceedings of the Indian National Science Academy* 37: 291–300

Verghese A, Jayanthi PDK (1999) Lepidopteran pest complex on mango inflorescence. *Insect Environment* 5: 51–52.

Wadhero HB, Hussain T, Talpur MA, Rustamani MA, Qureshi KH (1998) Relative resistance of sesame varieties to whitefly and red pumpkin beetle. *Pakistan Entomologist* 20: 98–100.

Walker J, Tesoriero L, Pascoe I and Forsberg LI (1988) Basal rot of *Syngonium* cultivars and the first record of *Ceratocystis fimbriata* from Australia. *Australasian Plant Pathology* 17: 22–23.

Walker K (2008) Mango bark beetle *(Hypocryphalus mangiferae)* Pest and Diseases Image Library. http://www.padil.gov.au. Accessed February 2011.

Waller JM, Bigger M, Hillocks RJ (2007) *Coffee pests, diseases and their management*. CAB International, Wallingford, UK.

Wang TC (1985) A new species of *Formicococcus* Takahashi from China (Homoptera: Pseudococcidae). *Acta Entomologica Sinica* 28: 444–446.

Waterhouse DF (1993) *The major arthropod pests and weeds of agriculture in Southeast Asia.* ACIAR, Canberra.

Waterhouse DF (1998) Biological control of insect pests: Southeast Asian prospects. *ACIAR Monograph No. 51.* Australian Centre for International Agricultural Research, Canberra, Australia.

Watson AJ (1971) *Foreign bacterial and fungus diseases of food, forage, and fiber crops.* USDA Agricultural Research Service, Washington DC. Paper edition.

Watson GW (2007) *Arthropods of economic importance: diaspididae of the world.* World Diversity Database (Natural History Museum, London). http://ip30.eti.uva.nl/BIS/diaspididae.php?menuentry=inleiding. Accessed 27 April 2007.

Weems HV, Heppner JB, Nation JL, Fasulo TR (2004) *Oriental fruit fly, Bactrocera (= Dacus) dorsalis (Hendel) (Insecta: Diptera: Tephritidae).* University of Florida Featured Creatures. http://creatures.ifas.ufl.edu/fruit/tropical/oriental_fruit_fly.htm. Accessed 20 June 2006.

Wen HC (1989) The distribution and control of grapevine thrips (*Rhipiphorothrips cruentatus* Hood) on wax apple. *Journal of Agricultural Research of China* 38: 100–103.

White IM, Elson-Harris MM (1992) *Fruit flies of economic significance: their identification and bionomics.* CAB international, Wallingford, UK.

Williams DJ (1986) *Rastrococcus invadens* sp. n. (Hemiptera: Pseudococcidae) introduced from the Oriental Region to West Africa and causing damage to mango, citrus and other trees. *Bulletin of Entomological Research* 76: 695–699.

Williams DJ (2004) *Mealybugs of Southern Asia.* The Natural History Museum and Southdene, London and Kuala Lumpur.

Wood SL (1982) The bark beetles and ambrosia beetles of North and Central America (Coleoptera: Scolytidae), a taxonomic monograph. Brigham Young University, Provo, UT.

WTO (1995) *Agreement on the application of sanitary and phytosanitary measures.* World Trade Organisation. http://www.wto.org/english/tratop_e/sps_e/spsagr_e.htm. Accessed 27 April 2007.

Wu W, Sutton BC, Gange AC (1996) *Coleophoma fusiformis* sp. nov. from leaves of *Rhododendron*, with notes on the genus *Coleophoma*. *Mycological Research* 100(8): 943–947.

Youssef SA, Maymon M, Zvelbil A, Klein-Gueta D, Sztejnberg A, Shalaby AA, Freeman S (2007) Epidemiological aspects of mango malformation disease caused by *Fusarium mangiferae* and source of infection in seedlings cultivated in orchards in Egypt. *Plant Pathology* 56: 257–263.

Zaman M, Karimullah (1987) Lepidoptera of jute cultivars in Peshawar. *Pakistan Journal of Agricultural Research* 8: 290–297.

Zaman MK (1987) Relative abundance of yellow mite, *Polyphagotarsonemus latus* (Banks), on six cultivars of jute in Peshawar. *Pakistan Journal of Zoology* 19: 133–139.