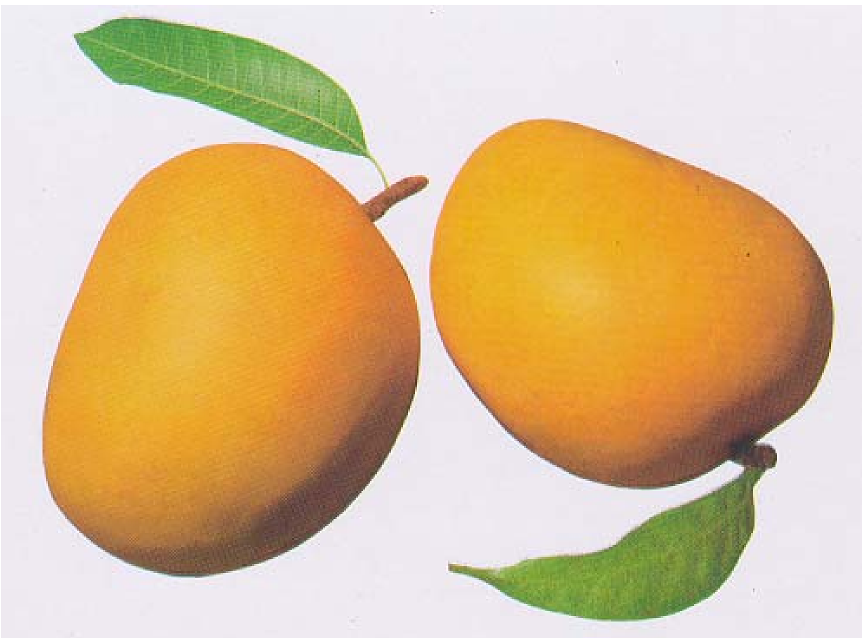
Australian Government

Biosecurity Australia

Policy for the Importation of Fresh Mangoes (*Mangifera indica* L.) from Taiwan



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GLOSSARY OF TERMS AND ABBREVIATIONS

Additional declaration	A statement that is required by an importing country to be entered on a phytosanitary certificate and which provides specific additional information pertinent to the phytosanitary condition of a consignment.
ALOP	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.
AQIS	Australian Quarantine and Inspection Service.
Area	An officially defined country, part of a country or all or parts of several countries.
BAPHIQ	Bureau of Animal Plant Health Inspection and Quarantine, Taiwan.
Biosecurity Australia	A prescribed agency within the Australian Government Department of Agriculture, Fisheries and Forestry. Biosecurity Australia provides science-based quarantine assessments and policy advice that protects Australia's favourable pest and disease status and enhances Australia's access to international animal and plant related markets.
BPI	Bureau of Plant Industry, Philippines.
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).
Control (of a pest)	Suppression, containment or eradication of a pest population.
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry.
DAWA	Department of Agriculture, Western Australia.
Endangered area	An area where ecological factors favour the establishment of a pest whose presence in the area will result in economically important loss.
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.
Establishment	Perpetuation, for the foreseeable future, of a pest within an area after entry.
Establishment potential	Likelihood of the establishment of a pest.
FAO	Food and Agriculture Organization of the United Nations.
Fresh	Living; not dried, deep-frozen or otherwise conserved.
Fruits and vegetables	A commodity class for fresh parts of plants intended for consumption or processing and not for planting.
Host	A species of plant capable, under natural conditions, of sustaining a specific pest.
ICON	AQIS Import Conditions database.
Import Permit	Official document authorising importation of a commodity in accordance with specified phytosanitary requirements.
Infestation (of a commodity)	Presence in a commodity of a living pest of the plant or plant product concerned. Infestation includes infection.
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.
Intended use	Declared purpose for which plants, plant products, or other regulated articles are imported, produced, or used.
Interception (of a pest)	The detection of a pest during inspection or testing of an imported consignment.
Introduction	The entry of a pest resulting in its establishment.
IPPC	International Plant Protection Convention, as deposited with FAO in Rome in 1951 and subsequently amended.
IRA	Import Risk Analysis, an administrative process through which quarantine policy is developed or reviewed, incorporating risk assessment, risk management and risk communication.
ISPM	International Standard for Phytosanitary Measures. An international standard adopted by the Conference of the Food and Agriculture Organisation, the Interim Commission on phytosanitary measures or the Commission on phytosanitary measures, established under

	the IPCC.
Lot	A number of units of a single commodity, identifiable by its homogeneity of composition, origin etc., forming part of a consignment.
National Plant Protection Organisation (NPPO)	Official service established by a government to discharge the functions specified by the IPPC. (DAFF is Australia's NPPO).
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.
Pathway	Any means that allows the entry or spread of a pest.
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products.
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.
Pest Free Area (PFA)	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.
Pest Risk Analysis (PRA)	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.
Pest risk analysis area	Area in relation to which a pest risk analysis is conducted.
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences.
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest.
Phytosanitary Certificate	Certificate patterned after the model certificates of the IPPC.
Phytosanitary measure	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.
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.
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.
Regulated article	Any plant, plant product, storage place, packing, 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.
Restricted risk	'Restricted' risk estimates apply to situations where risk management measures are used
Spread	Expansion of the geographical distribution of a pest within an area.
SPS Agreement	WTO Agreement on the Application of Sanitary and Phytosanitary Measures.
Stakeholders	Government agencies, individuals, community or industry groups or organisations, whether in Australia or overseas, including the proponent/applicant for a specific proposal
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 phytosanitary protection.
Unrestricted risk	'Unrestricted' risk estimates apply in the absence of risk management measures.
VHT	Vapour heat treatment
WTO	World Trade Organization

EXECUTIVE SUMMARY

Australia initiated a pest risk analysis for the importation of fresh mangoes from Taiwan in October 2005, following a request for market access from Taiwan's Bureau of Animal and Plant Health, Inspection and Quarantine (BAPHIQ) in June 2003.

Subject to a range of risk management measures and phytosanitary procedures, Australia currently permits the importation of mango fruit (*Mangifera indica* L.) from the Republic of the Philippines (Guimaras Island only), Mexico and Haiti.

A preliminary assessment by Biosecurity Australia of the pests potentially associated with mangoes from Taiwan indicated that the pests do not pose significantly different quarantine risks, or require significantly different management measures, than those for which policy exists. In view of this Biosecurity Australia considered this access request as a review and extension of existing import policy.

This final policy report recommends that fresh mangoes from Taiwan be allowed entry into Australia subject to the imposition of phytosanitary measures for two fruit flies and four mealybugs:

- *Bactrocera cucurbitae* (Coquillett, 1899) [Diptera: Tephrididae] - melon fruit fly
- *Bactrocera dorsalis* (Hendel, 1912) [Diptera: Tephrididae] - Oriental fruit fly
- *Planococcus lilacinus* (Cockerell, 1905) [Hemiptera: Pseudococcidae] - coffee mealybug
- *Pseudococcus cryptus* Hempel [Hemiptera: Pseudococcidae] - citriculus mealybug
- *Pseudococcus jackbeardsleyi* Gimpel & Miller [Hemiptera: Pseudococcidae] - Jack Beardsley mealybug
- *Rastrococcus spinosus* (Robinson, 1918) [Hemiptera: Pseudococcidae] - Philippine mango mealybug

The following risk management measures will be implemented in addition to Taiwan's standard commercial production practices:

- pre-export vapour heat treatment (VHT) for the management of fruit flies;
- inspection and remedial action for mealybugs;
- operational systems for the maintenance and verification of the phytosanitary status of mangoes from Taiwan including;
- registration of export orchards;
- registration of packing houses and auditing of procedures;
- packaging and labelling requirements;
- specific conditions for storage and movement;
- phytosanitary certification by Taiwanese quarantine authorities; and

- on-arrival quarantine clearance by Australian quarantine authorities.

These measures will ensure that the risk associated with the importation of mangoes from Taiwan meets Australia's appropriate level of protection (ALOP). This policy has been determined following consideration of stakeholder comments to the *Draft extension of policy for the importation of fresh mangoes (Mangifera indica L.) from Taiwan* (DAFF 2005).

INTRODUCTION

Biosecurity Australia is a prescribed agency within the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF). Biosecurity Australia is responsible for developing international quarantine policy for imports and for liaising with overseas National Plant Protection Organisations (NPPOs) to determine their requirements for exports of Australian plants and plant products.

In June 2003, the Taiwan Bureau of Animal and Plant Health, Inspection and Quarantine (BAPHIQ) requested market access for mangoes (*Mangifera indica* L.) into Australia. Quarantine policy currently exists for the importation into Australia of fresh mangoes from the Republic of the Philippines (Guimaras Island), Mexico and Haiti. In addition, a *Mangoes from India Draft Revised Import Policy* (DAFF 2004) was released for stakeholder comment on 2 July 2004.

After a preliminary assessment of the pests associated with mangoes from Taiwan it was evident that these pests did not pose significantly different quarantine risks, or require significantly different management measures, than those for which policy already exists. Biosecurity Australia therefore determined that the market access request for mangoes from Taiwan could be progressed as an extension of existing import policy.

This policy report is based on import policy for mango fruit from the Republic of the Philippines (Guimaras Island), detailed in the import risk analysis (IRA) (AQIS 1998; AQIS 1999) and the *Mangoes from India Draft Revised Import Policy (*DAFF 2004). This policy also takes into consideration stakeholders' submissions on the *Draft extension of policy for the importation of fresh mangoes (Mangifera indica L.) from Taiwan* (DAFF 2005).

As the initial step in the pest risk analysis (PRA) process, Biosecurity Australia identified and categorised pests associated with mangoes from Taiwan to identify the quarantine pests for Australia. Detailed risk assessments of these 18 arthropods and one fungal pathogen were conducted using the likelihood of entry, establishment or spread and associated consequences to determine an unrestricted risk estimate for each species.

The phytosanitary risk management measures were then identified for each quarantine pest that did not meet the appropriate level of protection (ALOP) for Australia. These recommended risk management measures form the basis for the recommendations of final import conditions.

This report contains the following:

- background to this review and extension of policy and Australia's current quarantine policy for the importation of fresh mangoes;

- methodology and results of pest categorisation and risk assessment;
- recommended risk management measures; and
- final import conditions.

PROPOSAL TO IMPORT MANGOES FROM TAIWAN

Background

Mangoes from Taiwan

In February and June 2003, BAPHIQ requested market access for mangoes into Australia. Biosecurity Australia requested a complete list of pests and diseases associated with the commodity, industry and production information, and proposed management options for quarantine pests. In June 2003, BAPHIQ provided a copy of the document '*Vapour Heat Treatment for Elimination of <u>Dacus dorsalis</u> and <u>Dacus cucurbitae</u> Infested in Mango Fruits Var. Haden*' (Kuo *et al*. 1989) in support of a treatment for fruit flies. In July 2004, BAPHIQ provided a copy of the document '*Production and Cultivation of Litchi, Carambola and Mango in Taiwan*' (BAPHIQ 2004) containing information on mango cultivars and production, and a list of pests and diseases of mangoes in Taiwan. In response to a request by Biosecurity Australia, BAPHIQ provided additional scientific literature references in August 2004.

Following a preliminary comparison of the pest lists, Biosecurity Australia determined that the quarantine risks of pests and diseases associated with mangoes from Taiwan were similar to those covered by the existing policy. The Biosecurity Australia Policy Memorandum (BAPM) 2005/14 released on 28 October 2005 notified stakeholders that Biosecurity Australia was considering an import proposal for fresh mango fruit from Taiwan as an extension of existing import policy. A BAPM 2005/21 released the draft extension of existing policy for public comment period of 60 days on the 20 December 2005.

Scope of the review and extension of policy

Biosecurity Australia has considered the quarantine risks associated with the importation of fresh mango fruit from Taiwan for the quarantine pests identified in the PRA section of this extension of policy, in accordance with *ISPM No. 11: Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms* (FAO 2004).

The PRA forms the basis for development of import policy for the entry of fresh mango fruit that have been cultivated, harvested, packed and transported under standard, commercial and agronomic conditions from Taiwan into Australia.

The import policy developed for mangoes from Taiwan is applicable to any cultivar of mango from Taiwan.

Australia's current quarantine policy for fresh mango fruit

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

International policy

Australia currently has import policy for fresh mangoes from the Republic of Philippines (Guimaras Island), Mexico and Haiti.

Details of the importation requirements for fresh mango fruit from the Republic of Philippines (Guimaras Island), Mexico and Haiti are available on the AQIS Import Condition database (ICON) at http://www.aqis.gov.au/icon. In addition to general requirements, specific import conditions are mandated for each country. All imported consignments of mangoes are subject to condition C6000 '*General import requirements for all fruits and vegetables*'. Condition C6000 requirements include an AQIS import permit, a quarantine entry, a Phytosanitary Certificate, use of appropriate packing materials, freedom from regulated articles, and on-arrival inspection and treatment by AQIS.

The specific import conditions for the Republic of Philippines (Guimaras Island) are relevant to this review and extension of existing policy and are summarised below.

The Republic of the Philippines (Guimaras Island)

A Specific Commodity Understanding (SCU) with the Republic of the Philippines (Guimaras Island) for the importation of mangoes was signed in 1993 by representatives of AQIS and the Bureau of Plant Industry (BPI), the Philippines. The SCU was amended in 1999 (AQIS 1999) and again in March 2000.

The SCU specifies that fresh mango fruit imported from the Philippines (Guimaras Island) must be produced on Guimaras Island only and subject to VHT treatment for fruit flies. Guimaras Island is considered to be free of the quarantine pests mango seed weevil and mango pulp weevil based on surveys and monitoring.

State quarantine regulations currently prohibit the entry of Philippine mangoes into the state of Western Australia.

The following ICON conditions apply:

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

Condition C9212 – Conditions relating to the Specific Commodity Understanding between the AQIS and the BPI.

THE FRESH MANGO INDUSTRY

The mango industry in Australia

Production

Mangoes are grown mainly in tropical and subtropical regions of Australia. The State of Queensland produced over 75% of Australia's total crop in 2003 and 65% of Australia's total crop in 2006 (Cirillo 2001; ABS 2004; Plant Health Australia 2006). Most of the Queensland crop is produced around Bowen, Home Hill, Ayr and the Atherton Tableland (near Mareeba) (Kernot *et al*. 1998). The Bowen region and the Atherton Tableland dominate the industry in planted area and current production (Kernot *et al*. 1998).

Mangoes are also grown in the Northern Territory, which produced approximately 16% of the national crop in 2004 and in 2006 produced approximately 27% of the national crop (ABS 2004; Plant Health Australia, 2006). Smaller production areas occur in Western Australia and along the northern coast of New South Wales (Cirillo 2001; ABS 2004).

The four main cultivars of mango grown in Australia are Kensington Pride (commonly known as Bowen Special), R2E2, Keitt and Palmer (Cirillo 2001). Kensington Pride is the most important cultivar in Australia (Mukherjee 1997), and accounts for almost 80% of production in Queensland (Kernot *et al*. 1998). In addition, relatively small numbers of fruit are produced from other cultivars, such as Kent and Nam Doc Mai (Kernot *et al*. 1998). These are grown in north Queensland, the Northern Territory and Western Australia. Two other cultivars (Brooks and Haden) are grown in Australia on a small scale. Haden makes up less than 2% of mango trees in Australia, and is mainly grown in the Kununurra district in Western Australia (Bally 2004). About 50% of new plantings in Queensland in the mid 1990s consisted of newer cultivars such as Keitt, R2E2, Palmer and Nam Doc Mai (Holmes 1997).

Because of the wide geographical distribution of growing regions, and the use of early and late-maturing cultivars, Australia is able to harvest mangoes for seven months of the year, from October to April (Kernot *et al*. 1998; Cirillo 2001). However, about 50% of Australian production occurs in December (Cirillo 2001). Kensington Pride is harvested from October to January, the R2E2 cultivar is harvested from December to January, and Keitt and Palmer cultivars are harvested from January to late March (Cirillo 2001).

Australian production is expected to increase as a result of current industry development and the significant plantings of mangoes over the last decade. Fluctuations in mango production occur between years because of irregular flowering (Australian Horticulture 1995). Annual mango production in Australia averaged 38,627 tonnes between the 2000 and 2004 seasons (ABS 2004). Australian mango production figures are presented in Table 1.

Table 1 Australia's mango production (tonnes) for 1999–2004

Season	NSW	NT	QLD	WA	TOTAL
1999–2000	–	5 244	30 770	1 922	37936
2000–01	386	6 718	28 233	2 060	37 398
2001-02	259	6 071	32 361	2 281	40 973
2002-03	260	6 704	29 300	2 706	38 970
2003-04	433	6 027	28 516	2 192	37 168

Source: Australian Bureau of Statistics (2000, 2002, 2003, 2004)

Export of mangoes from Australia

Quantities of mangoes for export have steadily increased since 1999, from 2700 tonnes in 1999 to 3600 tonnes in 2001 (Collins *et al*. 2004). The major export markets for Australian mangoes are Singapore and Hong Kong, each of which imported over 1000 tonnes in 2002-03 (Collins *et al*. 2004). Mangoes are also exported to Japan, the United Arab Emirates, Saudi Arabia, Malaysia, France, Lebanon, Qatar, Oman, New Zealand and other smaller markets. Australia gained access for mangoes to the People's Republic of China in 2004; no exports have taken place to date.

Mango industry in Taiwan

Cultivars

Mangoes have been grown in Taiwan for over four hundred years (BAPHIQ 2004). Commercial cultivation of mangoes in Taiwan centres on the production of six cultivars:

(1) *Ts Xine* – Fruit of this cultivar possesses fruit with green peel, orange-yellow pulp and a large seed. Fruit are small and kidney-shaped, with an average weight of approximately 160 grams. The fruit is fibrous, but it has a good flavour and is suitable for eating or juicing (BAPHIQ 2004).

(2) *Irwin* – Fruit of this cultivar are elongate, egg-shaped, and have thin, red skin. They weigh on average 326 grams, and the pulp has few fibres (BAPHIQ 2004).

(3) *Jin Hwang* –These fruit are the largest of the six cultivars, and weigh an average of 1200 grams. They are elongate and oval in shape, and have a thin, flat seed which constitutes approximately 5% of the fruit's total weight. The skin and pulp are orange-yellow in colour (BAPHIQ 2004).

(4) *Haden* – This cultivar originated in Florida, USA (Bally 2004), and the fruit are egg-shaped, and weigh on average 325 grams. The skin is thick, and red on the outside and yellow on the inside (Bally 2004). The pulp has few fibres, and ripens from June to July (BAPHIQ 2004).

(5) *Keitt* – Fruit of this cultivar are medium-sized, weighing on average 679 grams. Fruit are egg-shaped, with thick pulp and either green or pale-red skin. It is fibrous only around the seed and ripens from August to October (BAPHIQ 2004).

(6) *Tainoung No. 1* – The fruit of this cultivar is egg-shaped and pointed at one end. The average weight is 221 grams and the fruit has yellow skin. The pulp is orange-yellow and strongly-flavoured, and it has a delicate texture and contains few fibres. The fruit can withstand storage for long periods, and it ripens from May to June (BAPHIQ 2004).

Production

Southern Taiwan produces approximately 210,000 tonnes of mangoes per annum, from plantings covering over 20,000 hectares (BAPHIQ 2004). Mango production in Taiwan occurs predominantly in the counties of Tainan and Pingtung, which produced 84% of the total crop in 2002 (BAPHIQ 2004). Details of mango production areas and yields for 2002 are given in Table 2 and the counties shown in Figure 1.

Table 2: Mango production areas and yield in Taiwan in 2002 (BAPHIQ 2004)

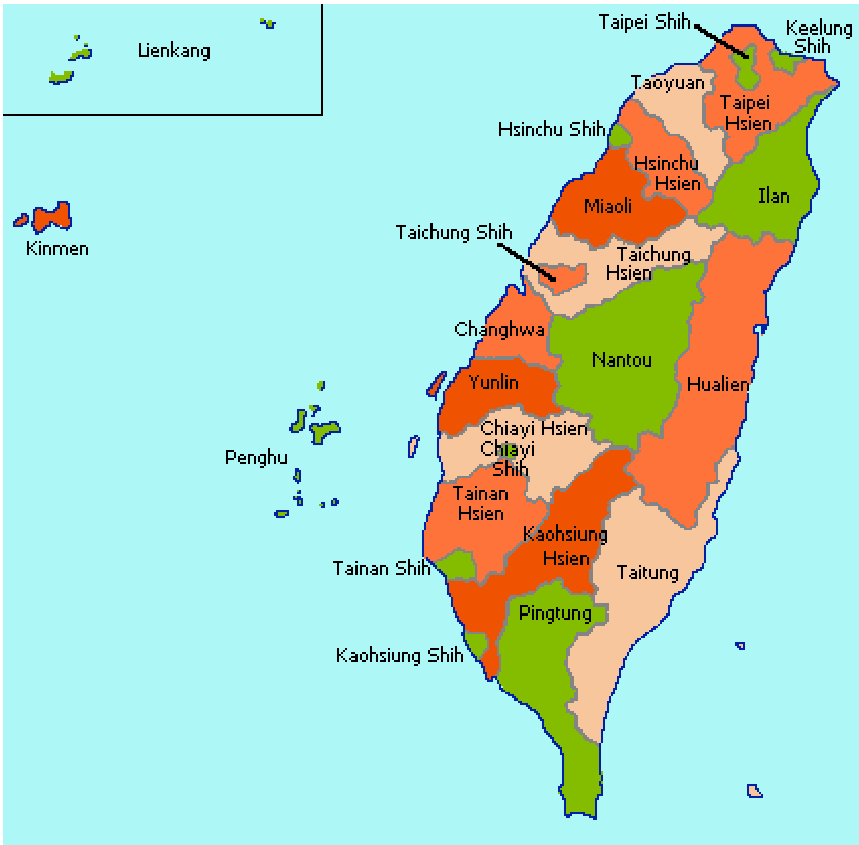
County	Production area (ha)	Yield (tonnes)
Tainan	8 084	94 290
Pingtung	8 079	84 963
Kouhsiung	2 330	20 703
Chiayi	342	5 542
Taitung	269	3 046
Taichung	108	1 083
Changhwa	96	889
Others	482	2 850
Total	**19 790**	**213 366**

The Taiwanese mango industry has been developing for several decades, and production period and cultivation techniques have been significantly improved (COA 2005). Mangoes are supplied to domestic and foreign markets from May to November (COA 2005).

Export of mangoes from Taiwan

Mangoes from Taiwan are exported to Hong Kong, Singapore, mainland China, Japan (COA 2005) and New Zealand (MAF 2004). Mangoes account for 12.5% of total fruit exports from Taiwan (Wu 2004).

Figure 1: Map of administrative divisions of Taiwan showing the principal mango production counties of Tainan and Pingtung and other production areas



Source: **http://www.world-gazetteer.com**

METHOD FOR PEST RISK ANALYSIS

An outline of the methodology used for PRA is given to provide the context for the technical information that is provided later in this report. In accordance with the *International Standards for Phytosanitary Measures No. 11: Pest Risk Analysis for Quarantine Pests including Analysis of Environmental Risks and Living Modified Organisms* (ISPM 11) (FAO 2004), this pest risk analysis comprises three discrete stages:

- Stage 1: initiation
- Stage 2: pest risk assessment
- Stage 3: pest risk management

Stage 1: Initiation

The aim of the initiation stage is to identify the pest(s) and pathway(s) (e.g. commodity imports) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

Stage 2: Pest Risk Assessment

The pest risk assessment is carried out in accordance with International Plant Protection Convention (IPPC) standards and reported in the following steps:

- pest categorisation;
- assessment of probability of entry, establishment or spread; and
- assessment of potential consequences (including environmental impacts).

Pest categorisation

Pest categorisation is a process to examine, for each pest, whether the criteria for a quarantine pest are satisfied. The process of pest categorisation is summarised by the IPPC in the five elements outlined below:

- identity of the pest;
- presence or absence in the endangered area;
- regulatory status;
- potential for establishment and spread in the PRA area; and
- potential for economic consequences in the endangered area.

The pests are categorised according to their presence or absence, their association with the commodity pathway, their potential to establish or spread, and their potential for economic consequences. Categorisation for potential of establishment and spread and potential for economic consequences was expressed using the terms ‘feasible’ / ‘not feasible’, and ‘significant’ / ‘not significant’, respectively.

Pests found to have potential for entry; establishment or spread and potential for economic consequences satisfy the criteria for a quarantine pest. A quarantine pest is defined as "*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 2002). The methodology used for the detailed risk assessments conducted on the quarantine pests is given below.

Assessment of the probability of entry, establishment or spread

Details of assessing the ‘probability of entry’, ‘probability of establishment’ and ‘probability of spread’ of a pest are given in *ISPM 11* (FAO 2004).

Assessing the probability of entry requires an analysis of each of the pathways with which a pest may be associated, from its origin to distribution in the PRA area. The probability of entry may be divided for assessment purposes into the following components:

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

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

In breaking down the probability of entry into these two components, Biosecurity Australia has not altered the original meaning. The two components have been identified and separated to enable onshore and offshore pathways to be described individually.

The probability of establishment is estimated on the basis of availability, quantity and distribution of hosts in the PRA area; environmental suitability in the PRA area; potential for adaptation of the pest; reproductive strategy of the pest; method of pest survival; and cultural practices and control measures. Similarly, the probability of spread is estimated on the basis of suitability of the natural and/or managed environment for natural spread of the pest; presence of natural barriers; the potential for movement with commodities or conveyances; intended use of the commodity; potential vectors of the pest in the PRA area; and potential natural enemies of the pest in the PRA area.

Qualitative likelihoods are assigned to the probability of entry (comprising an importation step and a distribution step), the probability of establishment and the probability of spread. Likelihoods are categorised according to a descriptive scale from ‘high’ to ‘negligible’ as shown in Table 3.

Table 3: Nomenclature for qualitative likelihoods

Likelihood	Descriptive definition
High	The event would be very likely to occur
Moderate	The event would occur with an even probability
Low	The event would be unlikely to occur
Very low	The event would be very unlikely to occur
Extremely low	The event would be extremely unlikely to occur
Negligible	The event would almost certainly not occur

The likelihoods of entry, of establishment and of spread are combined using the tabular matrix shown in Table 4.

Table 4: Matrix of rules for combining descriptive likelihoods

	High	Moderate	Low	V. Low	E. Low	Negligible
High	High	Moderate	Low	V. Low	E. Low	Negligible
Moderate		Low	Low	V. Low	E. Low	Negligible
Low			V. Low	V. Low	E. Low	Negligible
Very low				E. Low	E. Low	Negligible
E. low					Negligible	Negligible
Negligible						Negligible

Assessment of consequences

The basic requirements for the assessment of consequences are described in the *SPS Agreement*, in particular Article 5.3 and Annex A. Further detail on assessing consequences is given in the "*potential economic consequences*" section of *ISPM 11*. This ISPM separates the consequences into "direct" and "indirect" and provides examples of factors to consider within each. In this PRA, the term "consequence" is used to reflect the "relevant economic factors"/"associated potential biological and economic consequences" and "potential economic consequences" terms as used in the *SPS Agreement* and *ISPM 11*, respectively.

The direct and indirect consequences were estimated based on four geographic levels. The terms 'local', 'district', 'regional' and 'national' are defined as:

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

District: a geographically or geopolitically associated collection of aggregates — generally a recognised section of a state, such as the 'North West Slopes and Plains' or 'Far North Queensland'

Region: a geographically or geopolitically associated collection of districts — generally a state, although there may be exceptions with larger states such as Western Australia

National: Australia-wide

The consequence was described as:

- *'unlikely to be discernible'* is not usually distinguishable from normal day-to-day variation in the criterion;
- *'minor significance'* is not expected to threaten economic viability, but would lead to a minor increase in mortality/morbidity or a minor decrease in production. For non-commercial factors, the consequence is not expected to threaten the intrinsic 'value' of the criterion — though the value of the criterion would be considered as 'disturbed'. Effects would generally be reversible.
- *'significant'* consequence would threaten economic viability through a moderate increase in mortality/morbidity, or a moderate decrease in production. For non-commercial factors, the intrinsic 'value' of the criterion would be considered as significantly diminished or threatened. Effects may not be reversible; and
- *'highly significant'* would threaten economic viability through a large increase in mortality/morbidity, or a large decrease in production. For non-commercial factors, the intrinsic 'value' of the criterion would be considered as severely or irreversibly damaged.

The values are translated into a qualitative score (A–F) using the schema outlined in Table 5.

Table 5: The assessment of local, district, regional and national consequences

Impact score	Local	District	Regional	National
F	-	-	-	Highly significant
E	-	-	Highly significant	Significant
D	-	Highly significant	Significant	Minor
C	Highly significant	Significant	Minor	Unlikely to be discernible
B	Significant	Minor	Unlikely to be discernible	Unlikely to be discernible
A	Minor	Unlikely to be discernible	Unlikely to be discernible	Unlikely to be discernible

Level

The overall consequence for each pest was achieved by combining the qualitative scores (A–F) for each direct and indirect consequence using a series of decision rules. These rules are mutually exclusive, and are addressed in the order that they appeared in the list — for example, if the first rule does not apply, the second rule is considered. If the second rule does not apply, the third rule is considered and so on until one of the rules applies:

- Where the impact score of a pest with respect to any direct or indirect criterion is 'F', the overall consequences are considered to be 'extreme'.
- Where the impact scores of a pest with respect to more than one criterion are 'E', the overall consequences are considered to be 'extreme'.

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

Method for determining the unrestricted risk estimate

The unrestricted risk estimate for each pest is determined by combining the likelihood estimates of entry, of establishment and of spread with the overall potential consequences. This is done using the risk estimation matrix shown in Table 6. The cells of this matrix describe the product of likelihood of entry, establishment or spread and consequences of entry, establishment or spread.

Table 6: Risk estimation matrix

Likelihood of entry, establishment or spread	Negligible impact	Very low	Low	Moderate	High	Extreme impact
High likelihood	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 likelihood	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Consequences of entry, establishment or spread

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 6 marked 'very low risk' represents Australia's ALOP.

Stage 3: Pest Risk Management

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

To implement risk management appropriately, it is necessary to formalise the difference between 'unrestricted' and 'restricted' risk estimates. Unrestricted risk estimates are those derived in the absence of specific risk management measures, or following only baseline risk management procedures based on commercial production practices. By contrast, restricted or mitigated risk estimates are those derived when 'risk management' is applied.

The conclusions from pest risk assessment are used to decide whether risk management is required and if so, the strength of measures to be used. Where the unrestricted risk estimate does not maintain Australia's ALOP, risk management measures are required to reduce this risk to a very low level. Since zero-risk is not a reasonable option, the guiding principle for risk management is to manage risk to achieve the required degree of safety that can be justified and is feasible within the limits of available options and resources.

ISPM 11 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 the introduction 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* – e.g. if no satisfactory measure can be found.

Risk management measures were identified for each pest that does not meet the ALOP as required and are presented in the Pest Risk Management section of this report. The pests that do not meet the ALOP require the use of risk management measures in addition to the standard commercial practices. The recommended phytosanitary regulations based on these measures are presented in the Final Import Conditions section of this report.

PEST RISK ANALYSIS

Stage 1: Initiation

Initiation of this PRA followed a market access request for mangoes (*Mangifera indica* L.) from Taiwan into Australia received from BAPHIQ in February and June 2003. This request constitutes a new pathway for potential quarantine pests. The pathway in this PRA is considered to be fresh mango fruit for human consumption from commercial export orchards in Taiwan.

The 'PRA area' is defined as Australia for the pests that do not occur in Australia or in the case of regional quarantine pests, the 'PRA area' is defined as the area of Australia that has regional freedom from the pest. The 'endangered area' is defined as area within Australia, where ecological factors favour the establishment of a pest that might be introduced in association with mangoes from Taiwan and whose presence in the area will result in economically important loss.

A list of pests likely to be associated with mangoes from Taiwan (i.e. the biosecurity risk pathway) was generated from information supplied by BAPHIQ, literature and database searches. This list was used in this PRA.

Stage 2: Pest Risk Assessment

Pest categorisation

The quarantine pests of mangoes from Taiwan have been determined through a comparison of the pests recorded on mangoes in Taiwan, and those recorded in the previous assessments of mangoes from the Republic of the Philippines (Guimaras Island) and India (draft) (AQIS 1999; DAFF 2004) and those known to occur in Australia. Pests were first categorised according to their presence or absence in Australia and presence on the fresh fruit pathway under consideration (Appendix 1) and secondly on their potential for establishment and spread in the PRA area and associated potential for consequences (Appendix 2). Pests that did not meet the definition of a quarantine pest were not considered further in the PRA process.

Nineteen quarantine pests, determined through the pest categorisation process, are listed in Table 7. These pests require detailed risk assessment as they meet the IPPC criteria for a quarantine pest, specifically:

- the pest is known to be associated with mangoes in Taiwan;
- the pest is absent from Australia, or has a limited distribution and is under official control;

- the pest has the potential for being on the pathway of fresh mango fruit;
- the pest has the potential for establishment and spread in the PRA area; and
- the pest has the potential for consequences.

Table 7: Quarantine pests of mangoes from Taiwan (species in bold text have not been previously assessed in AQIS (1999) or DAFF (2004))

Pest Type	Common name
ARTHROPODS	
Diptera (fruit flies)	
Bactrocera dorsalis (Hendel, 1912) [Diptera: Tephrididae]	Oriental fruit fly
Bactrocera cucurbitae (Coquillett, 1899) [Diptera: Tephrididae]	melon fruit fly
***Bactrocera latifrons* (Hendel, 1915) [Diptera: Tephrididae]**	**solanum fruit fly**
Bactrocera tau (Walker) [Diptera: Tephrididae]	pumpkin fruit fly
Hemiptera (armoured scales, soft scales, mealybugs, aphids)	
**Abgrallaspis cyanophylli* (Signoret, 1869) [Hemiptera: Diaspididae]	cyanophyllum scale
***Aonidomytilus albus* (Cockerell) [Hemiptera: Diaspididae]**	**tapioca scale**
***Lepidosaphes laterochitinosa* (Green) [Hemiptera: Diaspididae]**	**armoured scale**
**Milviscutulus mangiferae* (Green, 1889) [Hemiptera: Coccididae]	mango shield scale
***Parlatoria pseudaspidiotus* (Lindinger 1905) [Hemiptera: Diaspididae]**	**vanda orchid scale**
Planococcus lilacinus (Cockerell, 1905) [Hemiptera: Pseudococcidae]	coffee mealybug
Protopulvinaria pyriformis (Cockerell) [Hemiptera: Coccidae]	pyriform scale
***Pseudococcus cryptus* (Hempel) [Hemiptera: Pseudococcidae]**	**citriculus mealybug**
***Pseudococcus jackbeardsleyi* Gimpel & Miller [Hemiptera: Pseudococcidae]**	**Jack Beardsley mealybug**
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	Philippine mango mealybug
***Toxoptera odinae* (van der Goot, 1917) [Hemiptera: Aphididae]**	**mango aphid**
***Unaspis acuminata* (Green) [Hemiptera: Diaspididae]**	**unaspis scale**
Lepidoptera (lymantrid moth)	
Orgyia australis postica (Walker) [Lepidoptera: Lymantidae]	cocoa tussock moth
Thysanoptera (thrips)	
Rhipiphorothrips cruentatus Hood, 1919 [Thysanoptera: Thripidae]	mango thrips
PATHOGENS	
Fungi	
**Elsinoë mangiferae* Bitancourt & Jenkins [Myriangiales; Elsinoaceae]	mango scab

*Western Australia only – this species is a quarantine pest for the State of Western Australia due to its absence.

Risk assessments for quarantine pests

Detailed risk assessments are presented in this PRA for the quarantine pests identified in the pest categorisation stage. Risk assessments were based on groups of pests (e.g. scales) where the pest species share similar biological characteristics, behaviour on the host and pathway and potential phytosanitary considerations. Individual risk assessments are presented for four species of fruit flies, mango aphid, cocoa tussock moth, mango thrips and mango scab. Risk assessments for groups of pests are presented for armoured scales (5 species), soft scales (2 species) and mealybugs (4 species).

Each risk assessment involved the 'assessment of the probability of entry, establishment or spread' and 'assessment of consequences' as described in the Method for Pest Risk Analysis. The unrestricted risk posed by each quarantine pest was estimated by combining the probabilities of entry, of establishment and of spread with the estimate of associated potential consequences. The unrestricted risk estimates were then compared with Australia's ALOP to determine which quarantine pests presented an unacceptable level of risk and required risk mitigation options.

Probability estimates of importation, distribution, establishment, spread and potential consequences are supported by relevant biological information. Detailed information on each quarantine pest within each group is provided in the data sheets in Appendix 3.

The risk assessments assumed standard cultivation, harvesting and packing activities in the commercial production of mangoes (e.g. in-field hygiene and management of pests, cleaning and hygiene during packing, and commercial quality control activities) in Taiwan.

Arthropod Pests

Oriental fruit fly

The fruit fly [Diptera: Tephritidae] examined in this pest risk analysis is:

- *Bactrocera dorsalis* (Hendel, 1912) – Oriental fruit fly

<u>Introduction and spread potential</u>

Probability of importation

The likelihood that *B. dorsalis* will arrive in Australia with the importation of fresh mangoes from Taiwan: **High**.

- *B. dorsalis* infests mango fruit in the entire Asian-Pacific region (Srivastava 1997). Oviposition by *B. dorsalis* causes an inconspicuous puncture because its colour blends with the colour of dark green fruit (Srivastava 1997), although it may be visible in some yellow and pale brown mango varieties. Some necrosis around the puncture mark following oviposition causes decomposition of the fruit that appears as black or brown lesions. Premature fruit drop from trees can occur (CAB International 2005).

- Eggs are deposited beneath the skin of the fruit (CAB International 2005) and larvae feed within the fruit for a few days after hatching. This location makes them difficult to detect pre-emergence.
- The major means of movement and dispersal are transportation of infected fruit and adult flight (Fletcher 1989). Infested fruit are unlikely to be detected during sorting, packing and quality inspection procedures in terms of blemishes, bruising or damage to the skin. The procedures are not specifically directed at the detection of pests.
- Cleaning procedures are undertaken within the packhouse including routine washing, however surface washing would not remove eggs or larvae present within the fruit.

Probability of distribution

The likelihood that *B. dorsalis* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **High**.

- It is likely that different life stages of *B. dorsalis* would survive storage and transportation because eggs can tolerate cold storage temperatures and adults tolerate temperatures as low as 2 ^{o}C (EPPO 2005).
- Fruit infested with undetected eggs and larvae are likely to be distributed throughout Australia for retail sale. Waste from such fruit provides a source of infestation to suitable hosts. *Bactrocera dorsalis* has a wide host range (Allwood *et al*. 1999).

Probability of entry (importation × distribution)

The likelihood that *B. dorsalis* will enter Australia as a result of trade in fresh mangoes from Taiwan and be distributed in a viable state to the endangered area: **High**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *B. dorsalis* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- Incursions of exotic fruit fly species of the *B. dorsalis* complex have previously occurred and subsequently been eradicated. *Bactrocera papayae* was detected near Cairns, northern Queensland in 1995. It was eradicated using a program of male annihilation and protein bait spraying (Cantrell *et al*. 2002). This example demonstrates that fruit fly species from the *B. dorsalis* complex can establish in Australia.

- Hosts of *B. dorsalis* are widely distributed throughout Australia. Adults may live for many months and the potential fecundity of females of *B. dorsalis* in the laboratory is well over 1000 eggs (Fletcher 1989).
- The *B. dorsalis* complex of fruit flies includes papaya fruit fly and therefore reproductive biology of *B. dorsalis* would be similar (CAB International 2005).

Probability of spread

The likelihood that *B. dorsalis* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- Flight of adults and the transport of infested fruit are the main means of dispersal of *B. dorsalis* to previously uninfested areas. Fruit fly species of the *B. dorsalis* complex have a wide host range of both commercial and wild species (EPPO 2005) which are widespread in Australia.
- Larvae can develop into adult flies, that are strong flyers (Fletcher 1989) and able to move directly from fruit into the environment to find a suitable host. Some *Bactrocera* spp. may fly 50-100 km (Fletcher 1989).
- The incursion of *B. papayae* into northern Australia in 1995 is indicative of the ability of introduced fruit fly species of the *B. dorsalis* complex to spread. Initially, the infested area covered 4,500 km^2 (Allwood 1995), and was centered on Cairns. The declared pest quarantine area later expanded to 78,000 km^2 of north Queensland, including urban areas, farms, rivers, coastline and a large part of the Wet Tropics World Heritage Area (Cantrell *et al*. 2002) before it was eradicated from Australia. *Bactrocera dorsalis* may be expected to have a similar capacity to spread in Australia as a result of its similarity to *B. papayae* and wide host range.

Probability of entry, establishment or spread

The overall likelihood that *B. dorsalis* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **High**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *B. dorsalis*: **HIGH**.

Criterion	Estimate
Direct consequences	
Plant life or health	**D** — *B. dorsalis* can cause direct harm to a wide range of plant hosts (e.g: *Citrus* spp., *Prunus* spp., *Malus pumila*, *Mangifera indica*) and are estimated to have highly significant consequences at the district level and consequences of minor significance at the national level.
Any other aspects of the environment	**B** — *B. dorsalis* introduced into a new environment will compete for resources with native species. There may be significant consequences of these pests for native plants at a local level, which would be unlikely to be discernible at a national level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200 and $900 per hectare, depending on the cultivar of fruit produced and the time of harvest (Anon. 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication program using male annihilation and protein bait spraying cost AU$35 million (SPC 2002). Cost of eradication will be much higher at current rates. *B. dorsalis* is estimated to have highly significant consequences at the regional level and significant consequences at the national level.
Domestic trade	**D** — The presence of *B. dorsalis* in commercial production areas will have a significant effect at the regional level because of any resulting interstate trade restrictions on a wide range of commodities. *Bactrocera dorsalis* is estimated to have consequences that are significant at the regional level and minor significance at the national level.
International trade	**D** — *B. dorsalis* is regarded as the most destructive pests of horticultural crops. Although they can cause considerable yield losses in orchards and suburban backyards, the major consequence for Australian horticultural industries would be the negative effect they have on gaining and maintaining export markets. For example, when the papaya fruit fly outbreak occurred in north Queensland, impacts on trade affected the whole of Australia. In the first two months of the papaya fruit fly eradication campaign, about $600,000 worth of exports were interrupted (Cantrell *et al*. 2002). Within a week of the papaya fruit fly outbreak being declared, Japan ceased imports of mangoes at a cost of about $570,000, New Zealand interrupted its $30,000 banana trade and the Solomon Islands completely stopped importing fruit and vegetables from Queensland (Cantrell *et al*. 2002) until the fly was eradicated in Queensland. *B. dorsalis* is estimated to have consequences that are highly significant at the district level and significant at the regional level.
Environment	**C** — Pesticides required to control *B. dorsalis* are estimated to have consequences that are significant at the district level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate for *B. dorsalis* as determined by combining the overall 'probability of entry, establishment or spread' with the 'consequences' using the risk estimation matrix (Table 6): **High**.

Melon fruit fly

The fruit fly [Diptera: Tephritidae] examined in this pest risk analysis is:

- *Bactrocera cucurbitae* (Coquillett) – Melon fruit fly

Introduction and spread potential

Probability of importation

The likelihood that *B. cucurbitae* will arrive in Australia with the importation of fresh mangoes from Taiwan: **Very Low**.

- *B. cucurbitae* is a very serious pest of cucurbit crops and primary hosts are species of Cucurbitaceae (CAB International 2005). Mango is not listed as a host by Allwood *et al.* (1999).
- Studies in Taiwan and India indicated that adult *B. cucurbitae* flies have been observed to ‘roost’ in mango trees, as well as citrus and guava, where they feed on honey dew produced by aphids and mealybugs (Lall and Singh 1969; Lee 1972).
- In India *B. cucurbitae* roosting occurs from December to mid February, during which time the females do not oviposit (Lall and Singh 1969).
- Adults migrate from roosting sites to cucurbits for oviposition (Lall and Singh 1969; Lee 1972).

Probability of distribution

The likelihood that *B. cucurbitae* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **High**.

- The pests are likely to survive storage and transportation because adults of *B. cucurbitae* may live for up to 222 days in the wild (Vargas and Carey 1990). Mean generation time is 72 days (Vargas and Carey 1990).
- Fruit infested with eggs and larvae are likely to be distributed throughout Australia for retail sale. Adults, larvae and eggs are likely to be associated with infested waste.
- Although damaged fruit are likely to be detected and removed from consignments because of quality concerns, fruit flies can complete their development in discarded fruit and transfer to suitable hosts. *Bactrocera cucurbitae* has a wide host range and adults can feed on flowers (pollen/nectar) and the juices of damaged plants (Severin *et al*. 1914).
- Where suitable host plants are not present it is likely that flies would migrate in search of suitable reproductive habitat. Adults may disperse over 2 km but do not move significant distances when suitable larval hosts and adult roosting sites are available (Peck *et al*. 2005).

Probability of entry (importation × distribution)

The likelihood that *B. cucurbitae* will enter Australia as a result of trade in fresh mangoes from Taiwan and be distributed in a viable state to the endangered area: **Very Low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *B. cucurbitae* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- A previous Australian incursion of the exotic fruit fly *B. papayae* was detected around Cairns, Queensland in 1995 and was eradicated from Queensland using male annihilation and protein bait spraying programs (SPC 2002). Successful eradication of *B. cucurbitae* has been implemented in Japan using sterile males (Kuba *et al*. 1996) and Naru (Allwood *et al*. 2003).
- Many preferred cucurbit oviposition hosts and adult roosting sites are popular domestic garden plants.
- Where suitable host plants are absent it is likely that flies would migrate in search of suitable habitat. Flies may disperse over 2 km but do not move significant distances when suitable larval host and adult roosting sites are available (Peck *et al*. 2005).
- Longevity of *B. cucurbitae* females has been recorded as a maximum of 222 days (Vargas and Carey 1990) and mean generation time is 72 days (Vargas and Carey 1990).

Probability of spread

The likelihood that *B. cucurbitae* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **Moderate**.

- *B. cucurbitae* has a higher mean generation time (T = 72 days), lowest net reproductive rate (Ro = 80.8) and lowest intrinsic rate of increase (Rm = 0.06) measured on papaya than *Ceratitis capitata* and *B. dorsalis* (Vargas and Carey 1990). This results in moderate spread potential for *B. cucurbitae*.
- Flies may disperse over 2 km but do not move significant distances when suitable larval host and adult roosting sites are available (Peck *et al*. 2005).
- A previous Australian incursion of the exotic fruit fly *B. papayae* was detected around Cairns, Queensland in 1995 and was eradicated from Queensland using male

annihilation and protein bait spraying programs (SPC 2002). Successful eradication of *B. cucurbitae* has been implemented in Japan using sterile males (Kuba *et al*. 1996) and Naru (Allwood *et al*. 2003).

Probability of entry, establishment or spread

The overall likelihood that *B. cucurbitae* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Very Low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *B. cucurbitae*: **High**.

Criterion	Estimate
Direct consequences	
Plant life or health	**D** — *B. cucurbitae* is a very serious pest of cucurbit crops. It can attack flowers as well as fruit, and additionally, will sometimes attack stem and root tissue. In Hawaii, pumpkin and squash fields (varieties of *Cucurbita pepo*) have been known to be heavily attacked prior to fruit set, with eggs being laid into unopened male and female flowers (Back and Pemberton 1914). Larvae have even developing successfully in the taproots, stems and leaf stalks (Back and Pemberton 1914). The effect of *B. cucurbitae* on cucurbit crops is estimated to have consequences that are highly significant at the district level and minor significance at the national level.
Any other aspects of the environment	**B** — *B. cucurbitae* introduced into a new environment will compete for resources with native species. These pests may have significant consequences for native plants at a local level, which are unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200 and $900 per hectare, depending on the variety of fruit produced and the time of harvest (Anon. 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication program using male annihilation and protein bait spraying cost AU$35 million (SPC 2002). Eradication and control measures for *B. cucurbitae* are estimated to have consequences that are highly significant at the regional level and significant consequences at the national level.
Domestic trade	**D** — The presence of *B. cucurbitae* in commercial production areas will have a significant effect at the regional level because of any resulting interstate trade restrictions on a wide range of commodities which are currently unaffected by fruit flies. *B. cucurbitae* is estimated to have consequences that are significant at the regional level and minor significance at the national level.
International trade	**D** — *B. cucurbitae* is regarded a serious pest of cucurbits crops. Currently Australian cucurbit crops are unaffected by fruit fly pests. In addition to serious effects on productivity the establishment of the disease would impact significantly on cucurbit exports which are currently free of fruit fly pests. For example, when the papaya fruit fly outbreak occurred in north Queensland, Australia experienced trade effects that affected the whole country. In the first

	two months of the papaya fruit fly eradication campaign, about $600,000 worth of exports were interrupted by Australian trade partners (Cantrell *et al*. 2002). Within a week of the papaya fruit fly outbreak being declared, Japan ceased imports of mangoes at a cost of about $570,000, New Zealand interrupted its $30,000 banana trade and the Solomon Islands completely stopped importing fruit and vegetables from Queensland (Cantrell *et al*. 2002) until the pest was eradicated. *B. cucurbitae* is estimated to have significant consequences at the regional level.
Environment	**A** — Pesticides required to control *B. cucurbitae* are estimated to have consequences that of minor significance at the local level and are unlikely to be discernible at the national level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate for *B. cucurbitae* as determined by combining the overall 'probability of entry, establishment or spread' with the 'consequences' using the risk estimation matrix (Table 6): **Low.**

Solanum fruit fly

The fruit fly [Diptera: Tephritidae] examined in this pest risk analysis is:

- *Bactrocera latifrons* (Hendel, 1915) – solanum fruit fly

Introduction and spread potential

Probability of importation

The likelihood that *B. latifrons* will arrive in Australia with the importation of fresh mangoes from Taiwan: **Negligible**.

- *B. latifrons* is native to Southeast Asia and mainly infests the fruit of solanaceous plants but occasionally attacks curcubits. (McQuate and Peck 2001).
- *B. latifrons* has not been reported in from quarantine interceptions of Taiwanese mango fruit in Japan (Iwaizuma 2004).
- The report of *B. latifrons* attacking mango in Malaysia (Vijaysegaran 1991) was considered by Liquido *et al*. (1994) to be questionable and in need of verification. Mango was not detected as a host in an extensive review of host records (Allwood *et al*. 1999).
- *B. latifrons* has not been detected on mango or in mango production areas in Taiwan (BAPHIQ 2006). BAHPIQ (2006) advise that *B. latifrons* was last detected in 2003 on pepper imports and has not been detected again in subsequent surveys.

- Adult females deposit eggs under the skin of mango fruit leaving inconspicuous puncture marks (CAB International 2005).

Probability of distribution

The likelihood that *B. latifrons* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **High**.

- Eggs hatch within 2 days and larvae feed for about 8 days before pupating in the soil (CAB International 2005). Adults emerge after pupating for approximately 10 days.
- Fruit infested with eggs and larvae are likely to be distributed throughout Australia for retail sale. Adults, larvae and eggs are likely to be associated with infested waste.
- Although damaged fruit are likely to be detected and removed from consignments because of quality concerns, fruit flies can complete their development in discarded fruit and transfer to suitable hosts. Solanum fruit fly has a host range which includes several solanaceous crop species (CAB International 2005).
- Where suitable host plants are not present it is likely that flies would migrate in search of suitable reproductive habitat. Many *Bactrocera* species can fly 50-100 km (Fletcher 1989)

Probability of entry (importation × distribution)

The likelihood that *B. latifrons* will enter Australia as a result of trade in fresh mangoes from Taiwan and be distributed in a viable state to the endangered area: **Negligible**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 6).

Probability of establishment

The likelihood that *B. latifrons* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- A previous Australian incursion of the exotic fruit fly of the genus *Bactrocera* (*B. papayae*) that was detected around Cairns, Queensland in 1995 and was eradicated using male annihilation and protein bait spraying programs (SPC 2002).
- Lure traps and baits are only weakly effective for *B. latifrons* (McQuate and Peck 2001). The lack of an effective bait would hamper eradication efforts.
- Many preferred solanaceous and cucurbit oviposition hosts and adult roosting sites are popular domestic garden plants.

- Where suitable host plants are absent it is likely that flies would migrate in search of suitable habitat.
- *B. latifrons* females oviposit over a period of 6-117 days (CAB International 2005).

Probability of spread

The likelihood that *B. latifrons* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- Many *Bactrocera* species can fly 50-100 km (Fletcher 1989).
- A previous Australian incursion of the exotic fruit fly *B. papayae* was detected around Cairns, Queensland in 1995 and was eradicated using male annihilation and protein bait spraying programs (SPC 2002). However, lure traps and baits are only weakly effective for *B. latifrons* (McQuate and Peck 2001).

Probability of entry, establishment or spread

The overall likelihood that *B. latifrons* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Negligible**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

<u>Consequences</u>

Consequences (direct and indirect) of *B. latifrons*: **High**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *B. latifrons* mainly affects solanaceous crops and some cucurbits which are currently unaffected by fruit fly. It is estimated to have minor significance at the regional level.
Any other aspects of the environment	**B** — *B. latifrons* introduced into a new environment will compete for resources with native species. These pests may have consequences that are significant for native plants at a local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200 and $900 per hectare, depending on the variety of fruit produced and the time of harvest (Anon. 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication program using male annihilation and protein bait spraying cost AU$35 million (SPC 2002). Cost of eradication will be much higher at current rates. Lure traps are only weakly affective hampering effective monitoring and baiting (McQuate and Peck 2001). Eradication and control measures for *B. latifrons* are estimated to have

	consequences that are highly significant at the regional level and significant at the national level.
Domestic trade	**D** — The presence of *B. latifrons* in commercial production areas will have a significant effect at the regional level because of any resulting interstate trade restrictions on a range of commodities which are currently unaffected by fruit flies. *B. latifrons* is estimated to have consequences that are significant at the regional level and of minor significance at the national level.
International trade	**D** — *B. latifrons* is regarded a potential pest of solanaceous and cucurbit crops. Currently cucurbit crops are unaffected by fruit fly pests. In addition to serious effects on productivity the establishment of the disease would impact significantly on cucurbit exports which are currently free of fruit fly pests. For example, when the papaya fruit fly outbreak occurred in north Queensland, Australia experienced trade effects that affected the whole country. In the first two months of the papaya fruit fly eradication campaign, about $600,000 worth of exports were interrupted by Australian trade partners (Cantrell *et al*. 2002), until the pest was eradicated. Within a week of the papaya fruit fly outbreak being declared, Japan ceased imports of mangoes at a cost of about $570,000, New Zealand interrupted its $30,000 banana trade and the Solomon Islands completely stopped importing fruit and vegetables from Queensland (Cantrell *et al*. 2002). *B. latifrons* is estimated to have consequences that are significant at the regional level.
Environment	**A** — Pesticides required to control *B. latifrons* are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.

Note: Refer to “Method for Pest Risk Analysis” section (text under the heading ‘Assessment of consequences’ and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate for *B. latifrons* as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Negligible**.

Pumpkin fruit fly

The fruit fly [Diptera: Tephritidae] examined in this pest risk analysis is:

- *Bactrocera tau* (Walker) – pumpkin fruit fly

Introduction and spread potential

Probability of importation

The likelihood that *B. tau* will arrive in Australia with the importation of fresh mangoes from Taiwan: **Extremely low**.

- *Bactrocera tau* is native to Taiwan and is considered an economic pest of cucurbits (White and Elson-Harris 1992).
- Mango was not detected as a host of *B. tau* in an extensive review of host records (Allwood *et al*. 1999). *Bactrocera tau* has been listed as a pest of mango fruit in India

by Peña and Mohyuddin (1997) and Srivastava (1997), however a primary source was not given by these authors. Bachang (*Mangifera foetida*) has been recorded as a host of *B. tau* in Malaysia (Tan and Lee 1982), in randomly collected fruit however, *B. tau* was not recorded from mango (*Mangifera indica*).

Probability of distribution

The likelihood that *B. tau* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **High**.

- Larvae develop over 30 days at 10 ^{o}C and 8 days at 30 ^{o}C (Chang and Ying 2000). Pupation takes approx 25 days at 15 ^{o}C and approx. 7 days at 30 ^{o}C (Chang and Ying 2000). Adults may live more than 6 months at 15-25 ^{o}C (Chang and Ying 2000).
- Fruit infested with eggs and larvae are likely to be distributed throughout Australia for retail sale. Adults, larvae and eggs are likely to be associated with infested waste.
- Although damaged fruit are likely to be detected and removed from consignments because of quality concerns, fruit flies can complete their development in discarded fruit and transfer to suitable hosts. *Bactrocera tau* has a host range which includes several cucurbitae crop species (Allwood 1999).
- Where suitable host plants are not present it is likely that flies would migrate in search of suitable reproductive habitat. Many *Bactrocera* species can fly 50-100 km (Fletcher 1989)

Probability of entry (importation × distribution)

The likelihood that *B. tau* will enter Australia as a result of trade in fresh mangoes from Taiwan and be distributed in a viable state to the endangered area: **Extremely low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *B. tau* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- A previous Australian incursion of the exotic fruit fly *B. papayae* was detected around Cairns, Queensland in 1995 and was eradicated from Queensland using male annihilation and protein bait spraying programs (SPC 2002).
- Many preferred cucurbit oviposition hosts and adult roosting sites are popular domestic garden plants.

- Female fecundity is high, ranging between 665 and 911 eggs per female (Liu and Lin 2001). In Taiwan there are two generations per year (Chen 2001).
- Where suitable host plants are absent it is likely that flies would migrate in search of suitable habitat.

Probability of spread

The likelihood that *B. tau* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- Many *Bactrocera* species can fly 50-100 km (Fletcher 1989).
- A previous Australian incursion of the exotic fruit fly *B. papayae* was detected around Cairns, Queensland in 1995 and was eradicated from Queensland using male annihilation and protein bait spraying programs (SPC 2002).
- *Bactrocera* species can be attacked in the larval stage by parasitoids or by vertebrates eating fruit (CAB International, 2005). Parasitoids appear to have little effect on the populations of most fruit flies (CAB International, 2005).

Probability of entry, establishment or spread

The overall likelihood that *B. tau* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Extremely low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *B. tau*: **High**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *B. tau* mainly affects cucurbit crops which are currently unaffected by fruit fly. It is estimated to have minor significance at the regional level.
Any other aspects of the environment	**B** — *B. tau* introduced into a new environment will compete for resources with native species. These pests may have consequences that are significant for native plants at a local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200 and $900 per hectare, depending on the variety of fruit produced and the time of harvest (Anon. 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication program using male annihilation and protein bait spraying cost AU$35 million (SPC 2002). Lure traps are only

	weakly affective hampering effective monitoring and baiting (McQuate and Peck 2001). Eradication and control measures for *B. tau* are estimated to have consequences that are highly significant at the regional level and significant at the national level.
Domestic trade	**D** — The presence of *B. tau* in commercial production areas will have a significant effect at the regional level because of any resulting interstate trade restrictions on a range of commodities which are currently unaffected by fruit flies.
International trade	**D** — *B. tau* is regarded a potential pest of cucurbit crops. Currently cucurbit crops are unaffected by fruit fly pests. In addition to serious effects on productivity the establishment of the disease would impact significantly on cucurbit exports which are currently free of fruit fly pests. For example, when the papaya fruit fly outbreak occurred in north Queensland, Australia experienced trade effects that affected the whole country. In the first two months of the papaya fruit fly eradication campaign, about $600,000 worth of exports were interrupted by Australian trade partners (Cantrell *et al*. 2002). Within a week of the papaya fruit fly outbreak being declared, Japan ceased imports of mangoes at a cost of about $570,000, New Zealand interrupted its $30,000 banana trade and the Solomon Islands completely stopped importing fruit and vegetables from Queensland (Cantrell *et al*. 2002). *B. tau* is estimated to have consequences that are significant at the regional level.
Environment	**A** — Pesticides required to control *B. tau* are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate for *B. tau* as determined by combining the overall 'probability of entry, establishment or spread' with the 'consequences' using the risk estimation matrix (Table 6): **Very Low**.

Armoured scales

Armoured or hard scales are strongly sexually dimorphic and display division of function between different developmental stages within their life cycle. The reproductive rates for armoured scales are weather dependent and more generations are produced in tropical climates.

They damage the host plant by sucking sap through their stylets. They do not produce honeydew, but their feeding can blemish fruit or cause leaf drop (Smith *et al*. 1997). They can inject toxins into plant tissues and high populations can reduce plant vigour or cause the death of trees (Beardsley and Gonzalez 1975; Smith *et al*. 1997).

Five armoured scale species have been grouped due to their similar biology and behaviour on the hosts. *Abgrallaspis cyanophylli* has previously been assessed (DAFF 2004).

The armoured scales [Hemiptera: Diaspididae] examined in this pest risk analysis are:

- **Abgrallaspis cyanophylli* (Signoret, 1869) - cyanophyllum scale, red scale
- *Aonidomytilus albus* (Cockerell) - tapioca scale
- *Lepidosaphes laterochitinosa* (Green) – armoured scale
- *Parlatoria pseudaspidiotus* (Lindinger 1905) - vanda orchid scale
- *Unaspis acuminata* (Green) – unaspis scale

* This species is a quarantine pest for Western Australia.

Introduction and spread potential

Probability of importation

The likelihood that armoured scales will arrive in Australia with the importation of fresh mangoes from Taiwan: **High**.

- Armoured scale species are considered present on the import pathway. Although usually causing only minor damage to mango in Taiwan, they may occasionally cause heavy damage (Lee 1988).
- First instar nymphs (or crawlers) are capable of movement onto fruit where they permanently attach and commence feeding (Beardsley and Gonzalez 1975). Subsequent instars are sessile (CAB International 2005) and may therefore, be difficult to remove by cleaning (Taverner and Bailey 1995).
- Armoured scales construct an external covering or 'scale', which protects against physical and chemical attack because of its hardness and impermeability (Foldi 1990). Hence, commercial fruit cleaning procedures undertaken within the packhouse are unlikely to remove or eliminate all viable scales (Foldi 1990).
- Inspection procedures carried out within the packhouse are concerned primarily with fruit quality with regard to blemishes, bruising or damage to the skin. These procedures are not specifically directed at the detection of small arthropod pests present on the fruit surface, especially at low levels.
- Adults and crawlers are likely to survive within the storage and transport environment; the fruit would provide an ample food supply during transit.

Probability of distribution

The likelihood that armoured scales will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **Moderate**.

- Infested fresh mango fruit are likely to be distributed throughout Australia within the retail sale pathway. Although, the intended use is human consumption, waste material (e.g. mango skin) would be generated and infested plant material may be disposed within the environment.

- Dispersal of crawlers (first-instar nymphs) is accomplished mainly by active wandering and the wind. Birds, insects and other animals, including humans may act as vectors (Beardsley and Gonzalez 1975).
- Armoured scales are polyphagous and all life stages survive in the environment for some time, they may be distributed and transferred to a suitable host.
- Crawlers are the primary dispersal life stage as later instars are sessile and adult females are flightless and remain on the host. While adult males are capable of weak flight they cannot feed and live only a few hours (Beardsley and Gonzalez 1975; CAB International 2005).
- The ability of armoured scales to disperse is moderated by the lack of an active longer range dispersal mechanism.

Probability of entry (importation × distribution)

The likelihood that armoured scales will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Moderate.**

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that armoured scales will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- Armoured scales are polyphagous and host plants are common in Australia (e.g. citrus and mango), particularly in the warmer subtropical and tropical regions.
- Existing control programs (e.g. application of broad spectrum pesticides) may control armoured scales on some hosts, but may not be effective on hosts where specific integrated pest management programs are used.
- Reproduction can be either sexual or asexual (without fertilisation) (CAB International 2005).
- It is unlikely that armoured scales would be contained by agronomic management practices or by regulation.

Probability of spread

The likelihood that armoured scales will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **Moderate**.

- Adults and nymphs have limited mobility but may be moved within and between orchards (or other commercial production sites) with the movement of equipment, personnel and infested plant material (Dreistadt *et al*. 1994).
- Crawlers may be moved within and between plantations by the movement of infested plant material, vectors and wind (Beardsley and Gonzalez 1975; Greathead 1990).
- If second and subsequent generations of armoured scales become established on commercial, susceptible household and wild host plants, they are likely to persist indefinitely and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and by the movement of infested plant material (Beardsley and Gonzalez 1975).

Probability of entry, establishment or spread

The overall likelihood that armoured scales will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of armoured scales: **Low**

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — Armoured scales can cause direct harm to a wide range of host plants, affecting fruit quality and plant health. Armoured scales are polyphagous and host plants are common in Australia (e.g. citrus, mango). Armoured scales are estimated to have consequences that are of minor significance at the regional level and unlikely to be discernible at the national level.
Any other aspects of the environment	**A** — Armoured scales introduced into a new environment may compete for resources with native species. They are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**C** — Programs to minimise the impact of these pests on host plants are likely to be costly and include pesticide applications and crop monitoring. Armoured scales are estimated to have consequences that are significant at the district level and unlikely to be discernible at the national level.
Domestic trade	**B**— The presence of these pests in commercial production areas may have a significant effect at the local level due to any resulting interstate trade restrictions on a wide range of commodities. These restrictions may lead to a loss of markets, which in turn would be likely to require industry adjustment. Armoured scales are estimated to have consequences that are significant at the local level and unlikely to be discernable at the regional level.
International trade	**B** — The presence of these pests in commercial production areas of

	various export commodities (e.g. citrus, mango) may have an effect due to possible limitations to access to overseas markets where these pests are absent. Armoured scales are estimated to have consequences that are significant at the local level and unlikely to be discernable at the regional level.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is considered to have consequences that are minor at the local level and unlikely to be discernable at the district level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall 'probability of entry, establishment or spread' with the 'consequences' using the risk estimation matrix (Table 6): **Very low.**

Soft scales

Soft scales predominantly reproduce asexually and occurrence of males is very rare. Under optimum conditions, these scales are reported to be capable of producing two to three generations a year. They damage host plants by sucking nutrients from plant parts, and excreting large amounts of sugary honeydew onto fruit and leaves (Smith *et al*. 1997). The main economic damage caused by soft scales is from the downgrading of fruit quality because of sooty mould fungus growing on the honeydew (Smith *et al*. 1997). Heavy infestations can reduce tree vigour and rates of photosynthesis.

Two soft scale species have been grouped due to their similar biology and the nature of their physical presence and behaviour on hosts. *Milviscutulus mangiferae* has been previously assessed (DAFF 2004).

The soft scales [Hemiptera: Coccidae] examined in this pest risk analysis are:

- **Milviscutulus mangiferae* (Green, 1889) - mango shield scale
- *Protopulvinaria pyriformis* (Cockerell) - pyriform scale

*This species is a quarantine pest for the State of Western Australia.

Introduction and spread potential

Probability of importation

The likelihood that soft scales will arrive in Australia with the importation of fresh mangoes from Tawian: **High**

- Soft scales are likely to survive storage and transport as the fruit would provide an ample food supply during transit.
- Adult males of *M. mangiferae* have well developed functional legs (Giliomee 1997) as do first instar nymphs which exhibit considerable mobility upon hosts (Ben-Dov 1997; Williams 1997)
- First instar nymphs permanently attach and commence feeding on plant parts including fruit. Therefore, they may be difficult to remove or detect during fruit sorting, especially at low population levels (Taverner and Bailey 1995).
- Soft scales secrete very little wax compared to armoured scales (Mau and Kessing 1992), but this still provides some level of protection against physical and chemical attack.
- Inspection procedures carried out within the packhouse are concerned primarily with fruit quality with regard to blemishes, bruising or damage to the skin. These procedures are not specifically directed at the detection of small arthropod pests present on the fruit surface, especially if present in low numbers.

Probability of distribution

The likelihood that soft scales will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **Moderate**.

- Adults and crawlers are likely to survive within the storage and transport environment; the fruit would provide an ample food supply during transit.
- Gravid females would need to be carried onto hosts by vectors such as people or animals. The first instar is the main means of dispersal, by active crawling over short distances and passive dispersal by wind and animals. Dispersal of first instar by wind can occur over considerable distances (Greathead 1997).
- Infested fresh mango fruit are likely to be distributed throughout Australia through the retail sale pathway. Although the intended use is human consumption waste material (e.g. mango skin) would be generated and infested plant material may be disposed within the environment.

Probability of entry (importation × distribution)

The likelihood that soft scales will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Moderate.**

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that soft scales will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- Soft scales are polyphagous and host plants are common in Australia (e.g. citrus, mango, eucalypts), particularly in the warmer subtropical and tropical regions.
- Existing control programs (e.g. application of broad spectrum pesticides) may control soft scales on some hosts, but may not be effective on hosts where specific integrated pest management programs are used.
- Soft scales have a high reproductive rate and *P. pyriformis* and *M. mangiferae* reproduce parthenogenetically (Ben-Dov *et al*. 2005).

Probability of spread

The likelihood that soft scales will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **Moderate**.

- *Protopulvinaria pyriformis* and *M. mangiferae* reproduce asexually (Ben-Dov *et al*. 2005) and occurrence of males is very rare (Ben-Dov and Hodgson 1997; Otanes 1936; Avidov and Zaitzov 1960).
- Under optimum conditions, these scales are reported to be capable of producing two to three generations a year. Female life span is reported to average 2-3.5 months (Avidov and Zaitzov 1960).
- Spread would be assisted by wind dispersal, vectors and by the movement of plant material (Greathead 1997). The crawler stage is the most active stage and is responsible for both active and passive dispersal. This dispersal is influenced mainly by temperature; crawlers are most active between 21 and 32 ^{o}C. Selection of an appropriate feeding site is critical for subsequent development. Mortality is generally highest during the 1st instar and failure to settle is considered to be one of the major mortality factors for many species (Beardsley and Gonzales 1975).

Probability of entry, establishment or spread

The overall likelihood that soft scales will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of soft scales: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — Soft scales can cause direct harm to a wide range of plant hosts, affecting fruit quality and whole plant health. Fruit quality can be reduced by the presence of secondary sooty mould. These soft scale species are polyphagous and host plants are common in Australia (e.g. citrus, mango). Soft scales are estimated to have consequences that are of minor significance at the regional level and unlikely to be discernible at the national level.
Any other aspects of the environment	**A** — Soft scales introduced into a new environment may compete for resources with native species. They are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**C** — Programs to minimise the impact of these pests on host plants are likely to be costly and include pesticide applications and crop monitoring. Existing control programs (e.g. application of broad spectrum pesticides) may control soft scales on some hosts, but may not be effective on hosts where specific integrated pest management programs are used. Soft scales are estimated to have consequences that are significant at the district level and unlikely to be discernible at the national level.
Domestic trade	**B** — The presence of these pests in commercial production areas is likely to have a significant effect at the local level because of any resulting interstate trade restrictions on various commodities. These restrictions may lead to a loss of markets, which in turn would be likely to require industry adjustment. Soft scales are estimated to have consequences that are significant at the local level and unlikely to be discernable at the regional level.
International trade	**B**— The presence of these pests in commercial production areas of a range of export commodities (e.g. citrus, mango) may have a significant effect at the local level because of any limitations to access to overseas markets where these pests are absent.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is estimated to have consequences that are of minor significance at the local level and unlikely to be discernable at the district level.

Note: Refer to “Method for Pest Risk Analysis” section (text under the heading ‘Assessment of consequences’ and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Very low.**

Mealybugs

Mealybugs have limited mobility and are small (0.5-4 mm). They have a high reproductive rate. The reproductive strategy and consequent persistence of these pests is based largely on the longevity and fecundity of adult females. Adult males are winged but fragile and short-lived and do not persist for more than 1-2 days (Mau and Kessing 1993).

Mealybugs injure host plants by sucking sap through tubular stylets, and by excreting large amounts of sugary honeydew onto fruit and leaves. Heavy infestations may damage plants directly. Sooty mould fungus growth on the honeydew secretions can render the fruit unmarketable, reduce the photosynthetic efficiency of leaves and cause leaf drop. Many mealybug species pose particularly serious problems to agriculture when introduced into new areas of the world where their natural enemies are not present (CAB International 2005).

Four mealybug species have been grouped due to their similar biology and the nature of their physical presence and behaviour on hosts. Mealybugs *Planococcus lilacinus* and *Rastrococcus spinosus* have been previously assessed (DAFF 2004).

The mealybugs [Hemiptera: Pseudococcidae] examined in this pest risk analysis are:

- *Planococcus lilacinus* (Cockerell, 1905) – coffee mealybug
- *Pseudococcus cryptus* (Hempel) – citriculus mealybug
- *Pseudococcus jackbeardsleyi* Gimpel & Miller – Jack Beardsley mealybug
- *Rastrococcus spinosus* (Robinson, 1918) – Philippine mango mealybug.

Introduction and spread potential

Probability of importation

The likelihood that mealybugs will arrive in Australia with the importation of fresh mangoes from Taiwan: **High**.

- Infestations on mango usually begin on the underside of leaves on terminal shoots. The mealybugs spread to young shoots, flowers and fruit as their population increases (Myfruits 2004). Mealybugs have limited mobility and are small (0.5-4 mm).
- Inspection procedures carried out in the packhouse are focused primarily on fruit quality with regard to blemishes, bruising or damage to the skin. Although all fruit is visually inspected, the procedures are not specifically directed at the detection of small arthropod pests present on the fruit surface.
- Routine cleaning procedures undertaken within packhouses may not remove all mealybugs from the fruit surface. Although mealybugs may be affected by the washing solution, they are unlikely to be destroyed by it. This is particularly true of those adult females or nymphs that are protected by waxy cocoons, coatings or coverings.
- On mango, the total development time for females and males is 28-32 and 30-32 days respectively (Ullah *et al.* 1992). The nymphal period for *P. lilacinus* can survive for up

to 25 days (Loganathan and Suresh 2001). Mealybugs are capable of hibernation during cold periods (Smith *et al*. 1997).

- In Pakistan, *R. spinosus* is considered as an important pest of mangoes, and has also been recorded on oleander, banana, guava, orange and other plants (Mahmood *et al.* 1980). It is recorded to be harmful to the young growth, flowers and mango fruit in the Philippines (Otanes 1936). *R. spinosus* has been found in US ports-of-entry on *Lansium* and *Tabernaemontana* from the Philippines and Singapore (Miller *et al.* 2005).

Probability of distribution

The likelihood that mealybugs will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **Moderate**.

- Mealybugs present on the fruit may survive distribution and be present on waste generated in Australia. The nymphal stage of *P. lilacinus* can survive for up to 25 days (Loganathan and Suresh 2001). Mealybugs are capable of hibernation during cold periods (Smith *et al*. 1997).
- Adult males are winged but fragile and short-lived and do not persist for more than 1-2 days (Mau and Kessing 1993). The first instar is the main means of dispersal, by active crawling and passive dispersal by wind and animal agents (CAB International 2005).
- Mealybugs can enter the environment in four ways: adults can be associated with discarded mango skin; first instar nymphs (crawlers) may be discarded with fruit; crawlers can be blown by wind currents (Ben-Dov 1994) from mangoes at the point of sale or after purchase by consumers.

Probability of entry (importation × distribution)

The likelihood that mealybugs will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Moderate**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that mealybugs will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- Many mealybugs are considered invasive and have been introduced into new areas and become established (Miller *et al*. 2002). These mealybug species have shown that they have the ability to establish after being introduced into new environments. For example, *P. lilacinus* is native to the Afrotropical region (Miller *et al*. 2002) and is now established in the Palaearctic, Malaysian, Oriental, Australasian and Neotropical regions (CAB International 2005).

- Mealybugs are polyphagous and host plants are common in Australia (e.g. citrus, mango and grapevine).
- Mealybugs have a high reproductive rate. The reproductive strategy and consequent persistence of these pests is based largely on the longevity and fecundity of adult females.
- On mango, the total development time for females and males is 28–32 and 30–32 days respectively (Ullah *et al.* 1992). Nymphs are active during the first instar stage and can disperse and locate new hosts by crawling, vectors or the wind before their mobility becomes limited in the remaining nymphal instars.

Probability of spread

The likelihood that mealybugs will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- After second and subsequent generations of mealybugs have become established, mealybugs are likely to persist and spread progressively over time (Miller *et al*. 2002).
- Adults and nymphs of mealybugs can be moved within and between plantations with the movement of infested plant material and animal vectors. Crawlers can be dispersed onto other plants by wind and animals (CAB International 2005).
- Insecticides do not always provide adequate control of mealybugs due to their waxy coating (CAB International 2005). Heavily infested branches may be pruned to control the pest, especially on the tender branches before flowering begins. Biological control using natural enemies (i.e. predators and parasitoids), is commonly used to control mealybugs locally in orchards (CAB International 2005).

Probability of entry, establishment or spread

The overall likelihood that mealybugs will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Moderate**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of mealybugs: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — Mealybugs can cause direct harm to a wide range of plant hosts (CAB International 2005). Fruit quality can be reduced by the presence of secondary sooty mould. Mealybugs are polyphagous and host plants are common in Australia (e.g. citrus, mango, grapevine). Mealybugs are estimated to have consequences that are of minor significance at the regional level and unlikely to be discernible at the national level.
Any other aspects of the environment	**A** — Mealybugs introduced into a new environment may compete for resources with native species. They are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**C** — Programs to minimise the impact of these pests on host plants are likely to be costly and include pesticide applications and crop monitoring. Existing control programs can be effective for some hosts (e.g. broad spectrum pesticide applications) but not all hosts (e.g. where specific integrated pest management programs are used). Insecticides do not always provide adequate control of mealybugs because of the waxy coating on the mealybug (CAB International 2005). Mealybugs are estimated to have consequences that are significant at the district level and unlikely to be discernible at the national level.
Domestic trade	**B** — The presence of these pests in commercial production areas is likely to have a significant effect at the local level because of any resulting interstate trade restrictions on a wide range of commodities. These restrictions can lead to a loss of markets, which in turn would be likely to require industry adjustment. Mealybugs are estimated to have consequences that are significant at the local level and are unlikely to be discernable at the regional level.
International trade	**C** — The presence of these mealybugs in commercial production areas of a wide range of commodities (e.g. citrus, mango, grapevine) could have a significant effect at the district level because of any limitations to access to overseas markets for a range of export fruits where these pests are absent. These pests are all associated with citrus. Australia exports citrus fruit to the USA from the Riverland-Sunraysia-Riverina (R-S-R) area. If these mealybugs became established in the R-S-R and other export areas in Australia, citrus trade with the USA and other countries might be compromised. Mealybugs are estimated to have consequences that are significant at the district level and unlikely to be discernable at the national level.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is estimated to have consequences that are of minor significance at the local level and are unlikely to be discernable at the district level.

Note: Refer to “Method for Pest Risk Analysis” section (text under the heading ‘Assessment of consequences’ and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Low**.

Mango Aphid

Aphids belong to the suborder Sternorrhyncha, within the order Hemiptera (Carver *et al*. 1991). Over 4000 species have been described (Dixon 1987), and most species live on one or a few species of a particular genus of plants, where they feed on the phloem (Carver *et al*. 1991). Loss of sap results in stunting, distortion or wilting, especially when large populations of aphids occur on young shoots (Carver *et al*. 1991).

The aphid [Hemiptera: Aphididae] examined in this pest risk analysis is:

- *Toxoptera odinae* (van der Goot, 1917) – mango aphid

Introduction and spread potential

Probability of importation

The likelihood that *T. odinae* will arrive in Australia with the importation of fresh mangoes from Taiwan: **Low**.

- Individuals of *T. odinae* would only rarely be found on the fruit pathway as mango aphids suck the sap from the leaves and shoots (Mondal *et al*. 1976; Shukla and Prasad 1983).
- Mango aphids are small (1.0-2.5 mm) (Blackman and Eastop 1984) and may be inconspicuous on fruit.
- Individuals of *T. odinae* are usually attended by ants (Mondal *et al*. 1976; Blackman and Eastop 1984). The presence of ants may indicate the presence of aphids, increasing the likelihood of detection of *T. odinae* on infested mango fruit.
- Post harvest grading, cleaning and packing procedures are likely to reduce the incidence of mango aphids on the fruit as the aphids are only anchored to the fruit while feeding.

Probability of distribution

The likelihood that *T. odinae* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **Low**.

- Aphids feed primarily on the phloem sap (Carver *et al*. 1991), which is found in plant stems and in veins of leaves.

- Aphids that may occur by chance on the mango fruit would be unlikely to survive storage and transportation and remain viable during distribution in Australia.
- Mangoes may be distributed throughout Australia for retail sale. The intended use of the commodity is human consumption, but waste material would be generated and infested material released to the environment.
- The aphid has both winged and wingless stages (Mondal *et al*. 1976) enabling some mobility.

Probability of entry (importation × distribution)

The likelihood that *T. odinae* will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Very low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *T. odinae* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- *T. odinae* has a wide host range (Mondal *et al*. 1976; Blackman and Eastop 1984; Martin 1989) and known host plants (e.g. mango, magnolia, citrus) are common in Australia.
- *T. odinae* is present in many countries in Asia (Mondal *et al*. 1976; Blackman and Eastop 1984; Martin 1989). The warmer regions of Australia would be highly suited for the survival and reproduction of mango aphid.
- Aphids have a high reproductive rate, and females can reproduce parthenogenetically, i.e. in the absence of males (Carver *et al*. 1991).
- There is a division of labour, with some stages in the life cycle concentrating on reproduction and others on dispersal (Carver *et al*. 1991). This may enhance the ability of *T. odinae* to establish in Australia.

Probability of spread

The likelihood that *T. odinae* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- The long distances between the main Australian commercial mango orchards would make it difficult for aphids to disperse directly from one mango-growing area to another. However, the polyphagous nature of these aphids should enable them to locate suitable hosts in-between orchards.

- *T. odinae* could be distributed in the environment through eggs and adults being carried on ornamental or crop plants during domestic trade. Immature stages of aphids are known to be transported by wind (Carver *et al*. 1991).
- Environmental conditions (e.g. temperature, rainfall) similar to those in Taiwan occur in parts of Australia.
- Chemical control of *T. odinae* has been shown to be effective (Shukla and Prasad 1983). Existing control programs may be effective against *T. odinae* on some hosts, but not all hosts (where specific integrated pest management programs are used).

Probability of entry, establishment or spread

The overall likelihood that *T. odinae* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Very low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *T. odinae*: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *T. odinae* can cause direct harm to a wide range of plant hosts (Mondal *et al*. 1976; Blackman and Eastop 1984; Martin 1989). However, *T. odinae* is not known to be a disease vector (Blackman and Eastop 1984). Aphids feed by sucking up plant juices through a food channel in their beaks. Light infestations are usually not harmful to plants, but higher infestations may result in leaf curl (Mondal *et al*. 1976), wilting, stunting of shoot growth, and delay in production of flowers and fruit, as well as a general decline in plant vigour. *T. odinae* is estimated to have consequences that are significant at the district level and unlikely to be discernable at the national level.
Any other aspects of the environment	**A** — Aphids introduced into a new environment may compete for resources with the native species. They are estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**C** — Programs to minimise the impact of these aphids on host plants are likely to be costly and include pesticide applications and crop monitoring. Existing control programs may be effective for some hosts (e.g. broad-spectrum pesticide application) but not all hosts (e.g. where specific integrated pest management programs are used. *T. odinae* is estimated to have consequences that are significant at the district level and unlikely to be discernable at the national level.

Domestic trade	**B** — The presence of these pests in commercial production areas may have a significant effect at the district level because of any resulting interstate trade restrictions on a wide range of commodities including mangoes and citrus. These restrictions can lead to a loss of markets, which in turn would be likely to require industry adjustment. *T. odinae* is estimated to have consequences on domestic trade that are significant at the local level and unlikely to be discernable at the national level.
International trade	**C** — The presence of this pest in commercial production areas of a range of commodities including mango may have a significant effect at the district level due to any limitations to access to overseas markets where this pest is absent. *T. odinae* is estimated to have consequences that are significant at the district level and unlikely to be discernable at the national level.
Environment	**A** — Although additional pesticide applications would be required to control *T. odinae* on susceptible crops, this is estimated to have consequences that are of minor significance at the local level and are unlikely to be discernable at the district level.

Note: Refer to “Method for Pest Risk Analysis” section (text under the heading ‘Assessment of consequences’ and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Negligible**.

Cocoa tussock moth

Adults of *Orgyia australis postica* live for about 5 days (Su 1985; Cheng *et al*. 2001). The flightless females cling to the exterior of their cocoons and call males to them. Oviposition is generally on the cocoon, with up to 60% of eggs producing larvae (Sanchez and Laigo 1968). The adult males are in flight in April and May in Taiwan (CAB International 2005).

The larvae of *O. australis postica* cause serious damage to the young leaves of cocoa both in nurseries and plantations. Large populations can cause total defoliation, killing or stunting the tree (Sanchez and Laigo 1968). The larvae also attack fruits, especially mango, rendering them unsuitable for sale (Fasih *et al*. 1989). In Taiwan it is a major pest of grapevines and roses (CAB International 2005). The tussock moth [Lepidoptera: Lymantriidae] examined in this pest risk analysis is:

- *Orgyia australis postica* (Walker) – cocoa tussock moth.

Introduction and spread potential

Probability of importation

The likelihood that *O. australis postica* will arrive in Australia with the importation of fresh mango fruit from Taiwan: **Low**.

- Infested fruit drop from the tree prematurely and those left on the tree have damaged skin and pulp, affecting their market value (Gupta and Singh 1986).
- Damaged fruit is unlikely to be packed for export.
- Detection of infested fruit during post harvest grading, cleaning and packing procedures is likely to reduce the incidence of larvae on the fruit.
- Oviposition is preferentially on the cocoon of the recently emerged adult (Sanchez and Liago 1968). As pupation occurs on leaves and stems (Sanchez and Liago 1968), cocoons would not be associated with packed fruit. Consequently eggs are not likely to be associated with the fruit.

Probability of distribution

The likelihood that *O. australis postica* will be distributed to the endangered area as a result of the processing, sale or disposal of mango fruit from Taiwan: **Low**.

- Adults only live for 5 days (Cheng *et al*. 2001). Larvae require 15-28 days to fully grow and pupate before reproduction can occur (Sanchez and Laigo 1968).
- Females are flightless and cling to the exterior of their cocoons and call flighted males to them (Sanchez and Laigo 1968). Oviposition is generally on the cocoon, with up to 60% of eggs producing larvae (Sanchez and Laigo 1968).
- The commodity is likely to be distributed throughout Australia for retail sale. The intended use of the commodity is human consumption, but waste material would be generated (e.g. mango skin, pulp and seed).
- If larvae were to survive storage and transport, they may enter the environment through discarded mango fruit.

Probability of entry (importation × distribution)

The likelihood that *O. australis postica* will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Very low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *O. australis postica* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **Moderate**.

- *O. australis postica* is polyphagous (Fasih *et al*. 1989) and many hosts are present in Australia. Larvae prefer to feed on fruit.

- Mating must occur to facilitate establishment. However, females are flightless and cling to the exterior of their cocoons, calling males to them (Sanchez and Laigo 1968). Adults only live for 5 days (Cheng *et al*. 2001).
- Oviposition is generally on the cocoon, with up to 60% of eggs producing larvae (Sanchez and Laigo 1968). Hatching larvae are not likely to be in close proximity to a suitable host.
- Eggs hatch after about 5-6 days, and the resulting male larvae take 15-26 days to become fully grown; the larger, female larvae take 15-28 days (Sanchez and Laigo 1968). The female and male pupal stages last 4-5 and 6-7 days, respectively (Sanchez and Laigo 1968).
- Optimum temperatures for egg hatch is 25 °C and for larval development 25–30 °C (Cheng *et al.* 2001). Suitable temperatures exist in Australia.

Probability of spread

The likelihood that *O. australis postica* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **Moderate**.

- Tropical or subtropical environments of Australia would be suitable for the spread of *O. australis postica* because it is recorded from these environments.
- Subtropical fruit and broad acre host plants are common in the Australian environment.
- Females are flightless and cling to the exterior of their cocoons and call flighted males to them (Sanchez and Laigo 1968). Oviposition is generally on the cocoon, with up to 60% of eggs producing larvae (Sanchez and Laigo 1968). Adults only live for 5 days (Cheng *et al*. 2001).This would limit the dispersal of *O. positica* in to the environment.

Probability of entry, establishment or spread

The overall likelihood that *O. australis postica* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Very low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *O. australis postica*: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *O. australis postica* can cause direct harm to a wide range of plant species of horticultural and broadacre agricultural importance (mango, lychee, cocoa, grapevines, soybean, mung bean, pear) and is estimated to have consequences that are of minor significance at the regional level and unlikely to be discernible at the national level.
Any other aspects of the environment	**A** — *O. australis postica* is estimated to have consequences that are of minor significance at the local level and are unlikely to be discernable at the district level.
Indirect consequences	
Eradication, control etc.	**B** — A control program would have to be implemented in infested orchards to reduce fruit damage and yield losses, thereby increasing production costs. *O. australis postica* is estimated to have consequences that are of minor significance at the district level and are unlikely to be discernible at the national level.
Domestic trade	**B** — The presence of this pest in commercial production areas is likely to have a significant effect at the local level due to any resulting interstate trade restriction on a wide range of commodities.
International trade	**C** — The presence of this pest in commercial mango production areas is likely to have a significant effect at the district level due to any limitations to access to overseas markets where this pest is absent.
Environment	**A** — Although additional pesticide applications would be required to control *O. australis postica* on susceptible crops, this is unlikely to affect the environment. The consequences are estimated to be of minor significance at the local level and are unlikely to be discernable at the district level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall 'probability of entry, establishment or spread' with the 'consequences' using the risk estimation matrix (Table 6): **Negligible**.

Mango Thrips

Thrips are minute insects with short segmented antennae, rasping and sucking mouthparts, and narrow wings. Both nymphs and adults feed by puncturing, lacerating and rasping the surface of leaves and other plant parts (Srivastava 1997).

The thrip species [Thysanoptera: Thripidae: Panchaetothripinae] examined in this pest risk analysis is:

- *Rhipiphorothrips cruentatus* Hood, 1919 – mango thrips or grapevine thrips

Introduction and spread potential

Probability of importation

The likelihood that *R. cruentatus* will arrive in Australia with the importation of fresh mangoes from Taiwan: **Moderate**.

- Mango thrips are known to be associated with mango fruit in Taiwan. Injury to the fruit occurs when thrips puncture the tissues during feeding (Lee and Wen 1982).
- Damaged fruit show discoloration of tissues at the feeding site (Ikisan 2000). Quality inspection procedures performed in the packhouse are likely to detect fruit with blemishes, bruising or damage to the skin.
- Mango thrips are small (1.2-1.5 mm) and may be inconspicuous on fruit.
- Post harvest grading, cleaning and packing procedures are likely to reduce the incidence of mango thrips on the fruit.
- Adult females can live for up to 20 days (Rahman and Bhardwaj 1937). Thrips on the fruit may survive storage and transportation and still be viable on arrival in Australia.

Probability of distribution

The likelihood that *R. cruentatus* will be distributed as a result of the processing, sale or disposal of fresh mangoes from Taiwan, to the endangered area: **Moderate**.

- Thrips on fruit may survive storage and transportation; however, adults do not tolerate temperatures below 4 °C for more than 5 hours (Rahman and Bhardwaj 1937).
- Adult females can live for up to 20 days (Rahman and Bhardwaj 1937).
- Thrips may remain with the commodity during distribution throughout Australia for wholesale or retail trade. The intended use of the commodity is human consumption, but waste material would be generated
- Thrips may be dispersed by wind, or carried by vectors.

Probability of entry (importation × distribution)

The likelihood that *R. cruentatus* will arrive in Australia as a result of trade in fresh mangoes from Taiwan, and be distributed to the endangered area: **Low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *R. cruentatus* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

- Mango thrips are polyphagous and host plants are common in Australia (e.g. mango and grapevine).
- Mango thrips have a moderate reproductive rate. On wax apples in Taiwan, females each produced about 13 eggs and reproduction is continuous (CAB International 2005; Chiu 1984). In India there are 5-8 generations annually (Rahman and Bhardwaj 1937), and the thrips over-winter in a pupal-like phase.
- Although sexual reproduction is normal for the mango thrips, parthenogenesis is also possible (CAB International 2005).
- The warmer regions of Australia would be suitable for the survival and reproduction of mango thrips. Mango thrips are able to survive brief exposure to cold temperatures. (Rahman and Bhadwaj 1937).
- Existing control programs may be effective for some hosts, but not all (e.g. where specific integrated pest management programs are used).

Probability of spread

The likelihood that *R. cruentatus* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **High**.

- The polyphagous nature of these thrips could enable them to locate suitable hosts in the intervening areas between production areas.
- Thrips have limited independent dispersal capabilities and are more likely to disperse in association with host plant material. Movement of commodities may aid in the dispersal of thrips. Adults and immature forms may spread undetected via the movement of fruit or infested vegetative host material.
- Environmental conditions (eg temperature, rainfall) similar to those in Taiwan occur in parts of Australia where suitable hosts are found.
- Existing control programs may be effective for some hosts, but not all (e.g. where specific integrated pest management programs are used).

Probability of entry, establishment or spread

The overall likelihood that *R. cruentatus* will enter Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Australia: **Low**.

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *R. cruentatus*: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *R. cruentatus* causes direct harm to a range of host plants including mango and grapevine by puncturing and sucking the sap from the epidermis of leaves and fruit. Affected areas turn dark, leaves curl and drop. In extreme cases, there may be complete defoliation of the host plant. Feeding wounds also serve as sources of entry for fungal attack (Lee and Wen 1982). Mango thrips are estimated to have consequences that are of minor significance at the regional level and are unlikely to be discernible at the national level.
Any other aspects of the environment	**A** — Introduced into a new environment, *R. cruentatus* may compete for resources with native species. *R. cruentatus* is estimated to have consequences that are of minor significance at the local level and unlikely to be discernible at the national level.
Indirect consequences	
Eradication, control etc.	**B** — Additional programs to minimise the impact of this pest on host plants may be necessary. Existing control programs can be effective for some hosts (e.g. broad spectrum pesticide applications) but not for all hosts (e.g. where specific integrated pest management programs are used). *R. cruentatus* is estimated to have consequences that are significant at the local level and unlikely to be discernable at the regional level.
Domestic trade	**B** — The presence of these pests in commercial production areas may have a significant effect at the local level because of any resulting interstate trade restrictions on a range of commodities. These restrictions can lead to a loss of markets, which in turn would be likely to require industry adjustment. *R. cruentatus* is estimated to have consequences for domestic trade that are significant at the local level and unlikely to be discernable at the regional level.
International trade	**C** — The presence of this pest in commercial production areas of commodities such as mango and grapevine could have a significant effect at the district level because of any limitations to accessing to overseas markets where this pest is absent.
Environment	**A** — Although additional pesticide applications would be required to control this pest on susceptible crops, this is estimated to have consequences that are minor at the local level and unlikely to be discernable at the district level.

Note: Refer to "Method for Pest Risk Analysis" section (text under the heading 'Assessment of consequences' and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Very low**.

Pathogen

Mango scab

Mango scab has only been recorded as infecting mango. The fungus is spread by rain splash and requires wet weather to produce new infections. Spores of the asexual stage cause the majority of new infections. Disease symptoms are extremely diverse and vary with the host condition and availability of free water. The mango scab [Dothideales: Elsinoaceae] examined in this pest risk analysis is:

- **Elsinoë mangiferae* Bitancourt & Jenkins Hood – mango scab

*This species is a quarantine pest for the State of Western Australia only.

Introduction and spread potential

Probability of importation

The likelihood that *E. mangiferae* will arrive in Western Australia with the importation of fresh mango fruit from Taiwan: **Low**.

- The conidia of *E. mangiferae* can only infect young tissue of the leaves, stem, flower, fruit stalk and young fruit. Fruit is no longer susceptible after it reaches about half size.
- Heavily affected fruit falls off the tree prematurely (CAB International 2005).
- Due to the visible symptoms of the disease on any mature fruit remaining on the tree, most infected fruit will be discarded during sorting, although some fruit with minor symptoms may not be observed and may be exported.
- The pathogen is likely to survive storage and transport. Partially developed infection may progress to visible lesions ranging from small black spots to small or large scarred areas during storage and transport (CAB International 2005).

Probability of distribution

The likelihood that *E. mangiferae* will be distributed as a result of the processing, sale or disposal of mango fruit from Taiwan in Western Australia: **Moderate**.

- The pathogen is likely to survive storage and transport. Partially developed infection may progress to visible lesions ranging from small black spots to small or large scarred areas during storage, transport or during distribution (CAB International 2005).

- The intended use of the commodity is human consumption, but waste material would be generated.
- This species is a quarantine pest for the State of Western Australia due to its absence from this state, but imported mangoes will be distributed throughout Australia. Approximately 10% of the commodity will go into WA, therefore reducing the probability of distribution to the PRA area.

Probability of entry (importation × distribution)

The likelihood that *E. mangiferae* will enter Western Australia as a result of trade in fresh mangoes from Taiwan, and be distributed in a viable state to the endangered area: **Low**.

The overall probability of entry is determined by combining the likelihoods of importation and of distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Probability of establishment

The likelihood that *E. mangiferae* will establish based on a comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **Moderate**.

- The host range of *E. mangiferae* is limited to mango.
- Conducive conditions for the establishment of *E. mangiferae* may occur in some production areas in Western Australia during the growing season. *E. mangiferae* was recorded in Australia (in Northern Territory and Queensland). Active lesions, characterised by pale brown growth of the conidiophores and conidia, have only been found during wet weather (CAB International 2005).
- Only young tissue is susceptible to infection, for instance fruit is no longer susceptible after it reaches about half size (Conde *et al*.1997).
- The skin of infected fruit may be discarded into environments containing the host. Therefore, the pathogen may survive and infect a mango host nearby, especially in the warmer subtropical and tropical regions of Western Australia where mangoes are grown.

Probability of spread

The likelihood that *E. mangiferae* will spread based on a comparative assessment of those factors in the area of origin and in Australia considered pertinent to the expansion of the geographical distribution of the pest: **Moderate**.

- Arid tropical or subtropical environments of Western Australia would be suitable for the spread of *E. mangiferae* if mango hosts were available.

- The pathogen requires rain splash and periods of free water to produce conidia and for the germination of these conidia to produce new infections.
- Sexual stages of the fungus (ascospores) were only rarely found and asexual conidia were responsible for the bulk of infections (CAB International 2005).

Probability of entry, establishment or spread

The overall likelihood that *E. mangiferae* will enter Western Australia as a result of trade in fresh mangoes from Taiwan, be distributed in a viable state to suitable hosts, establish in that area and subsequently spread within Western Australia: **Low**

The probability of entry, establishment or spread is determined by combining the likelihoods of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihoods (Table 4).

Consequences

Consequences (direct and indirect) of *E. mangiferae*: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — *E. mangiferae* is likely to cause significant direct harm to mango production at the district level. Newly set fruit develop small black spots and when affected by several black lesions the fruit drop off. Affected fruit remaining on the tree develop scar tissue that renders them unmarketable or causes downgrading. Scab infections in mango nurseries can be very severe (Conde *et al*. 1997). *E. mangiferae* is estimated to have consequences that are significant at the district level and unlikely to be discernable at the national level.
Any other aspects of the environment	**A** — *E. mangiferae* only affects mango, and is estimated to have consequences that are minor at the local level and unlikely to be discernable at the district level.
Indirect consequences	
Eradication, control etc.	**B** — Programs to minimise the impact of this disease on host plants are likely to be required and are likely to incur costs for fungicide sprays and additional crop monitoring. *E. mangiferae* is estimated to have consequences that are significant at the local level and unlikely to be discernable at the regional level.
Domestic trade	**B** — The presence of this disease in commercial production areas may have a significant effect at the local level because of any resulting interstate trade restrictions on mangoes within Western Australia. *E. mangiferae* is estimated to have consequences for domestic trade that are significant at the local level and unlikely to be discernable at the regional level.
International trade	**B** — The presence of this disease in commercial production areas of mango may have a significant effect at the local level because of any limitations to access to overseas markets where this pest is absent. *E. mangiferae* is estimated to have consequences for international trade that are significant at the local level and unlikely to be discernable at the regional level.
Environment	**A** — Although additional fungicide applications would be required to control this disease on mango, this is unlikely to affect the environment. *E. mangiferae* is estimated to have consequences that are minor at the

	local level and unlikely to be discernable at the district level.

Note: Refer to “Method for Pest Risk Analysis” section (text under the heading ‘Assessment of consequences’ and Table 5) for details on the method used for consequence assessment.

Unrestricted risk estimate

The unrestricted risk estimate as determined by combining the overall ‘probability of entry, establishment or spread’ with the ‘consequences’ using the risk estimation matrix (Table 6): **Very low.**

Table 8: Summary of pest risk assessments and unrestricted risk estimates

Pest name	Probability of					Overall probability of entry, of establishment and of spread	Consequences	Unrestricted Risk
	Entry			Establishment	Spread			
	Importation	Distribution	Overall probability of entry					
ARTHROPODS (no.)								
Oriental fruit fly	High	High	High	High	High	High	High	**High**
Melon fruit fly	Very Low	High	Very low	High	Moderate	Very low	High	**Low**
Solanum fruit fly	Negligible	High	Negligible	High	High	Negligible	High	Negligible
Pumpkin fruit fly	E. Low	High	E. Low	High	High	E. Low	High	Very low
Armoured scales (5)	High	Moderate	Moderate	High	Moderate	Low	Low	Very low
Soft scales (2)	High	Moderate	Moderate	High	Moderate	Low	Low	Very low
Mealybugs (4)	High	Moderate	Moderate	High	High	Moderate	Low	**Low**
Mango aphid	Low	Low	Very low	High	High	Very low	Low	Negligible
Cocoa tussock moth	Low	Low	Very low	Moderate	Moderate	Very low	Low	Negligible
Mango thrips	Moderate	Moderate	Low	High	High	Low	Low	Very low
PATHOGEN								
Mango scab	Low	Moderate	Low	Moderate	Moderate	Low	Low	Very low

Risk assessment conclusion

Table 8 summarises the detailed risk assessments and provides unrestricted risk estimates for the quarantine pests considered to be associated with mangoes from Taiwan.

Oriental fruit fly was assessed to have an unrestricted risk estimate of ‘high’, while melon fly and mealybugs were assessed to have unrestricted risk estimates of ‘low’. These risks are above Australia’s ALOP. Phytosanitary risk management measures are therefore required. The remaining pests were assessed to have an unrestricted risk of ‘very low’ or below and therefore they do not require the application of any specific phytosanitary measures in order to meet Australia’s ALOP.

Table 9 provides the final list of quarantine pest of mangoes from Taiwan that require the use of phytosanitary risk management measures in addition to the standard cultivation, harvesting and packing activities used in the commercial production of mangoes in Taiwan to meet Australia’s ALOP. The recommended risk management measures are described in the following section.

Table 9: Quarantine pests of mangoes from Taiwan assessed to have an unrestricted risk estimate that does not meet Australia’s ALOP and requires risk management measures

Pest	Common name
ARTHROPODS	
Bactrocera cucurbitae (Coquillett, 1899) [Diptera: Tephrididae]	melon fruit fly
Bactrocera dorsalis (Hendel, 1912) [Diptera: Tephrididae]	Oriental fruit fly
Planococcus lilacinus (Cockerell, 1905) [Hemiptera: Pseudococcidae]	coffee mealybug
Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae]	citriculus mealybug
Pseudococcus jackbeardsleyi Gimpel & Miller [Hemiptera: Pseudococcidae]	Jack Beardsley mealybug
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	Philippine mango mealybug

Stage 3: Pest Risk Management

Pest risk management evaluates and selects measures to reduce the risk of entry, establishment or spread of quarantine pests with an unrestricted risk estimate that does not meet Australia’s ALOP. In this case, risks are due to the importation of commercially produced mangoes from Taiwan, i.e. fruit from commercial production sites and subjected to standard cultivation, harvesting and packing activities.

Unrestricted risk estimates should take into account only the minimum border procedures used by relevant government agencies and not measures intended to mitigate risks associated with the commodity itself. The minimum procedures include verifying that the commodity is as described in the shipping documents and identifying external and internal contamination of containers and packaging.

Risk management measures and operational systems

Biosecurity Australia considers that the risk management measures recommended in this report, implemented in conjunction with the operational system for the maintenance and verification of the phytosanitary status of mangoes from Taiwan, will provide an appropriate level of protection against the pests identified in the risk assessment.

The following risk management measures and phytosanitary procedures are recommended to mitigate the risks identified in the PRA:

- pre-export vapour heat treatment (VHT) for the management of fruit fly species;
- inspection and remedial action for mealybugs; and
- supporting operational systems to maintain and verify phytosanitary status.

The measures described in detail below will form the basis of the import conditions for fresh mangoes from Taiwan.

Biosecurity Australia does, however, recognise that other risk management measures may be suitable to manage the risks associated with mangoes from Taiwan and it will consider any other measures that would provide an equivalent level of protection.

[1] Pre-export disinfestation for the management of fruit fly species

Bactrocera cucurbitae (melon fly) and *B. dorsalis* (Oriental fruit fly) have been assessed to have an unrestricted risk estimate of ‘low’ and ‘high’ respectively for mangoes from Taiwan and therefore require measures to mitigate that risk.

Visual inspection alone is not considered to be an appropriate risk management option in view of the level of risk identified and because clear visual signs of infestation (particularly in recently infested fruit) may not be present. If infested fruit was not detected at inspection, fruit flies might enter, establish and spread in Australia.

Measures that might be applied to mitigate risks associated with fruit flies are either, the sourcing of fruit from pest free areas or the use of disinfestation treatments such as vapour heat treatment. These measures were identified as in-principle options for fruit flies.

Taiwan has identified VHT as their preferred treatment option against fruit flies for export of mangoes to Australia. Taiwan treats mango fruit with vapour heat for current export of mangoes from Taiwan to Japan and New Zealand.

Vapour heat treatment is used as an effective disinfestation treatment for certain fruit fly species in certain fruit in international trade.

In 2003, Taiwan proposed the use of VHT for the disinfestation of fruit flies. BAPHIQ provided a report ‘Vapour Heat Treatment for Elimination of *Dacus dorsalis* and *Dacus cucurbitae* Infested in Mango Fruits var. Haden’ (Ku *et al*. 1989) on the efficacy of using VHT for the disinfestation of for these species. Eggs and larvae of *Bactrocera dorsalis* (the most heat tolerant species) and *B. cucurbitae* were killed when the mango fruit pulp temperature was maintained at 46.5 °C for 30 minutes.

It has therefore been demonstrated that VHT proposed by Taiwan (Kuo *et al.* 1989) adequately mitigates the risk posed by fruit fly species of quarantine concern associated with mango fruit from Taiwan to a level that meets Australia’s ALOP.

Biosecurity Australia recommends the option of a pre-export VHT of 46.5 °C (fruit pulp temperature) for 30 minutes for all mango cultivars from Taiwan. The total treatment time would be for a minimum time of two hours, including both the warming and cooling periods to bring the fruit pulp to the target temperature. Treatment would commence when the fruit pulp temperature of all monitored fruit reaches, or is above, the required temperature (46.5 °C) and this temperature is maintained for the required period (30 minutes).

All registered treatment facilities would be inspected and audited by Biosecurity Australia and/ or AQIS before the commencement of exports to treat mangoes for export to Australia. Subsequently, registered treatment facilities would be annually inspected and audited by BAPHIQ and AQIS would audit as required. Details of the treatment and temperature values would be recorded and monitored by BAPHIQ.

The quarantine security of the product would be maintained after the VHT to prevent reinfestation by fruit flies during storage, movement and shipping of the treated fruit. Phytosanitary inspection of the treated fruit would be conducted by BAPHIQ and the details of the treatment included on the Phytosanitary Certificate (see measure 3f).

[2] Inspection and remedial action for mealybugs

Mealybugs *Pseudococcus cryptus* (citriculus mealybug), *P. jackbeardsleyi* (Jack Beardsley mealybug), *Planococcus lilacinus* (coffee mealybug) and *Rastrococcus spinosus* (Philippine mango mealybug) were assessed as having an unrestricted risk estimate of ‘low’, therefore measures are required to mitigate that risk.

Biosecurity Australia considers that, for the fruit sourced from registered export orchard growers, consignment freedom from mealybugs can be verified by targeted visual inspection pre-export and on-arrival in view of the level of risk identified and given trained inspectors can readily detect these pests. Mango fruit would be inspected for the presence of the mealybugs. Visual inspection would involve the examination of a 600-unit sample of mango fruit to detect the presence of mealybugs during pre-export inspection in Taiwan

(3e) and on-arrival clearance in Australia (3g). Pre-export inspection is to be completed after VHT.

Remedial action when pests are detected is required as the risk management option for these pests. If infested fruit was not inspected and detected, these pests might enter, establish and spread in Australia. The objective of this measure is to ensure that consignments of mangoes from Taiwan infested with these pests can be identified and subjected to remedial action. Biosecurity Australia considers that this measure is appropriate to mitigate the risk associated with mealybugs to 'very low', which meets Australia's ALOP.

[3] Operational systems for the maintenance and verification of phytosanitary status

It is necessary to have a system of operational procedures in place to ensure that the phytosanitary status of mangoes from Taiwan is maintained and verified during the process of production and export to Australia. This is to ensure that the objectives of the risk mitigation measures previously identified have been met and are being maintained.

Biosecurity Australia recommends a system for that purpose which is equivalent to the system currently in place for the importation of fresh mangoes from the Republic of the Philippines (Guimaras Island). This is to ensure that requirements are appropriate to the circumstances of Taiwan for mango production and export.

The recommended system of operational procedures for the production and export of fresh mangoes to Australia from Taiwan consists of:

- registration of export orchards;
- registration of packhouses and auditing of procedures;
- packaging and labelling;
- specific conditions for storage and movement of treated produce;
- phytosanitary certification by BAPHIQ;
- pre-export phytosanitary inspection and remedial action by BAPHIQ; and
- on-arrival phytosanitary inspection and remedial action, and clearance by AQIS.

[3a] Registration of export orchards

All mango fruit for export to Australia must be sourced from export orchards and growers registered with BAPHIQ. The BAPHIQ is required to register all export orchards before exports commence.

The hygiene of export orchards must be maintained by appropriate pest management options that have been approved by BAPHIQ, to manage pest and diseases of quarantine concern to Australia. Registered growers must keep records of control measures for auditing purposes. Information on BAPHIQ approved orchard control program and audit records must be made available to AQIS if requested.

The objective of this procedure is to ensure that orchards from which mangoes are sourced can be identified. This is to allow trace-back to individual orchards and growers in the event of non-compliance. For example, if live pests are intercepted, the ability to identify a specific orchard/grower allows the investigation and corrective action to be targeted rather than applying to all contributing orchards.

[3b] Registration of packhouses, treatment facilities and auditing of procedures

Registration of all packhouses and treatment facilities in the initial export season is to include an audit program conducted by Biosecurity Australia and/or AQIS of the packhouses and treatment facilities before exports commence. After the initial approval of the registered packhouses and treatment facilities, AQIS will require BAPHIQ to audit the facilities at the beginning of each season to ensure that packhouses are suitably equipped to carry out the specified phytosanitary tasks and treatments. Records of annual BAPHIQ audits must be available to AQIS on request.

All packhouses intending to export mango fruit to Australia need to be registered with BAPHIQ for trace-back purposes.

Vapour heat treatment for pre-export disinfestation of fruit flies is to be performed within the registered packhouses/treatment facilities in Taiwan. AQIS will only accept designated and identified VHT facilities that are registered by BAPHIQ.

The targeted inspection for freedom from fruit fly and mealybugs is to be carried out within the registered packhouses following VHT.

Packhouses are required to identify the individual orchard with a numbering system and identify fruit from individual orchards. The list of registered packhouses must be kept by BAPHIQ before the export season commences, with any updates provided when packhouses are added or removed from the list. Packhouse registration records must be made available to AQIS if required.

The objective of this procedure is to ensure that packhouses at which the VHT and inspections are conducted can be identified. This is to allow trace-back to individual packhouses and orchards/growers in the event of non-compliance.

[3c] Packing and labelling

All packages of mangoes for export to Australia are to be free from all regulated articles[1] and pests of quarantine concern to Australia, and must also meet Australia's general import conditions for fresh fruit and vegetables (*C6000 General Requirements for all fruit and vegetables*, available at http://www.aqis.gov.au/icon/).

Treated and inspected fruit is required to be packed in new boxes. Packing material is to be synthetic or highly processed if of plant origin. No unprocessed packing material of plant origin, such as straw, will be allowed. All wood material used in packaging of mango fruit must comply with the AQIS conditions (e.g. those in '*Cargo containers: Quarantine aspects and procedures*' (AQIS 2005)).

All boxes should be labelled with the packhouse registration number and treatment facility number for the purposes of trace-back in the event that this is necessary. Where boxes are palletised, the pallets are to be securely strapped only after phytosanitary inspection has been carried out following mandatory post-harvest treatments. Palletised product is to be identified by attaching a uniquely numbered pallet card (containing the information that would be included on the boxes) to each pallet or part pallet to enable trace back to registered orchards.

The objectives of this procedure are to ensure that:

- the mango fruit exported to Australia is not contaminated by quarantine pests or regulated articles;
- unprocessed packing material (which may vector pests identified as not on the pathway and pests not known to be associated with mangoes) is not imported with the mangoes; and
- the packaged mango fruit are labelled in such a way to identify the packhouse and treatment facility (see measures 3a,b).

[3d] Storage and movement

Packed product and packaging is to be protected from pest contamination during and after packing, after treatment, after inspection, during storage, during movement between locations (e.g. packhouse to cool storage/depot, to inspection point, to export point) and shipping.

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[1] The IPPC defines regulated article as "any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved".

Product for export to Australia that has been treated, inspected and certified by BAPHIQ must be maintained in a secure manner to prevent mixing with untreated fruit for export to other destinations or any fruit for domestic market, in order for the quarantine integrity of the fruit to be maintained.

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

[3e] Pre-export phytosanitary inspection and remedial action by BAPHIQ

BAPHIQ will inspect all consignments for all visually detectable quarantine pests and other regulated articles (e.g. trash). The BAPHIQ export inspections should be on treated and packed fruit. The AQIS sampling protocol requires inspection of 600 units (mango fruit) for quarantine pests, in systematically selected random samples per homogeneous consignment[2] or lot[3].

Biometrically, if no pests are detected by the inspection, this sample size achieves a confidence level of 95% that not more than 0.5% of the units in the consignment are infested / infected. The level of confidence depends on each fruit in the consignment having about the same likelihood of being affected by a quarantine pest and the inspection technique being able to reliably detect all quarantine pests in the sample. For mangoes, AQIS defines a unit as a single mango fruit.

The detection of quarantine pests or regulated articles during an inspection will result in the failure of the inspection lot. Remedial action may then be taken. Action may include:

- withdrawing the consignment from export to Australia; or
- treatment and re-inspection of the consignment to ensure that the pest is no longer viable.

If live fruit flies are detected in the consignments, the treatment facility must be suspended until AQIS/Biosecurity Australia and BAPHIQ are satisfied that appropriate corrective action has been taken.

Records of interceptions made during these inspections (live or dead quarantine pests, and regulated articles) are to be maintained by BAPHIQ and made available to Biosecurity Australia if 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.

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[2] A consignment is the number of boxes of mango fruit from shipment from Taiwan to Australia covered by one phytosanitary certificate.

[3] An inspection lot is the number of boxes presented for a single phytosanitary inspection.

The objective of this procedure is to verify the effectiveness of orchard and packhouse controls and to ensure that mango fruit exported to Australia do not contain quarantine pests or regulated articles, and comply with packing and labelling requirements.

[3f] Phytosanitary certification by BAPHIQ

BAPHIQ will issue an International Phytosanitary Certificate (IPC) for each consignment upon completion of pre-export treatment and phytosanitary inspection. The objective of this procedure is to provide formal documentation to AQIS verifying that the relevant measures have been undertaken offshore.

Each IPC is to contain the following information that is consistent with *ISPM No. 7 Export Certification Systems* (FAO 1997):

Additional declarations

"*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*".

Distinguishing marks

The packhouse registration number/treatment centre registration number, number of boxes per consignment, 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.

Treatments

Details of VHT (i.e. fruit pulp temperature, duration and packhouse/treatment facility number, date) must be included in the treatment section on the IPC.

A consignment is the quantity of mango fruit covered by one IPC that arrives at one port in one shipment. Consignments need to be shipped directly from one port or city in Taiwan to a designated port or city in Australia or transhipped in sealed containers.

[3g] On-arrival phytosanitary inspection and remedial action, and clearance by AQIS

On arrival in Australia, each consignment will be inspected by AQIS. AQIS undertakes documentation compliance examination for consignment verification purposes at the first port of entry in Australia before inspection, clearance and release from quarantine.

The standard AQIS inspection protocol will apply. Fruit from each consignment will be randomly sampled for inspection. The sampling methodology provides 95% confidence that there is not more than 0.5% infestation in a consignment. No land bridging of goods will be permitted unless goods have cleared quarantine. The detection of quarantine pests and/or regulated articles will result in the failure of the inspection lot.

The objective of this procedure is to verify that the required measures have been adequately undertaken in the exporting country.

[4] Action for non-complying lots

Where inspection lots are found to be non-compliant with import requirements at AQIS on-arrival inspection because of the presence of quarantine pests or other regulated articles, remedial action must be taken. Action may include:

- re-export of the consignment from Australia; or
- destruction of the consignment; or
- treatment (where an appropriate treatment is available) and re-inspection of the consignment to ensure that the pest is no longer viable.

If live fruit flies are detected in the consignments, the treatment facility will be suspended until AQIS/Biosecurity Australia and BAPHIQ are satisfied that appropriate corrective action has been taken.

If product continually fails to comply with the import requirements, Biosecurity Australia and/or AQIS reserve the right to suspend the mango exports from Taiwan and conduct an audit of the mango export management systems in Taiwan. The program will recommence only after Biosecurity Australia and/or AQIS are satisfied that appropriate corrective action has been taken.

[5] Uncategorised pests

If an organism that is detected on mangoes from Taiwan has not been categorised, it will require assessment to determine its quarantine status and whether phytosanitary action is required. The detection of any significant pests of quarantine concern not already identified in the analysis may result in the suspension of the trade while a review is conducted to ensure that the existing measures continue to provide the appropriate level of phytosanitary protection for Australia.

IMPORT CONDITIONS

The components of the final import conditions are summarised in dot point format below. The recommended risk management measure that links with each component is given in parentheses.

Biosecurity Australia considers that the risk management measures and operational systems identified in the previous section, upon which these import conditions are based, are commensurate with the identified risks. Note that Biosecurity Australia regards the import conditions listed below to be consistent with, and equivalent to, those currently in place for the importation of fresh mangoes from the Republic of the Philippines (Guimaras Island).

- Registration of export orchards (3a);
- Registration of packhouses, treatment facilities and auditing of procedures (3b);
- Pre-export vapour heat treatment for fruit flies (1a);
- Packing and labelling (3c);
- Storage and movement (3d);
- Pre-export inspection and remedial action by BAPHIQ (2, 3a, 3e);
- Phytosanitary certification by BAPHIQ (3f);
- On-arrival quarantine inspection and remedial action, and clearance by AQIS (2, 3a, 3b, 3g, 4);
- Uncategorised pests (5);
- Audit of protocol; and
- Review of policy.

1 Registration of export orchards

All mango fruit for export to Australia must be sourced from export orchards and growers registered with BAPHIQ before the commencement of the export season. Registration by BAPHIQ is required to enable trace-back in the event of non-conformity.

All export orchards must produce commercial mango fruit under standard cultivation, harvesting and packing activities. Registered export orchard growers must implement an orchard control program (i.e. good agricultural practices and/ general hygiene programs for export fruit) that has been approved by BAPHIQ, incorporating field sanitation and appropriate biocontrol and/or pesticide applications for the management of quarantine pests of concern to Australia.

Registration of export orchards is to include an audit program conducted by BAPHIQ to ensure that a BAPHIQ-approved orchard control program has been implemented. An audit is to be conducted for registration and then conducted annually. Information on BAPHIQ approved orchard control program and audit records must be made available to AQIS if requested.

2 Registration of packhouses, treatment facilities and auditing of procedures

Registration of all packhouses and treatment facilities in the initial export season is to include an audit program conducted by Biosecurity Australia and/or AQIS of the packhouses and treatment facilities before exports commence. After the initial approval of the registered packhouses and treatment facilities, AQIS will require BAPHIQ to audit the facilities at the beginning of each season to ensure that packhouses are suitably equipped to provide security of fruit against reinfestation/reinfection. Records of annual BAPHIQ audits must be available to AQIS on request.

Inspection for freedom from quarantine pests and regulated articles is to be carried out within the registered packhouses.

Packhouses are required to identify the individual orchard with a numbering system and identify fruit from individual orchards. The list of registered packhouses must be kept by BAPHIQ before the export season commences, with any updates provided when packhouses are added or removed from the list. Packhouse registration records must be made available to AQIS if required.

If any new pest of potential quarantine concern to Australia is detected, BAPHIQ must notify Biosecurity Australia and/or AQIS immediately to ensure appropriate action is taken.

3 Pre-export vapour heat treatment (VHT)

The export fruit must undergo vapour heat treatment for fruit fly disinfestation prior to export.

Vapour heat treatment for pre-export disinfestation for fruit flies is to be conducted within the registered packhouses and VHT facilities registered with, and audited by, BAPHIQ to ensure they are suitably equipped to carry out the specified VHT.

All treatment facilities must have heat treatment equipment capable of achieving and maintaining the required fruit pulp temperatures. Treatment facilities must keep records of temperature and humidity values of all fruit lot treatments for audit purposes by BAPHIQ and AQIS.

AQIS will only accept designated and identified VHT facilities that are approved and registered by BAPHIQ.

Registered facilities must be initially inspected and audited by quarantine officials from Biosecurity Australia and/or AQIS before the commencement of treatment of mango fruit for export to Australia.

Facilities must be designed to prevent the entry of fruit flies into areas where unpacked and packed treated fruit is held and include a provision for treated fruit to be discharged directly into insect-proof and secure packing rooms. The management of the treatment facility will be required to provide details of the systems in place to ensure isolation and segregation from other fruit throughout the treatment, packing, storage and transport stages before exports commence. These details would be audited for compliance with AQIS requirements in the initial export season.

Subsequently, any additional un-registered treatment facilities must be inspected and audited by quarantine officials from Biosecurity Australia and/or AQIS before they commence treating mango fruit for export to Australia. All costs associated with Biosecurity Australia and/or AQIS audits or inspections are to be paid for by Taiwan.

AQIS will require BAPHIQ to audit the treatment facilities at the beginning of each season to ensure that they comply with AQIS requirements before registration is renewed. BAPHIQ is to monitor the treatment facilities throughout their operational season to ensure continued compliance with AQIS requirements. Reports of BAPHIQ audits noting any non-conformity together with appropriate corrective action would be submitted to AQIS if requested.

BAPHIQ officers will ensure the following:

- registered treatment facilities are maintained in a condition that will provide efficacy in treatment programs;
- all areas are hygienically maintained (cleaned daily of damaged, blemished, infested fruit);
- premises are maintained to exclude the entry of pests from outside and between treated and untreated fruit;
- all measurement instruments are regularly calibrated and records are retained for verification;
- records kept of the movements of fruit from the time of arrival at the registered treatment centre through to the time of export; and
- security of fruit is maintained at all times when fruit is on the premises.

BAPHIQ must monitor all heat treatments. Mango fruit must be treated at or above 46.5 °C (fruit pulp temperature) for a minimum of 30 minutes in accordance with the following schedule:

- Treatment time will be for a minimum of two hours, including the warming and cooling periods to bring the fruit pulp to the required temperature (46.5 °C).
- Treatment commences when the fruit pulp temperature of all probe-monitored fruit reaches, or is above, the required temperature. This temperature must be maintained for the required period (30 minutes).

Details of the treatment and temperature values must be recorded and monitored by BAPHIQ and forwarded to AQIS as an attachment to the Phytosanitary Certificate.

The phytosanitary security of the product must be maintained after the VHT to prevent reinfestation by fruit flies or any other external pests. Phytosanitary inspection of the treated fruit must be conducted by BAPHIQ and the details of the treatment included on the Phytosanitary Certificate.

4 Packing and labelling

All packages of mangoes for export must be free from regulated articles and must meet Australia’s general import conditions for fresh fruits and vegetables (*C6000 General requirements for all fruit and vegetables*, available at http://www.aqis.gov.au/icon/).

BAPHIQ must ensure that fruit destined for Australia is not mixed with fruit for other destinations. The identity and origin of the fruit for export must be maintained throughout the packing process.

Treated and inspected fruit for export to Australia will be required to be packed in new boxes. Packing material must be synthetic or highly processed if of plant origin. No unprocessed packing material of plant origin, such as straw, will be allowed. All wood material used in packaging of mango fruit must comply with the AQIS conditions (e.g. those in ‘*Cargo containers: Quarantine aspects and procedures*’ (AQIS 2005)).

All boxes should be labelled with the packhouse/treatment facility registration number for the purposes of trace-back if that is necessary. If boxes are palletised, the pallets should be securely strapped only after phytosanitary inspection has been carried out following mandatory post-harvest treatments. Palletised product is to be identified by attaching a uniquely numbered pallet card to each pallet or part pallet to enable trace-back to packhouses and treatment facilities.

5 Storage and movement

Product, and its packaging, are to be protected from pest contamination during and after treatment packing, during storage and during movement between locations (that is, from packhouse to cool storage/depot, to inspection point, to export point) and shipping.

Product for export to Australia that has been inspected and certified by the BAPHIQ must be maintained in secure conditions that will prevent mixing with untreated fruit for export to other destinations or any fruit for domestic market using one of the following methods:

- packed fruit can be directly transferred at the packhouse into a shipping container, which is to be sealed and not opened until the container reaches Australia; or
- fruit packed into boxes installed with screened ventilation holes; the screening mesh size not to exceed 1.6 mm and not less than 0.16 mm strand thickness; or
- segregation of fruit for export to Australia in separate storage facilities; or
- packed fruit boxes on pallets shrink-wrapped in plastic or netted; or
- sealed boxes kept in cold storage before loading into a shipping container.

BAPHIQ must ensure that records are properly maintained to facilitate auditing of fruit during or after storage. Security of the consignment is to be maintained until arrival in Australia to protect from pest contamination.

6 Pre-export inspection and remedial action by BAPHIQ

BAPHIQ will inspect all consignments for all visually detectable quarantine pests and regulated articles[4]. The BAPHIQ export inspections should be on treated and packed fruit. The AQIS sampling protocol requires inspection of 600 units for quarantine pests, in systematically selected random samples per homogeneous consignment[5] or lot[6]. For mangoes, AQIS defines a unit as one mango fruit. Biometrically, if no pests are detected by the inspection, this size sample achieves a confidence level of 95% that not more than 0.5% of the units in the consignment are infested / infected. The level of confidence depends on each fruit in the consignment having about the same likelihood of being affected by a quarantine pest and the inspection technique being able to reliably detect all quarantine pests in the sample.

The detection of quarantine pests or regulated articles during the inspection will result in the failure of the inspection lot. The following remedial action must be taken:

- withdrawing the consignment from export to Australia; or

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[4] The IPPC defines regulated article as “any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved”.

[5] A consignment is the number of boxes of mango fruit from shipment from Taiwan to Australia covered by one phytosanitary certificate.

[6] An inspection lot is the number of boxes presented for a single phytosanitary inspection.

- treatment and re-inspection of the consignment to ensure that the pest is no longer viable.

If live fruit flies are detected in the consignments, the treatment facility must be suspended until AQIS and/or Biosecurity Australia and BAPHIQ are satisfied that appropriate corrective action has been taken.

The inspection must be undertaken on packed fruit in boxes that have already undergone the heat treatment, and must be completed in packhouses that are registered with, and audited by, BAPHIQ. Records of interceptions made during these inspections (live or dead quarantine pests and regulated articles) are to be maintained by BAPHIQ and made available to Biosecurity Australia 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.

7 Phytosanitary certification by BAPHIQ

BAPHIQ is required to issue an International Phytosanitary Certificate (IPC) for each consignment upon completion of treatment for fruit flies and pre-export inspection. Each IPC is to contain the following information:

Additional declaration

Additional declaration stating:

"*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*".

Distinguishing marks

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

A consignment is the quantity of mango fruit covered by one Phytosanitary Certificate that arrives at one port in one shipment. Consignments need to be either shipped directly from one port or city in Taiwan to a designated port or city in Australia, or if transhipped in Taiwan or Australia, containers must remain sealed.

Treatments

Details of VHT (i.e. temperature, duration, packhouse/treatment facility number, and date of treatment) must be included in the treatment section on the Phytosanitary Certificate.

8 On-arrival quarantine inspection and remedial action, and clearance by AQIS

On arrival, AQIS will undertake a documentation compliance examination for consignment verification purposes at the port of entry in Australia prior to inspection and release from quarantine. Any ‘consignment’ with incomplete/inadequate documentation, or where certification does not conform to specifications, or seals on the containers are damaged or missing, will be held pending clarification by BAPHIQ and determination by AQIS, with the options of re-export or destruction. BAPHIQ will be notified by AQIS of any such problems.

Consignments will be inspected by AQIS using the standard AQIS inspection protocol. The sampling provides 95% confidence that there is not more than 0.5% infestation in a consignment. The detection of live quarantine pests and/or regulated articles will result in the failure of the inspection lot.

An example of a sample size for inspection of mangoes is given below. The unit is defined as single mango fruit.

Consignment size (Units*)	Sample size (Units)
For consignments of fruit of less than 1000 units	Either 450 units or 100% of consignment (whichever is smaller)
For consignments of fruit of greater than or equal to 1000 units	600 units

* Unit = one mango fruit

If no live quarantine pests are detected in the sample, the consignment is considered to be free from quarantine pests and will be released from quarantine. No land bridging of goods will be permitted unless goods have cleared quarantine.

Action for non-complying lots

Where consignments are found to be non-compliant with import requirements at AQIS on-arrival inspection because of the presence of quarantine pests or other regulated articles, remedial action will be taken. Remedial action is limited to:

- re-export of the consignment from Australia; or
- destruction of the consignment; or
- treatment (where an appropriate treatment is available) and re-inspection of the consignment to ensure that the pest is no longer viable.

If live fruit flies are detected in the consignments, exports from the relevant treatment facility will be suspended until AQIS/Biosecurity Australia and BAPHIQ are satisfied that appropriate corrective action has been taken.

If product continually fails to comply with the import requirements, Biosecurity Australia and/or AQIS reserves the right to suspend the mango exports from Taiwan and conduct an audit of the mango export management systems in Taiwan. The program will recommence only after Biosecurity Australia and/or AQIS are satisfied that appropriate corrective action has been taken.

Documentation errors

Any consignment with incomplete documentation, or where certification does not conform to specifications, or certification is not original, or seals on the containers are damaged or missing, will be held pending further clarification by BAPHIQ and determination by AQIS, with the options of re-export or destruction. BAPHIQ will be notified immediately by AQIS of any such problems.

9 Uncategorised pests

If an organism that is detected on mango from Taiwan has not been categorised, it will require assessment to determine its quarantine status and whether phytosanitary action is required. The detection of any pests of quarantine concern not already identified in the analysis may result in the suspension of the trade while a review is conducted to ensure that the existing measures continue to provide the appropriate level of phytosanitary protection for Australia.

10 Audit of protocol

During the first season of trade, an officer from Biosecurity Australia and/or an officer from AQIS will visit the areas in Taiwan designated for the export of mangoes to Australia to audit the operation of the protocol including registration, operational procedures and VHT facilities.

11 Review of policy

Biosecurity Australia reserves the right to review the adopted policy at any time after significant trade has occurred or when there is reason to believe that the phytosanitary status of the exporting country has changed.

CONCLUSIONS

The findings of this policy are based on a comprehensive analysis of relevant available scientific literature and existing import requirements for mangoes from the Republic of the Philippines (Guimaras Island) and Mexico.

Biosecurity Australia considers that the risk management measures recommended in this import of policy for fresh mangoes from Taiwan provide an appropriate level of protection against the quarantine pests identified in the PRA.

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APPENDIX 1: PEST CATEGORISATION FOR MANGOES FROM TAIWAN

* Pests listed in pest risk assessments for the importation of mangoes from the Republic of Philippines (Guimaras Island)(AQIS 1999) and/or India (DAFF 2004).

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
ARTHROPODA						
ACARINA						
Cisaberoptus kenyae Keifer Syn: *Cisaberoptus kenya* Huang [Acarina: Eriophyidae]	Mango leaf mite	Yes	Yes (Lee 1988; Huang *et al*. 1990)	Yes (Knihinicki & Boczek 2002)		No
Oligonychus mangiferus (Rahman & Sapra, 1940) Syns: *Paratetranychus insularis* McGregor; *Paratetranychus terminalis* Sayed; *Oligonychus terminalis* (Sayed) Basionym: *Paratetranychus mangiferus* Rahman & Sapra; [Acarina: Tetranychidae]	Mango red spider mite	Yes	Yes (Lee 1988)	Yes (Halliday 1998; 2000)		No
Tegonotus mangiferae (Keifer) [Acarina: Eriophyidae]	Mango leaf rust mite	Yes	Yes (Huang *et al*. 1990)	Yes (Knihinicki & Boczek 2002)		No
Tegonotus paramangiferae (Huang *et al*., 1989) [Acarina: Eriophyidae]		No	Yes (Huang *et al*. 1990)	No (Halliday 1998; 2000)	No. A pest of mango trees in Taiwan (Huang *et al*. 1990). No records of fruit attack found.	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Tetranychus cinnabarinus (Boisduval, 1867) [Acarina: Tetranychidae]	Carmine spider mite	Yes	Yes (Anon 1980)	Yes (Halliday 1998; 2000)		No
Tyrophagus longior (Gervais, 1844) [Acarina: Tetranychidae]	Seed mite	Yes	Yes (Tjying 1970; 1971)	Yes (Halliday 1998; 2000)		No
INSECTA						
COLEOPTERA						
Anomala anthusa Ohaus [Coleoptera: Scarabaeidae]		No	Yes (Lee 1988)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Anomala cypriogastra Ohaus Recorded as: *Anomala ypryogastra* [sic.] Ohaus in BAPHIQ (2004) [Coleoptera: Scarabaeidae]		No	Yes (Lee 1988; BAPHIQ 2004)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees (Lee 1988). Minor pest, affecting leaves of mango trees in Taiwan (BAPHIQ 2004).	No
Anomala expansa Bates [Coleoptera: Scarabaeidae]	May beetle	No	Yes (Lee 1988; BAPHIQ 2004)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees (Lee 1988). Minor pest, affecting leaves of mango trees in Taiwan (BAPHIQ 2004).	No
Anomala siniopyga Ohaus [Coleoptera: Scarabaeidae]		No	Yes (Lee 1988)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Anomala trachypyga Bates Syn: *Euchlora trachypyga* Bates [Coleoptera: Scarabaeidae]		No	Yes (Lee 1988)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Crossotarsus externedentatus (Fairmaire, 1849) [Coleoptera: Platypodidae]	Stem borer	Yes	Yes (Wood & Bright 1992; Beaver & Shih 2003; Huang *et al*. 2003)	Yes (Wood & Bright 1992)		No
Deporaus marginatus (Pascoe, 1883) [Coleoptera: Curculionidae]	Mango leaf cutting weevil	Yes	Yes (CAB International 2005)	No (CAB International 2005)	No. Eggs are laid on the leaves of the mango plant; both adults and larvae feed on leaves (CAB International 2005).	No
Diapus quinquespinatus Chapuis, 1865 [Coleoptera: Platypodidae]		No	Yes (Wood & Bright 1992)	Yes (Wood & Bright 1992)		No
Eccoptopterus spinosus (Oliver, 1795) [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	Yes (Wood & Bright 1992)		No
Eucorynus crassicornis (Fabricius, 1801) [Coleoptera: Anthribidae]	Tephrosia seed weevil	Yes	Yes (Morimoto 1979)	Yes (Zimmerman 1994)		No
Euwallacea interjectus (Blandford, 1894c) [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. Bores into the trunk of host plants such as *Prunus mume* and *Brownea capitella* (Huang *et al.* 2003).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Hypomeces squamosus (Fabricius, 1792) [Coleoptera: Curculionidae]	Green weevil	Yes	Yes (Clausen 1933; CAB International 2005)	No (CAB International 2005)	No. Mango is a minor host; adults feed on leaves and larvae feed on roots (CAB International 2005).	No
Hypothenemus javanus (Eggers, 1908c) [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. Breeds within the pith of twigs of a wide variety of hosts (Atkinson & Peck 1994).	No
Hypothenemus setosus (Eichhoff, 1868e) [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. Breeds within the pith of twigs of a wide variety of hosts (Atkinson & Peck 1994). In Malaysia, it bores into the wood of *Dyera costulata* and *Sindora sp*. (Norhara 1981).	No
Lepidiota nana Sharp [Coleoptera: Scarabaeidae]		No	Yes (Lee 1988)	No (Cassis *et al*. 2002)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Platypus jansoni Chapuis, 1865 [Coleoptera: Platypodidae]		No	Yes (Wood & Bright 1992)	Yes (Wood & Bright 1992)		No
Platypus solidus Walker, 1859 [Coleoptera: Platypodidae]	Stem borer	Yes	Yes (Wood & Bright 1992; Beaver & Shih 2003)	Yes (Wood & Bright 1992)		No
Protaetia brevitarsis Lewis [Coleoptera: Cetonidae]		No	Yes (Chiu 1991)	No (Booth *et al*. 1990)	No. Adult cetonids generally feed on tree sap and leaves; larvae feed on roots and rotten timber (Booth *et al*. 1990).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Sinoxylon mangifera Chujo [Coleoptera: Bostrichidae]		No	Yes (Lee 1988)	No records found	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Xyleborus haberkorni Eggers, 1920 [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. *Xyleborus* spp are generally stem borers.	No
Xyleborus metacuneolus Eggers, 1940d [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. *Xyleborus* spp are generally stem borers.	No
Xyleborus perforans (Wollaston, 1857) [Coleoptera: Scolytidae]	Island pinhole borer	Yes	Yes (Wood & Bright 1992)	Yes (Wood & Bright 1992)		No
Xyleborus similis Ferrari, 1867 [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	Yes (Wood & Bright 1992)		No
Xylopsocus capucinus (Fabricius, 1781) [Coleoptera: Bostrichidae]	False powder-post beetle	No	Yes (Lee 1988)	Yes (USDA 2001)		No
Xylosandrus compactus (Eichhoff, 1875) [Coleoptera: Scolytidae]	Chestnut beetle	Yes	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. Borer of seedlings, shoots and twigs of mango and other hosts in Florida, USA (Wolfenbarger 1973, Ngoan *et al.* 1976).	No
Xylosandrus crassiusculus (Motschulsky, 1866) [Coleoptera: Scolytidae]	Asian ambrosia beetle	No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. Bores into roots, stems and branches of mango trees in Pakistan (Khuhro *et al.* 2005).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		*** the Philippines and/or India**	**Taiwan**			
Xylosandrus discolor (Blandford, 1898) [Coleoptera: Scolytidae]		No	Yes (CAB International 2005)	No (CAB International 2005)	No. Mango is a minor host and stems of host trees are attacked by this species (CAB International 2005)	No
Xylosandrus mancus (Blandford, 1898a) [Coleoptera: Scolytidae]		No	Yes (Wood & Bright 1992)	No (Wood & Bright 1992)	No. *Xylosandrus* spp. are generally stem, borers.	No
DIPTERA						
Bactrocera cucurbitae (Coquillett, 1899) Syn: *Dacus cucurbitae* [Diptera: Tephritidae]	Melon fruit fly	Yes	Yes (Wen 1985; Chang *et al*. 2003; Lin *et al*. 2005)	No (Hardy & Foote 1996)	Yes. The female selects mature mango fruit and lays eggs through the skin, into the fruit pulp in Taiwan (Lin *et al*. 1976).	**Yes**
Bactrocera dorsalis (Hendel, 1912) Syn: *Bactrocera ferruginea* Fabricius, 1794 [Diptera: Tephritidae]	Oriental fruit fly	Yes	Yes (Lee 1988; Hardy & Foote 1996; Tandon 1998; Chang *et al*. 2003; Lin *et al*. 2005)	No (Hardy & Foote 1996)	Yes. The female selects mature mango fruit and lays eggs through the skin, into the fruit pulp (Lee 1988). Commonly occur on mango fruit in Taiwan (Chiu 1991).	**Yes**
Bactrocera latifrons (Hendel, 1915) [Diptera: Tephritidae]	Solanum fruit fly	No	Yes (Hardy & Foote 1996)	No (Hardy & Foote 1996)	Yes. The report of solanum fruit fly attacking mango in Malaysia (Vijaysegaran 1991) was considered by Liquido *et al*. (1994) to be questionable and in need of verification. Mango was not detected as a host in extensive fruit rearing surveys (Clarke *et al.* 2001; Allwood *et al*. 1999). Questionable association with fruit but included for further consideration.	**Yes**

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Bactrocera tau (Walker) [Diptera: Tephritidae]	Fruit fly	Yes	Yes (Chang *et al*. 2003; Lin *et al*. 2005)	No (Hardy & Foote 1996)	Yes. During surveys of various orchards in India for fruit fly damage of at least seven crop types, Grewel and Kapoor (1986) identified only two out of six fruit fly species, *B. dorsalis* and *B. zonata*, infesting mango fruit. *Bactrocera tau* was only reared from pears, along with four other fruit fly species and a suite of other insects. Peña & Mohyuddin (1997) appears to have misquoted that *B. tau* attacks mango fruit. Narayanan and Batra (1960) concluded that similarities between *B. tau* and *B. cucurbitae* had probably resulted in confusion between biology. Questionable association with fruit but included for further consideration.	**Yes**
HEMIPTERA						
Abgrallaspis cyanophylli (Signoret, 1869) Syn: *Hemiberlesia cyanophylli* (Signoret) [Hemiptera: Diaspididae]	Cyanophyll scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Donaldson & Tsang 2002). Not in WA (DAWA 2003).	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes (for WA only)**

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Aleurocanthus woglumi Ashby, 1915 [Hemiptera: Aleyrodidae]	Citrus blackfly	Yes	Yes (EPPO 2005)	No (EPPO 2005)	No. Eggs and immature stages can occur on the underside of mango leaves (EPPO 2005). Mango fruit can be cosmetically affected by secondary sooty mould development on honeydew produced by this species (EPPO 2005).	No
Aleurodicus dispersus Russell, 1965 [Hemiptera: Aleyrodidae]	Spiraling whitefly	Yes	Yes (Wen *et al*. 1997)	Yes (Mani & Krishnamoorthy 2002). Localised in Qld and NT. Movement of plants to some states is subject to phytosanitary measures. However, there are no interstate restrictions on movement of fruit (QDPIF 2000a, 2000b).		No
Aonidiella aurantii (Maskell, 1879) [Hemiptera: Diaspididae]	California red scale	Yes	Yes (Lee 1988; BAPHIQ 2004; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Aonidiella citrina (Craw, 1890) [Hemiptera: Diaspididae]	Citrus yellow scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Aonidiella inornata McKenzie, 1938 [Hemiptera: Diaspididae]	Armoured scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Aonidomytilus albus (Cockerell) [Hemiptera: Diaspididae]	Tapioca scale	No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Aspidiotus destructor Signoret, 1869 [Hemiptera: Diaspididae]	Coconut scale, transparent scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Aulacaspis rosae (Bouché, 1833) [Hemiptera: Diaspididae]	Mango snow scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Aulacaspis tubercularis Newstead, 1906 [Hemiptera: Diaspididae]	Mango scale; white mango scale	Yes	Yes (Lee 1988; BAPHIQ 2004; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Aulacaspis vitis (Green, 1896) [Hemiptera: Diaspididae]	Armoured scale	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Calophya mangiferae Burckhardt & Basset Syn: *Microceropsylla nigra* (Crawford) Recorded as *Croceropsylla* [sic.] *nigra* Crawford in BAPHIQ (2004) [Hemiptera: Calophyidae]	Mango psyllid	No	Yes (Lee 1988; BAPHIQ 2004)	Yes (Hollis 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Ceroplastes ceriferus (Fabricius, 1798) [Hemiptera: Coccidae]	Indian wax scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Ceroplastes floridensis Comstock Syn: *Paracerostegia floridensis* (Comstock) [Hemiptera: Coccidae]	Florida wax scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Ceroplastes pseudoceriferus (Green) Recorded as *Ceroplastes pseudoceriferens* [sic.] in Lee (1988) [Hemiptera: Coccidae]		Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Swirski *et al*. 1997; Ben-Dov *et al*. 2005)	No. Infestations of mangoes cause wilting of leaves, malformation of flowers, and failure of twigs to produce flowers (Swirski *et al*. 1997).	No
Ceroplastes rubens Maskell, 1893 [Hemiptera: Coccidae]	Pink wax scale	Yes	Yes (Lee 1988; Wen *et al*. 2002; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Chrysomphalus aonidum (Linnaeus, 1758) Syn: *Chrysomphalus ficus* Ashmead [Hemiptera: Diaspididae]	Florida red scale	Yes	Yes (Lee 1988; BAPHIQ 2004; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Chrysomphalus dictyospermi (Morgan, 1889) [Hemiptera: Diaspididae]	Spanish red scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Coccus discrepans (Green, 1904) [Hemiptera: Coccidae]	Soft scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Pest affects leaves of mango trees (USDA 2001).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Coccus hesperidum Linnaeus, 1758 [Hemiptera: Coccidae]	Brown soft scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Coccus longulus (Douglas, 1887) [Hemiptera: Coccidae]	Long soft scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Coccus viridis (Green, 1889) [Hemiptera: Coccidae]	Green coffee scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Diaspis bromeliae Signoret [Hemiptera: Diaspididae]		No	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Duplachionaspis graminis (Green) [Hemiptera: Diaspididae]		No	Yes (Lee 1988)	No (Ben-Dov *et al*. 2005)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Duplaspidiotus claviger (Cockerell) [Hemiptera: Diaspididae]		No	Yes (Lee 1988)	Yes (Donaldson & Tsang 2002)		No
Dysmicoccus brevipes (Cockerell, 1893) [Hemiptera: Pseudococcidae]	Pineapple mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Eucalymnatus tessellatus (Signoret, 1873) Recorded as: *Eucalymnatus tessellates* [sic.] in Lee (1988) [Hemiptera: Coccidae]	Palm scale, tessellated scale	No	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Ferrisia virgata (Cockerell, 1893) [Hemiptera: Pseudococcidae]	Striped mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Fiorinia fioriniae (Targioni Tozzetti, 1867) [Hemiptera: Diaspididae]	Avocado scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Fiorinia proboscidaria Green [Hemiptera: Diaspididae]		No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Attacks leaves and branches of citrus in China (Kuwana 1931).	No
Hemiberlesia lataniae (Signoret, 1869) [Hemiptera: Diaspididae]	Latania scale, palm scale, grape vine scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Hemiberlesia rapax (Comstock, 1881) Misidentified as: *Aspidiotus camelliae* Signoret in Lee (1988) [Hemiptera: Diaspididae]	Greedy scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Howardia biclavis (Comstock) [Hemiptera: Diaspididae]		No	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Icerya aegyptiaca (Douglas, 1890) [Hemiptera: Margarodidae]	Egyptian fluted scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (CAB International 2005)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988).	No
Icerya purchasi Maskell, 1879 [Hemiptera: Margarodidae]	Cottony cushion scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Icerya seychellarum (Westwood, 1855) Syn: *Icerya okadae* Kuwana [Hemiptera: Margarodidae]	Seychelles scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Idioscopus clypealis (Lethierry, 1889) [Hemiptera: Cicadellidae]	Mango green leafhopper	Yes	Yes (Lee 1988; Tandon 1998; Wen 2000; BAPHIQ 2004)	Yes (Fletcher & Dangerfield 2002)		No
Idioscopus nitidulus (Walker, 1870) Syn: *Idioscopus niveosparsus* Lethierry, 1889 in BAPHIQ (2004) [Hemiptera: Cicadellidae]	Mango brown leafhopper	Yes	Yes (Lee 1988; Tandon 1998; Wen 2000; BAPHIQ 2004)	Yes (Day & Fletcher 1994; Fletcher & Dangerfield 2002)		No
Ischnaspis longirostris (Signoret, 1882) Syn: *Ischnaspis filiformis* Douglas [Hemiptera: Diaspididae]	Black thread scale, black line scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Kerria greeni (Chamberlin) Syn: *Laccifer greeni* (Camberlin) [Hemiptera: Kerriidae]		No	Yes (Takahashi 1928; Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Species of this genus are known to attack stems (BAPHIQ 2004).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Kerria lacca (Kerr, 1782) [Hemiptera: Kerriidae]	Lac insect	Yes	Yes (Lee 1988; Wen *et al*. 2002; BAPHIQ 2004)	No (Ben-Dov *et al*. 2005)	No. This species attack stems of mango in Taiwan (BAPHIQ 2004).	No
Kilifia acuminata (Signoret, 1873) [Hemiptera: Coccidae]	Acuminate scale, mango shield scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Attacks leaves of mangoes in North America (Peña & Mohyuddin 1997).	No
Lepidosaphes beckii (Newman, 1869) [Hemiptera: Diaspididae]	Mussel scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Lepidosaphes gloverii (Packard, 1869) Syn: *Insulaspis gloverii* (Packard) [Hemiptera: Diaspididae]	Glover's scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Lepidosaphes laterochitinosa Green Syn: *Parainsulaspis laterochitinosa* (Green) [Hemiptera: Diaspididae]	Armoured scale	No	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Lindingaspis proteus (Curtis) [Hemiptera: Diaspididae]		No	Yes (Lee 1988)	No records found	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Lindingaspis rossi (Maskell, 1891) [Hemiptera: Diaspididae]	Circular black scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Maconellicoccus hirsutus (Green, 1908) [Hemiptera: Pseudococcidae]	Pink hibiscus mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Milviscutulus mangiferae (Green, 1889) Syn: *Protopulvinaria mangiferae* (Green) Basionym: *Coccus mangiferae* Green [Hemiptera: Coccidae]	Mango shield scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes—But distribution is limited to Cape York Peninsula, Queensland (Blüthgen *et al*. 2003; NAQS 2003)	Yes. Branch, fruit, leaf, trunk of mango trees in Israel (Peña & Mohyuddin 1997)	**Yes (for WA only)**
Morganella longispina (Morgan, 1889) [Hemiptera: Diaspididae]	Maskell scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Nipaecoccus viridis (Newstead, 1894) Syn: *Nipaecoccus vastator* [Hemiptera: Pseudococcidae]	Spherical mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Paralecanium expansum (Green, 1896) [Hemiptera: Coccidae]	Flat scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Parasaissetia nigra (Nietner, 1861) [Hemiptera: Coccidae]	Nigra scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Paratachardina theae Green, 1907 [Hemiptera: Kerriidae]	Scale	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Inadequate biology data concerning this species. However, *P. lobata lobata* is not associated with fruit or leaves, attacking small diameter branches and stems of mango in Florida, USA (Howard *et al*. 2004a; Howard *et al*. 2004b; Pemberton 2004).	No
Parlatoria camelliae Comstock, 1883 [Hemiptera: Diaspididae]	Camellia parlatoria scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Parlatoria oleae (Colvée, 1880) [Hemiptera: Diaspididae]	Olive scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Parlatoria proteus (Curtis) [Hemiptera: Diaspididae]		No	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Parlatoria pseudaspidiotus Lindinger, 1905 Syn: *Parlatoria mangiferae* Marlatt, 1908 [Hemiptera: Diaspididae]	Vanda orchid scale	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Pinnaspis aspidistrae (Signoret, 1869) [Hemiptera: Diaspididae]	Aspidistra scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Pinnaspis strachani (Cooley, 1899) [Hemiptera: Diaspididae]	Cotton white scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Planococcus citri (Risso, 1813) [Hemiptera: Pseudococcidae]	Citrus mealybug	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Planococcus lilacinus (Cockerell, 1905) [Hemiptera: Pseudococcidae]	Coffee mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a minor host but pest can damage the whole tree including fruit (CAB International 2005).	**Yes**
Planococcus minor (Maskell, 1897) [Hemiptera: Pseudococcidae]	Pacific mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Platysaissetia formicarii (Green) Syn: *Coccus formicarii* (Green, 1896) Recorded as: *Saissetia formicarii* in Lee (1988) [Hemiptera: Coccidae]	Soft scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. A pest of mango leaves in India (USDA 2001).	No
Protococcus acutissimus (Green, 1896) Syns: *Leacnium acutissimum* Green; *Coccus acutissimus* (Green) [Hemiptera: Coccidae]	Banana-shaped scale; slender soft scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Pest affects leaves of mango trees (Peña & Mohyuddin 1997).	No
Protopulvinaria pyriformis (Cockerell) [Hemiptera: Coccidae]	Pyriform scale	No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Pseudaonidia trilobitiformis (Green, 1896) [Hemiptera: Diaspididae]	Trilobite scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Pseudaulacaspis cockerelli (Cooley, 1897) [Hemiptera: Diaspididae]	False oleander scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Pseudaulacaspis pentagona (Targioni Tozzetti, 1886) [Hemiptera: Diaspididae]	Mulberry scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae]	Citriculus mealybug	No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Pseudococcus jackbeardsleyi Gimpel & Miller [Hemiptera: Pseudococcidae]	Jack Beardsley mealybug	No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a minor host but pest attacks fruit and leaves (CAB International 2005)	**Yes**
Pseudococcus longispinus (Targioni Tozzetti, 1867) Misidentification: *Pseudococcus adonidum* (Westwood) in Lee (1988) [Hemiptera: Pseudococcidae]	Long-tailed mealybug	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Pulvinaria polygonata Cockerell, 1905 [Hemiptera: Coccidae]	Cottony citrus scale	Yes	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Pulvinaria psidii Maskell, 1893 Syn: *Chloropulvinaria psidii* (Maskell) [Hemiptera: Coccidae]	Green shield scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Pulvinaria taiwana Takahashi [Hemiptera: Coccidae]	Scale	No	Yes (Lee 1988; Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	Philippine mango mealybug	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a major host (CAB International 2005)	**Yes**
Saissetia coffeae (Walker, 1852) [Hemiptera: Coccidae]	Hemispherical scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Saissetia hemisphaerica (Targioni-Tozzetti, 1948) [Hemiptera: Coccidae]	Scale	No	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Saissetia oleae (Olivier, 1791) [Hemiptera: Coccidae]	Black scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Selenaspidus articulatus (Morgan) [Hemiptera: Diaspididae]	Armoured scale	No	Yes (Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
Semelaspidus mangiferae Takahashi, 1939 Recorded as: *Semilaspidus* [sic.] *mangiferae* in Indian mango Draft review (DAFF 2004) [Hemiptera: Diaspididae]	Armoured scale	Yes	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	No. Mango is a host of this species (Ben-Dov *et al*. 2005), Reported only on mango branches and leaves (Takahashi 1939) and leaves (Nafus 1997).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Sophonia rufofascia Kuoh & Kuoh, 1983 [Hemiptera: Cicadellidae]	Two-spotted leafhopper	No	Yes (CAB International 2005)	No (CAB International 2005)	No. Mango is a major host but this species feeds on leaves causing dieback (CAB International 2005).	No
Toxoptera citricida (Kirkaldy) [Hemiptera: Aphididae]	Aphid	No	Yes (Tao & Wu 1968)	Yes (CAB International 2005)		No
Toxoptera odinae (van der Goot, 1917) [Hemiptera: Aphididae]	Mango aphid	Yes	Yes (Lee 1988; Blackman & Eastop 2000; BAPHIQ 2004)	No records found	Yes. Affects leaves, flowers and fruit of mango in Taiwan (BAPHIQ 2004).	**Yes**
Unaspis acuminata (Green) [Hemiptera: Diaspididae]	Unaspis scale	No	Yes (Ben-Dov *et al*. 2005)	No (Ben-Dov *et al*. 2005)	Yes. Mango is a host of this species (Ben-Dov *et al*. 2005), and feasibly associated with fruit.	**Yes**
Vinsonia stellifera (Westwood, 1871) [Hemiptera: Coccidae]	Stellate scale	Yes	Yes (Lee 1988; Ben-Dov *et al*. 2005)	Yes (Ben-Dov *et al*. 2005)		No
HYMENOPTERA						
Anoplolepis gracilipes (Smith, 1857) [Hymenoptera: Formicidae]	Crazy ant; long legged ant	Yes	Yes (ISSG 2005)	Yes (ISSG 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
ISOPTERA						
Coptotermes formosanus Shiraki, 1909 [Isoptera: Rhinotermitidae]	Formosan subterranean termite	Yes	Yes (Su & Hsu 2003)	No (Watson & Abbey 1993; Watson *et al.* 1998)	No. Attacks trunk of mango trees in North America (Peña & Mohyuddin 1997).	No
LEPIDOPTERA						
Acherontia styx (Westwood, 1847) [Lepidoptera: Sphingidae]	Indian death's head hawkmoth	Yes	Yes (Lin 1987)	No (Nielsen *et al.* 1996)	No. Eggs are laid on leaves, larvae feed on leaves and shoots and pupate in the soil (CAB International 2005).	No
Acrocercops astaurota Meyrick Syn: *Spulerina astaurota* (Meyrick) [Lepidoptera: Gracillariidae]	Mango leaf miner	No	Yes (Lee 1988; BAPHIQ 2004)	No (Nielsen *et al.* 1996)	No. Causes serious damage to newly developing leaves and the epidermis of tender shoots on mango trees in Taiwan (Lee 1988).	No
Acrocercops cathedraea Meyrick Syn: *Telamoptilia cathedraea* (Meyrick, 1908) [Lepidoptera: Gracillariidae]	Leaf miner	Yes	Yes (De Prins 2002)	No (Nielsen *et al.* 1996)	No. Damages leaves of mango in India (Robinson *et al.* 2004).	No
Agrius convolvuli (Linnaeus, 1758) [Lepidoptera: Sphingidae]	Sweet potato moth	Yes	Yes (CAB International 2005)	Yes (Nielsen *et al.* 1996)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Amsacta lactinea (Cramer) [Lepidoptera: Arctiidae]	Red tiger moth; black hairy caterpillar	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Feeds on leaves of mango in India (Srivastava 1997).	No
Attacus atlas (Linnaeus, 1758) [Lepidoptera: Saturniidae]	Atlas moth	Yes	Yes (Heppner *et al.* 1989; Paukstadt & Paukstadt 2002)	No (Nielsen *et al.* 1996)	No. Attacks leaves of mango in Indonesia (Robinson *et al.* 2004).	No
Cadra cautella (Walker, 1863) [Lepidoptera: Pyralidae]	Almond moth	Yes	Yes (CAB International 2005)	Yes (CAB International 2005)		No
Chlumetia transversa (Walker, 1863) Syns: *Chlumetia guttivenris* Walker; *Ariola corticea* Snellen; *Chlumetia guangxiensis* Wu & Zhu; *Salagena transversa* (Walker); *Sholumetia transversa* (Walker) Basionym: *Nachaba transversa* Walker [Lepidoptera: Noctuidae]	Mango shoot borer; mango shoot caterpillar; mango tip borer	Yes	Yes (Lee 1988; Tandon 1998; BAPHIQ 2004)	Yes (Nielsen *et al.* 1996)		No
Conogethes punctiferalis (Guenée, 1854) [Lepidoptera: Pyralidae]	Castor seed caterpillar	Yes	Yes (CAB International 2005)	Yes (CAB International 2005)		No
Dasychira mendosa Hübner Syn: *Olene mendosa* Hübner, 1823 [Lepidoptera: Lymantriidae]	Tussock caterpillar	Yes	Yes (Zhang 1994)	Yes (Nielsen *et al.* 1996)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		*** the Philippines and/or India**	**Taiwan**			
Dudua aprobola (Meyrick, 1886) [Lepidoptera: Tortricidae]	Moth	Yes	Yes (Meijerman & Ulenberg 2005)	Yes (Nielsen *et al.* 1996)		No
Eucosma melanoneura Meyrick [Lepidoptera: Tortricidae]		No	Yes (Lee 1988)	No (Nielsen *et al*. 1996)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Eudocima fullonia (Clerck, 1764) [Lepidoptera: Noctuidae]	Fruit piercing moth	Yes	Yes (CAB International 2005)	Yes (Nielsen *et al.* 1996)		No
Eudocima salaminia (Cramer, 1777) [Lepidoptera: Noctuidae]		No	Yes (Kluesener 1994)	Yes (Fay & Halfpapp 1999)		No
Eumeta variegata Niitsu Syns: *Eumeta preyeri (Leech); Clania preyeri* Leech; *Cryptothelea formosicola* Strand [Lepidoptera: Psychidae]	Giant bag-worm	No	Yes (Lee 1988; BAPHIQ 2004)	Yes (APPD 2005)		No
Euproctis scintillans (Walker, 1856) [Lepidoptera: Lymantridae]	Tussock caterpillar	Yes	Yes (Lin 2002)	No (Nielsen *et al.* 1996)	No. Occurs on leaves of mango in India (Srivastava 1997).	No

Scientific name	**Common name(s)**	**Associated with mango in**		**Present in Australia**	**Associated with mango fruit**	**Consider further**
		*** the Philippines and/or India**	**Taiwan**			
Euproctis taiwana (Shiraki) Recorded as the Basionym: *Porthesia taiwana* Shiraki in BAPHIQ (2004) [Lepidoptera: Lymantriidae]	Tussock moth	No	Yes (BAPHIQ 2004)	No (Nielsen *et al.* 1996)	No. Available scientific literature indicates that this species feeds on the leaves of gladiolus and lily plants (Liu 1998), the leaves of soybean (Talekar *et al*. 1988), leaves of grapevine (Chang 1988) and the leaves of rose (Wang 1982) in Taiwan. BAPHIQ (2004) correspondence reports that this species occurs on leaves, flowers and fruit of mango in Taiwan.	No
Heleanna melanomochla Meyrick [Lepidoptera: Tortricidae]		No	Yes (Robinson *et al.* 2004)	No (Nielsen *et al.* 1996)	No. Found on leaves of mango in Taiwan (Robinson *et al.* 2004).	No
Helicoverpa armigera (Hübner, 1805) [Lepidoptera: Noctuidae]	Cotton bollworm	Yes	Yes (CAB International 2005)	Yes (Nielsen *et al.* 1996)		No
Homona coffearia (Nietner, 1861) [Lepidoptera: Tortricidae]	Coffee tortrix	Yes	Yes (CAB International 2005)	No, CAB International (2005) shows presence of the disease however taxonomic re-examination has shown the original report to be in error. The name *H. spargotis* Meyrick was reinstated for this pest (Whittle *et al*. 1987).	No. Leaf (CAB International 2005)	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Lymantria mathura Moore, 1865 [Lepidoptera: Lymantriidae]	Rosy (pink) gypsy moth	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Found on leaves of mango in India (Srivastava 1997; Robinson *et al.* 2004).	No
Maruca vitrata (Fabricius, 1787) [Lepidoptera: Pyralidae]	Bean pod borer	Yes	Yes (CAB International 2005)	Yes (Nielsen *et al.* 1996)		No
Orgyia australis postica (Walker, 1855) Regarded by some authors to be *Orgyia postica* (Walker, 1855) Recorded as *Notolophorus australis posticus* Walker [sic.] in BAPHIQ (2004) [Lepidoptera: Lymantriidae]	Cocoa tussock moth	Yes	Yes (Lee 1988; BAPHIQ 2004)	No (CAB International 2005)	Yes. Mango is a major host of this species; it affects the leaves (CAB International 2005), flowers and fruit (BAPHIQ 2004).	**Yes**
Parasa lepida (Cramer, 1799) [Lepidoptera: Limacodidae]	Nettle caterpillar	Yes	Yes (Yanagita & Nakao 2005)	No (Nielsen *et al.* 1996)	No. Feeds on leaves of mango in India (Kapoor *et al.* 1985; Jeyabalan & Murugan 1996).	No
Penicillaria jocosatrix (Guenée) Syn: *Bombotelia jocosatrix* (Guenée) [Lepidoptera: Noctuidae]	Large mango tip borer	Yes	Yes (Lee 1988)	Yes (Nielsen *et al.* 1996)		No
Perina nuda (Fabricius, 1787) [Lepidoptera: Lymantriidae]	Clear-winged tussock moth	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Feeds on leaves of mango in India (Srivastava 1997)	No
Pingasa ruginaria Guenée [Lepidoptera: Geometridae]		No	Yes (Lee 1988)	No (Nielsen *et al*. 1996)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Pyroderces simplex Walsingham [Lepidoptera: Cosmopterigidae]	Flower eating caterpillar	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Found on flowers of mango in India (Robinson *et al.* 2004)	No
Scirpophaga excerptalis Walker, 1863 [Lepidoptera: Pyralidae]	Sugarcane top borer	Yes	Yes (CAB International 2005)	Yes (Nielsen *et al.* 1996). Not in WA (DAWA 2003)	No. Mango is a minor host and this species attacks leaves, shoots and growing points (CAB International 2005).	No
Selepa celtis Moore, 1858 [Lepidoptera: Noctuidae]	Aonla hairy caterpillar	Yes	Yes (Holloway 2005)	Yes (Nielsen *et al.* 1996)		No
Spilarctia obliqua Walker Syn: *Spilosoma obliqua* (Walker, 1865) [Lepidoptera: Arctiidae]	Common hairy caterpillar	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Feeds on leaves of mango in India (Srivastava 1997)	No
Spodoptera litura (Fabricius) [Lepidoptera: Noctuidae]	Armyworm	No	Yes (Lee 1988; CAB International 2005)	Yes (Nielsen *et al.* 1996)		No
Stauropus alternus Walker [Lepidoptera: Notodontidae]		Yes	Yes (Lee 1988; Yanagita & Nakao 2005)	No (Nielsen *et al.* 1996)	No. Occurs on branches and leaves of mango in Indonesia (Robinson *et al.* 2004)	No
Strepsicrates rhothia (Meyrick) [Lepidoptera: Tortricidae]	Eucalyptus leafroller	Yes	Yes (Zhang 1994)	No (Nielsen *et al.* 1996)	No. Occurs on leaves of mango in India (Robinson *et al.* 2004)	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Thalassodes veraria Guenée [Lepidoptera: Geometridae]		No	Yes (Lee 1988)	No (Nielsen *et al*. 1996)	No. Can cause considerable damage to mango trees in Taiwan (Lee 1988). No records of fruit attack found.	No
Tirathaba mundella Walker, 1865 [Lepidoptera: Pyralidae]	Oil palm bunch moth	Yes	Yes (Hwang 2000)	No (Nielsen *et al.* 1996)	No. Damages banana fruit in Taiwan (Hwang 2000). This species bores into young fruit of *Mangifera andamanica* after fruit set and causes premature dropping of fruit in India (Bhumannavar & Jacob 1990; Srivastava 1997).	No
Zeuzera coffeae Nietner [Lepidoptera: Cossidae]	Carpenter worm	No	Yes (Lee 1988; CAB International 2005)	No (Nielsen *et al.* 1996)	No. Species is a woodboring insect that damages twigs of *Annona* species in South East Asia. In China and Taiwan, eggs are laid in bark crevices; larvae bore into branches and pupation occurs below the bark surface in longan and lychee plants (Pĕna *et al.* 2002).	No
THYSANOPTERA						
Heliothrips haemorrhoidalis (Bouché, 1833) [Thysanoptera: Thripidae]		Yes	Yes (Chen 1981)	Yes (Mound 1996)		No
Megalurothrips distalis (Karny, 1913) [Thysanoptera: Thripidae]		Yes	Yes (CAB International 2005)	No, (Mound 2001)	No (CAB International 2005)	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Rhipiphorothrips cruentatus Hood, 1919 Syn: *Rhipiphorothrips arma* Ramakrishnan [Thysanoptera: Thripidae]	Mango thrip	Yes	Yes (Lee 1988; BAPHIQ 2004)	No (Mound 1996)	Yes. Occurs on mature leaves of mango trees during the dry season in Taiwan (Lee 1988). Affects leaves and fruit of mango (BAPHIQ 2004).	**Yes**
Scirtothrips dorsalis Hood, 1919 Syn: *Neophysopus fragariae* Girault [Thysanoptera: Thripidae]	Yellow thrip	Yes	Yes (Lee 1988; BAPHIQ 2004)	Yes (Mound 1996)		No
Selenothrips rubrocinctus (Giard, 1901) [Thysanoptera: Thripidae]	Redbanded thrip	Yes	Yes (Chen 1981)	Yes (Mound 1996)		No
Taeniothrips varicornis Moulton Syn: *Megalurothrips typicus* [Thysanoptera: Thripidae]		No	Yes (Anon. 1980)	Yes (Mound 2002)		No
Thrips hawaiiensis (Morgan, 1913) [Thysanoptera: Thripidae]	Banana flower thrip	Yes	Yes (Lee 1988)	Yes (Mound 1996)		No
ALGAE						
Cephaleuros virescens Kunze [Trentepohliales: Trentepohliaceae]	Algal leaf spot	Yes	Yes (Hsieh *et al*. 2000)	Yes (Johnson & Hobman 1982)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
PATHOGENS						
BACTERIA						
Erwinia carotovora subsp. *Carotovora* (Jones, 1901) Bergey, Harrison, Breed, Hammer & Huntoon, 1923 Syn: *Erwinia carotovara* (Thomma *et al*. 2001) [Enterobacteriaceae]	Bacterial rot	Yes	Yes (CAB International 2005)	Yes (CAB International 2005)		No
Erwinia herbicola (Löhnis, 1911) Dye, 1964 [Enterobacteriaceae]	Bacterial grapevine blight	Yes	Yes (CAB International 2005)	Yes (CAB International 2005)		No
Xanthomonas campestris pv. *Mangiferaeindicae* (Patel, Moniz & Kulkarni, 1948) Robbs, Ribeiro & Kimura, 1974 Syns: *Pseudomonas mangiferae indicae* Patel; *Erwinia mangiferae* var. *Indicae* Stapp [Xanthomonadaceae]	Bacterial canker	Yes	Yes (Bradbury 1986; BAPHIQ 2004)	Yes (Bradbury 1986)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
FUNGI						
Acremonium polychromum (J.F.H. Beyma) W. Gams Syn: *Gliomastix polychroma* (J.F.H. Beyma) Matsushima [Anamorphic Hypocreales]		No	Yes (Matsushima 1980)	No (APPD 2005)	No. Recorded as saprophytic in Taiwan (Matsushima 1980).	No
Alternaria alternata (Fries: Fries) Keissler Syns: *Alternaria alternata* f.sp. *fragariae* Dingley; *Alternaria alternata* f.sp. *lycopersici* Grogan *et al*.; *Alternaria fasciculata* (Cooke & Ellis) L. Jones & Grout; *Alternaria tenuis* Nees; *Macrosporium fasciculatum* Cooke & Ellis; *Macrosporium maydis* Cooke & Ellis [Anamorphic Lewia]	Alternaria leaf spot	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No
Aspergillus niger var. *Niger* Tieghem Syn: *Aspergillus niger* van Tieghem [Anamorphic Emericella]	Aspergillus ear rot; black mould	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No
Aspergillus terreus Thom [Anamorphic Emericella]	Stem end rot	Yes	Yes (Chung *et al.* 1971)	Yes (APPD 2005) Not in WA (DAWA 2003).	No. On stems (Patel *et al*. 1985).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Athelia rolfsii (Curzi) C.C. Tu & Kimbrough Syns: *Corticium rolfsii* Curzi; *Pellicularia rolfsii* (Curzi) E. West; *Sclerotium rolfsii* Saccardo [Polyporales: Atheliaceae]	Collar rot	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No
Aureobasidium pullulans (de Bary) G. Arnaud var. *pullulans* [Anamorphic: Discosphaerina]	Blue stain	Yes	Yes (Lin *et al.* 2004)	Yes (APPD 2005)		No
Beltraniella portoricensis (F. Stevens) Pirozynski & S.D. Patil Syn: *Ellisiopsis gallesiae* Batista & Nascimento [Anamorphic: Leiosphaerella]		No	Yes (Matsushima 1980)	Yes (APPD 2005) Not in WA (DAWA 2003)	No. Saprophyte (Matsushima 1980) found on leaf litter (Farr *et al.* 1989).	No
Botryosphaeria dothidea (Mougeut: Fries) Cesati & de Notaris [Dothideales: Botryosphaeriaceae]	Fruit rot	Yes	Yes (Ko *et al.* 2003)	Yes (APPD 2005) Not in WA (DAWA 2004)	No. Inflorescence, leaf, stem (Johnson *et al*. 1993). This is a post-harvest disease that affects mango fruit during storage (Johnson *et al*. 1993).	No (storage rot)
Botryosphaeria rhodina (Berkeley & M.A. Curtis) Arx Syns: *Physalospora rhodina* Berkeley & M.A. Curtis; *Diplodia natalensis* Pole-Evans [Dothideales: Botryosphaeriaceae]	Stem end rot	No	Yes (Anon. 1979)	Yes (APPD 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Botryosphaeria ribis Grossenbacher & Duggar [Dothideales: Botryosphaeriaceae]	Canker	No	Yes (Kuo *et al.* 1989)	Yes (APPD 2005)		No
Ceratocystis fimbriata Ellis & Halsted [Microascales: Ceratocystidaceae]	Ceratocystis blight	No	Yes (CAB International 2005)	Yes (APPD 2005)		No
Ceratocystis paradoxa (Dade) C. Moreau [Microascales: Ceratocystidaceae]	Base rot; black rot; bulb rot	Yes	Yes (CAB International 2005)	Yes (APPD 2005) Not in WA (DAWA 2003)	No. Leaf, root, seed, stem (CAB International 2005), This is a post-harvest disease (CAB International 2005).	No
Cercospora mangiferae Koorders Syns: *Scolecostigmina mangiferae* (Koorders) U. Braun & Mouchacca; *Stigmina mangiferae* (Koorders) M.B. Ellis [Anamorphic Mycosphaerella]	Stigmina leaf spot	Yes	Yes (Anon. 1979; Hsieh & Goh 1990)	Yes (Farr *et al.* 2005) Not in WA (DAWA 2003)	No. Leaf (Rawal 1998).	No
Cladosporium cladosporioides (Fresenius) G.A. de Vries [Anamorphic Mycosphaerella]	Black mould	Yes	Yes (MSRC 2005)	Yes (APPD 2005)		No
Colletotrichum acutatum J.H. Simmonds [Anamorphic Glomerella]	Strawberry black spot	Yes	Yes (BAPHIQ 2004)	Yes (APPD 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Colletotrichum orbiculare (Berkeley & Montagne) Arx Syn: *Glomerella lagenaria* (Passerini) F. Stevens [Phyllachorales: Phyllachoraceae]		No	Yes (Akai *et al*. 1958)	Yes (CAB International 2005)		No
Corticium salmonicolor Berkeley & Broome Syn: *Erythricium salmonicolor* (Berkeley & Broome) Burdsall [Polyporales: Corticiaceae]	Pink disease	Yes	Yes (CAB International 2005)	Yes (APPD 2005) Not in WA (DAWA 2003)	No. Bark, branch, trunk (Lim & Khoo 1985); leaf, stem (CAB International 2005).	No
Diaporthe citri F.A. Wolf Anamorph: *Phomopsis citri* H.S. Fawcett [Diaportales: Valsaceae]		Yes	Yes (Tsay & Chuang 1989)	Yes (CAB International 2005)		No
Elsinoë mangiferae Bitancourt & Jenkins [Myriangiales: Elsinoaceae]	Mango scab	Yes	Yes (CAB International 2005)	Yes (APPD 2005) Not in WA (DAWA 2003)	Yes. Infects fruit (Condé *et al*. 1997).	**Yes** **(for WA only)**
Erysiphe cichoracearum Jaczewski [Erysiphales: Erysiphaceae]	Powdery mildew	Yes	Yes (Farr *et al.* 2005)	Yes (APPD 2005)		No
Fusarium oxysporum Schlechtendahl: Fries [Anamorphic: Gibberella]	Wilt, basal rot Not Mango malformation	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Ganoderma australe (Fries: Fries) Patouillard Syns: *Fomes australis* (Fries: Fries) Cooke; *Polyporus adspersus* Schulzer; [Polyporales: Ganodermataceae]		No	Yes (BAPHIQ 2004)	Yes (APPD 2005)		No
Ganoderma applanatum (Persoon) Patouillard [Polyporales: Ganodermataceae]	Ornamentals white butt rot	Yes	Yes (Anon. 1979) Note: possible misidentification, *G. applanatum* is replaced by *G. australe* in the tropics. Distribution is thought to overlap in NW India and Pakistan (Steyaert 1975a, 1975b).	No, misidentified in APPD (2005). *G. applanatum* is replaced by *G. australe* in the tropics (Steyaert 1975a, 1975b) and Australia (Smith & Sivasithamparam 2000, 2003).		No
Gibberella zeae (Schweinitz) Petch [Hypocreales: Nectriaceae]	Cobweb disease	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No
Glomerella cingulata (Stoneman) Spaulding & H. Schrenk Anamorphs: *Colletotrichum gloeosporioides* (Penzig) Penzig & Saccardo; *Gloeosporium mangiferae* Henn. [Insertae sedis: Glomerellaceae]	Anthracnose	Yes	Yes (BAPHIQ 2004; Anon. 1979)	Yes (APPD 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Lasiodiplodia theobromae (Patouillard) Griffon & Maublanc Syn: *Botryodiplodia theobromae* Patouillard [Aanamorphic: Botryosphaeria]	Bark canker	Yes	Yes (BAPHIQ 2004)	Yes (APPD 2005)		No
Macrophomina phaseolina (Tassi) Goidanich [Anamorphic: Ascomycete]	Charcoal rot	Yes	Yes (Wu 1985)	Yes (APPD 2005)		No
Meliola mangiferae Earle [Meliolales: Meliolaceae]	Black mildew	Yes	Yes (BAPHIQ 2004; Anon. 1979)	No (APPD 2005)	No. Affects fruit and leaves in India (Sharma & Badiyala 1991). However, this species is a sooty mould, which is considered a cosmetic problem (Nameth *et al*. 2003). Sooty mould is easily removed during fruit washing (Laemmlen 2003).	No
Nectria haematococca Berkely & Broome Anamorph: *Fusarium solani* (Mortius) Saccardo [Hypocreales: Nectriaceae]	Dry root rot disease	Yes	Yes (CAB International 2005)	Yes (APPD 2005)		No
Nectria rigidiuscula Berkely & Broome Anamorph: *Fusarium decemcellulare* Brick [Hypocreales: Nectriaceae]	Green point gall	No	Yes (CAB International 2005)	Yes (APPD 2005) Not in WA (DAWA 2003)	No. Associated with twigs and branches and galls CAB International 2005).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Oidium mangiferae Arthaud-Berthet [Anamorphic: Erysipe]	Powdery mildew	Yes	Yes (BAPHIQ 2004; Anon. 1979)	Yes (APPD 2005)		No
Pestalotiopsis mangiferae (Hennings) Steyaert Syn: *Pestalotia mangiferae* Hennings [Anamorphic: Pestalosphaeria]	Grey leaf spot of mango	Yes	Yes (Anon. 1979)	Yes (APPD 2005)		No
Phyllachora pomigena (Schweinitz) Saccardo Syn: *Gloeodes pomigena* (Schweinitz) Colby [Phyllachorales: Pyllachoraceae]	Sooty blotch	No	Yes (Chao & Wu 1979)	Yes (APPD 2005)		No
Phytophthora palmivora (E.J. Butler) E.J. Butler Syns: *Phytophthora faberi* Maublanc; *Phytophthora theobromae* L.C. Coleman [Pythiales: Pythiaceae]	Black pod rot of cocoa; fruit rot	Yes	Yes (BAPHIQ 2004)	Yes (APPD 2005) Not in WA (DAWA 2004)	No. Causes root and crown rot of mango and not associated with fruit (Ploetz 2003); root rot, canker and gummosis of the trunk and branches of several crops including mango (Azzopardi *et al*. 2002); root rot of mango (Pernezny & Simone 2000).	No
Pyricularia leersiae (Sawada) S. Ito [Anamorphic: Magnaporthe]		No	Yes (Matsushima 1980)	No (APPD 2005)	No. Recorded as a saprophyte in Taiwan (Matsushima 1980).	No
Pythium splendens Hans Braun [Pythiales: Pythiaceae]		No	Yes (Chang 1993)	Yes (APPD 2005)		No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Rhizopus oryzae Went & Prensen Geerligs Syn: *Rhizopus arrhizus* A. Fisco. [Mucorales: Mucoraceae]	Fruit rot	Yes	Yes (Ho & Chen 1998)	Yes (APPD 2005) Not in WA (DAWA 2003)	Yes. On fruit (Badyal & Sumbali 1990) but is a post harvest disease.	No
Rosellinia necatrix Berlese ex Prillieux [Xylariales: Xylariaceae]	Dematophtora root rot	No	Yes (CAB International 2005)	Yes (APPD 2005)		No
Septobasidium bogoriense Patouillard [Septobasidiales: Septobasidiaceae]		No	Yes (Anon. 1979; Sawada 1959)	No (APPD 2005)	No. Occurs on branches and twigs of mango trees in Sarawak, Malaysia (Teo & Kueh 1984).	No
Stemphylium vesicarium (Wallroth) E.G.Simmons [Anamorphic: Pleospora]	Stemphylum rot	Yes	Yes (Li & Wu 2002)	Yes (APPD 2005)		No
Tripospermum myrti (Lind) S. Hughes [Anamorphic: Trichomerium]	Sooty mould	Yes	Yes (Matsushima 1980)	No (APPD 2005)	No. Recorded as saprophytic in Taiwan (Matsushima 1980). This species is a sooty mould on mango fruit (Prakash 1991), which is considered a cosmetic problem (Nameth *et al*. 2003). Sooty mould is easily removed during fruit washing (Laemmlen 2003).	No
Triposporiopsis spinigera (Höhnel) W. Yamam. [Capnodiales: Capnodiaceae]		No	Yes (Anon. 1979; Sawada 1959)	No (APPD 2005)	No. Occurs on leaves of mango in Taiwan (TFRI 2005).	No

Scientific name	Common name(s)	Associated with mango in		Present in Australia	Associated with mango fruit	Consider further
		* the Philippines and/or India	Taiwan			
Verticillium dahliae Klebahn [Anamorphic: Hypomyces]	Wilt	No	Yes (CAB International 2005)	Yes (APPD 2005)		No
Zygosporium gibbum (Saccardo, M. Rousseau & E. Bommer) S. Hughes [Anamorphic: Ascomycete]		No	Yes (Matsushima 1980)	Yes (APPD 2005) Not in WA (DAWA 2003)	No. Associated with leaves and litter (Nair & Kaul 1984; Markovskaja & Treigiene 2004).	No

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APPENDIX 2: POTENTIAL FOR ESTABLISHMENT OR SPREAD AND CONSEQUENCES

Only valid names are used in this table. For lists of synonyms and outdated names please refer to Appendix 1.

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
ARTHROPODS						
DIPTERA						
Bactrocera cucurbitae (Coquillett, 1899) [Diptera: Tephritidae]	Melon fruit fly	**Feasible**	Australian climate and host availability provide an environment conducive to the establishment of this species. High egg laying capacity and mobility suggest species can disperse rapidly (CAB International 2005). Oviposition occurs ~10 days after emergence. Females lay up to 300 eggs in natural conditions (CAB International 2005).	**Significant**	*Bactrocera cucurbitae* is a very serious pest of cucurbit crops throughout its native range (tropical Asia) and in introduced areas such as the Hawaiian Islands. Damage levels can be anything up to 100% of unprotected fruit (CAB International 2005). Melon flies have more than 80 hosts (CAB International 2005).	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Bactrocera dorsalis (Hendel, 1912) [Diptera: Tephritidae]	Oriental fruit fly	**Feasible**	Wide host range (Tsuruta *et al*. 1997; Allwood *et al*. 1999). Dispersed by infected fruit and adult flight. Strong flyers, adults can fly 50–100 km (Fletcher 1989). Adults occur throughout the year and can live up to 12 months (CAB International 2005). A total of 150–200 eggs are laid per female (Srivastava 1997).	**Significant**	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets. Species is a very serious pest of a wide variety of fruits and vegetables, and damage levels can be anything up to 100% of unprotected fruit (CAB International 2005). In Nauru, before its eradication, *B. dorsalis* infested up to 95% of mangoes and 90% of guavas (SPC 2002).	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Bactrocera latifrons (Hendel, 1915) [Diptera: Tephritidae]	Solanum fruit fly	**Feasible**	Species has a limited host range; however, egg production is not affected by periods of host deprivation (Liquido *et al*., 1994). Major hosts are peppers, bell pepper, and black nightshade. Minor hosts are chilli, tomato, currant tomato, cape gooseberry, aubergine, Jerusalem-cherry, turkey berry (CAB International, 2005). Generation time is ~ 20 days. Population clusters have established in marginal arid and windswept areas in Hawaii, where other tephritids have been less successful (Liquido *et al*., 1994).	**Significant**	It was introduced into Hawaii in ~1983 and since then has become established over all major islands of the Hawaiian chain, impacting production of solanaceous and cucurbitaceous crops (Liquido *et al*., 1994).	**Yes**
Bactrocera tau (Walker) [Diptera: Tephritidae]	Fruit fly	**Feasible**	Infests fruit of susceptible hosts, which are grown in Australia (CAB International, 2005).	**Significant**	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets.	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
ARTHROPODS						
HEMIPTERA						
Abgrallaspis cyanophylli (Signoret, 1869) [Hemiptera: Diaspididae]	Cyanophyllum scale	**Feasible**	*Abgrallaspis cyanophylli* is present in Australia (Donaldson & Tsang 2002). It is not present in Western Australia (DAWA 2003).	**Significant**	Considered to be a serious pest in Israel, USSR and USA (Florida) (Miller & Davidson 1990).	**Yes**
Aonidomytilus albus (Cockerell) [Hemiptera: Diaspididae]	Tapioca scale	**Feasible**	Widely established. Major host is cassava. Minor hosts include papaw, chrysanthemums, mango, sensitive plants and nightshade (CAB International 2005).	**Significant**	Can infest a wide range of plant species. Therefore, has potential to cause economic damage if introduced.	**Yes**
Aulacaspis vitis (Green, 1896) [Hemiptera: Diaspididae]	Armoured scale	**Feasible**	Cosmopolitan species and distribution is tropical. Not likely to spread to non-tropical or arid tropical zones (Watson 2005).	**Not significant**	Tropical species without a documented history of economic impact on mango or other crops. No reports of economic impact have been found (Watson 2005).	No

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
Lepidosaphes laterochitinosa Green [Hemiptera: Diaspididae]	Armoured scale	**Feasible**	Wide host range including mango, citrus, grapevine, and other agricultural and ornamental species (Ben-Dov *et al*. 2005). No information available on the biology of this species. Other Lepidosaphes species typically have 1 or 2 generations per year, and females lay up to 100 eggs each during their lifetime (e.g. Xu *et al*. 1995; Lin *et al*. 1997; Ozgokce *et al*. 1999; Song 2002). Over 20 species of Lepidosaphes are established in Australia (APPD 2005).	**Significant**	There is no information available on the economic significance of this species. However, other related species such as *Lepidosaphes ulmi*, *L. pineti* and *L. beckii* are economically significant on fruit crops and forestry plants (Ozgokce *et al*. 1999; Smaili *et al*. 2000; Song 2002).	**Yes**
Milviscutulus mangiferae (Green, 1889) [Hemiptera: Coccidae]	Mango shield scale	**Feasible**	Polyphagous host range (Ben-Dov *et al*. 2005)	**Significant**	This species can infest a wide range of host plants. Therefore, it has the potential to cause economic damage if introduced.	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Parlatoria pseudaspidiotus Lindinger, 1905 [Hemiptera: Diaspididae]	Vanda orchid scale	**Feasible**	Reported on several species including *Mangifera indica* (Ben-Dov *et al*. 2005). Widely distributed and listed as a pest (Ben-Dov *et al*. 2005).	**Significant**	This species can infest a wide range of host plants. Therefore, it has the potential to cause economic damage if introduced.	**Yes**
Planococcus lilacinus (Cockerell, 1905) [Hemiptera: Pseudococcidae]	Coffee mealybug	**Feasible**	Extremely wide host range (Ben Dov *et al. 20*05; CAB International 2005). Susceptible hosts are present in Australia. Most mealybugs have a high reproductive rate (Waite & Hwang 2002).	**Significant**	*Planococcus lilacinus* is a pest of cocoa throughout temperate and southeast Asia and the South Pacific (CAB International 2005). It also damages a wide variety of economically important crops such as coffee, tamarinds, custard apples, coconuts, citrus, grapes, guavas and mangoes (CAB International 2005). Therefore, it has potential to cause economic damage if introduced.	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Protopulvinaria pyriformis (Cockerell) [Hemiptera: Coccidae]	Pyriform scale	**Feasible**	Polyphagous pest attacking many agricultural hosts (Swirski *et al*. 1997a). Hosts are present, and the environment is conducive to establishment of this species in Australia. Females can reproduce parthenogenetically (Ben-Dov *et al.* 2005).	**Significant**	Economic importance of the Coccidae mainly results from reduced host vigour due to sap feeding. Appears to be a minor pest of mango (Swirski *et al*. 1997b), but the species is reported as a serious pest of fruit trees and ornamentals in several tropical and subtropical countries (Ben-Dov 1985; De Meijer *et al*. 1989; Del Rivero 1966; Gill 1988; Hamon & Williams 1984).	**Yes**
Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae]	Citriculus mealybug	**Feasible**	Wide host range including mango (Ben-Dov 1994).	**Significant**	Can infest a wide range of plant species. Therefore, it has potential to cause economic damage if introduced.	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Pseudococcus jackbeardsleyi Gimpel & Miller [Hemiptera: Pseudococcidae]	Jack Beardsley mealybug	**Feasible**	Reported on mango (Ben-Dov *et al*. 2005; CAB International 2005). Many mealybugs are considered invasive with a history of establishment in new areas (Miller *et al*. 2002).	**Significant**	Reported on a diverse array of fruits, vegetables, and ornamentals from 88 genera in 38 plant families (CAB International 2005). Mealybugs can directly harm hosts by feeding damage, are reported as disease vectors.	**Yes**
Pulvinaria taiwana Takahashi [Hemiptera: Coccidae]	Soft scale	**Feasible**	Reported on *Mangifera indica* from Taiwan (Ben-Dov *et al*. 2005).	Not significant	No significant economic impact documented.	No
Rastrococcus spinosus (Robinson, 1918) [Hemiptera: Pseudococcidae]	Philippine mango mealybug	**Feasible**	Wide host range and susceptible hosts are present in Australia (Ben-Dov *et al.* 2005). On mango, the total development times for males and females are 29 and 35 days respectively (Ullah *et al*. 1992).	**Significant**	*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**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Toxoptera odinae (van der Goot, 1917) [Hemiptera: Aphididae]	Mango aphid	**Feasible**	Species reproduces asexually, with wingless and winged adult forms aiding dispersal potential. Found seasonally on mango in Malaysia. Reported host range is relatively limited with major hosts being *Anacardium, Coffea* (coffee), *Mangifera indica* (mango). Minor hosts are *Aralia*, *Rhododendron* (Azalea), *Rhus* (Sumach), *Viburnum* (CAB International 2005; MTFIS 2004), but these species are present within Australia.	**Significant**	On economically important plants the aphids mainly cause a minor reduction in fruit yield and timber quality (CAB International 2005). Certain species of aphids are potential disease vectors.	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	**Comments**	**Significant/ not significant**	**Comments**	
Unaspis acuminata (Green) [Hemiptera: Diaspididae]	Unaspis scale	**Feasible**	Host range includes mango, citrus species, and *Ficus* species amongst others (Ben-Dov *et al*. 2005). No information available on the biology of this species. Other species of this genus have 2 or 3 generations per year and overwinter as adult females (Gill 1997). *Unaspis citri* is established in Australia (APPD 2005).	**Significant**	Although there is no information available on the economic significance of this species, other species in this genus have a high impact on their hosts. For example, *U. euonymi* can cause death of euonymus plants in California (Gill 1997), and *U. citri* is a major pest of citrus plants in the South Pacific (Williams & Watson 1988).	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
LEPIDOPTERA						
Orgyia australis postica (Walker, 1855) Regarded by some authors to be *Orgyia postica* Recorded as *Notolophorus australis posticus* Walker [sic] in BAPHIQ (2004) [Lepidoptera: Lymantriidae]	Cocoa tussock moth	**Feasible**	*Orgyia australis postica* is a forest species which has adapted well to orchards and forest plantations (CAB International 2005). Susceptible hosts are present in Australia. Host range includes widely cultivated plants such as mango, pear, grapevine and tea (CAB International 2005). Optimum development for *O. australis postica* is 25°C; at this temperature the life-cycle takes 33 days. Females have been recorded laying up to 500 eggs each (Cheng *et al*. 2001).	**Significant**	In Taiwan, *O. postica* is a major pest of cultivated grapevines (Chang 1988) and roses (Wang 1982). Larvae cause serious damage to young leaves of cacao in the Philippines, both in nurseries and plantations (Sanchez & Laigo 1968; CAB International 2005). When very numerous they can cause total defoliation, killing or stunting of the tree (Sanchez & Laigo 1968). The species is recorded as an economically significant pest of mango in India (Gupta & Singh 1986), and of soybeans, mungbeans and red beans in Taiwan (Su 1987). Reported to be of minor importance by BAPHIQ (2004).	**Yes**

Scientific name	Common name	Potential for establishment and spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
THYSANOPETRA (thrips)						
Rhipiphorothrips cruentatus Hood, 1919 [Thysanoptera: Thripidae]	Mango thrips	**Feasible**	Host range includes mango, guava, grapevine, pomegranate, cashew and sugar apple (CAB International 2005). Both sexual reproduction and parthenogenesis is known for this species. Females lay about 13 eggs each on wax apple in Taiwan (Chiu 1984).	**Significant**	*Rhipiphorothrips cruentatus* is one of the most important pests of grapevine in India (Rahman & Bhardwaj 1937). In Taiwan, wax apple has been severely attacked (Chiu 1984), and other crops such as mango and guava have also been damaged (Chang 1995).	**Yes**
FUNGI						
Elsinoë mangiferae Bitancourt & Jenkins [Myriangiales: Elsinoaceae]	Mango scab	**Feasible**	Establishment and spread is limited as mango is the only reported host. Dispersal of conidia is via rain and wind and germination is reliant on free water (Bitancourt & Jenkins 1943, 1946; CAB International 2005). Mature fruit is resilient to attack.	**Significant**	There are no reports of *E. mangiferae* infecting plants other than mango. However, losses from the disease can be relatively high if uncontrolled. Established in Australia (Northern Territory and Queensland) (CAB International 2005), but Western Australia has area freedom.	**Yes**

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APPENDIX 3: DATA SHEETS FOR QUARANTINE PESTS

Fruit flies

Bactrocera dorsalis (Hendel) [Diptera: Tephritidae] – Oriental fruit fly

Synonyms and changes in combination:

Dacus dorsalis Hendel, 1912; *Bactrocera conformis* Doleschall, 1858 (preocc.); *Bactrocera ferrugineus* (Fabricius); *Chaetodacus dorsalis* (Hendel); *Chaetodacus ferrugineus* (Fabricius); *Chaetodacus ferrugineus dorsalis* (Hendel); *Chaetodacus ferrugineus okinawanus* Shiraki, 1933; *Dacus ferrugineus* Fabricius; *Dacus ferrugineus dorsalis* Fabricius; *Dacus ferrugineus* var. *dorsalis* Fabricius; *Dacus ferrugineus okinawanus* (Shiraki); *Musca ferruginea* Fabricius (preocc.); *Musca ferruginea* Fabricius, 1794; *Strumeta dorsalis* (Hendel); *Chaetodacus ferrugineus* (Fabricius); *Strumeta ferrugineus* (Fabricius).

Hosts:

This species is a very serious pest of a wide variety of fruits and vegetables (CAB International 2005). Due to the confusion between *B. dorsalis* and related species in the Oriental fruit fly species complex (some 52 species that are found in the Oriental region, and a further 16 species native to Australasia), there are very few published host records which definitely refer to true *B. dorsalis* (CAB International 2005). No host plant survey has yet been carried out to show which hosts are of particular importance within the Asian range of true *B. dorsalis*.

Recorded commercial hosts are: *Aegle marmelos* (bael fruit), *Anacardium occidentale* (cashew), *Annona reticulata* (bullock's heart), *A. squamosa* (sugar apple), *Areca catechu* (betelnut palm), *Artocarpus altilis* (breadfruit), *A. heterophyllus* (jackfruit), *Capsicum annuum* (bell pepper), *Chrysophyllum cainito* (caimito), *Citrus maxima* (pummelo), *C. reticulata* (mandarin orange), *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *C. sativus* (cucumber), *Dimocarpus longan* (longan), *Ficus racemosa* (cluster fig), *Litchi chinensis* (lychee), *Malus pumila* (apple), *Mangifera foetida* (bachang mango), *M. indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Momordica charantia* (bitter gourd), *Muntingia calabura* (Jamaica cherry), *Musa* sp. (banana), *Nephelium lappaceum* (rambutan), *Persea americana* (avocado), *Prunus armeniaca* (apricot), *P. avium* (gean), *P. cerasus* (sour cherry), *P. domestica* (plum, prune), *P. mume* (Japanese apricot), *P. persica* (peach), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Pyrus communis* (pear), *Syzygium aqueum* (water apple), *S. aromaticum* (clove), *S. cumini* (jambolan), *S. jambos* (rose apple), *S. malaccense* (Malay apple), *S. samarangense* (wax apple), *Terminalia catappa* (Indian almond), *Ziziphus jujuba* (jujube); *Z. mauritiana* (Chinese date) (Tsuruta *et al*. 1997; Allwood *et al*. 1999).

Plant part(s) affected:

Fruit (Peña and Mohyuddin 1997; Srivastava 1997; CAB International 2005).

Distribution:

True *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). CAB International (2005) 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 northern areas of the Indian subcontinent (CAB International 2005).

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).

Biology:

The eggs of *Bactrocera oleae* were described in detail by Margaritis (1985) and those of other species are similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis 1985). Females lay a number of eggs per fruit. Clutch sizes of 3–30 eggs have been recorded for *B. dorsalis* (Fletcher 1989). Eggs of *B. dorsalis* are laid below the skin of the host fruit. These hatch within a day (although this can be delayed up to 20 days in cool conditions) and the larvae feed for another 6–35 days, depending on the season. Eggs are visible to the naked eye (CAB International 2005). Third instar larva of *B. dorsalis* are medium-sized, 7.5–10.0 mm long and 1.5–2.0 mm wide (White and Elson-Harris 1994).

Pupation occurs in the soil under the host plant for 10–12 days but may be delayed for up to 90 days under cool conditions (Christenson and Foote 1960). Pupae are barrel-shaped with most larval features unrecognisable. Puparium are usually 60–80% length of larva. Pupae can be found in the growing medium, accompanying plants, and are also visible to the naked eye, being white to yellow-brown in colour. Plant parts other than fruit are not known to carry the pest in trade and or transport (CAB International 2005). Fruits and growing media are liable to carry pupae of this fruit fly in trade and or transport (CAB International 2005).

Adults are predominantly black or dark fuscous, or a balanced mixture of black and yellow. When the thorax is viewed dorsally, there are a number of pale whitish to yellow lateral stripes over the anterior plates. In addition, the posterior thoracic plates are black with orange to red-brown areas, or black. The abdomen is oval or parallel sided with a mediolateral dark stripe running most of its length (Carrol *et al*. 2002). Adults occur throughout the year and begin mating after 8–12 days, and may live 1–3 months depending on temperature—up to 12 months in cool conditions (Christenson and Foote 1960). Adults may live for many months and in laboratory studies, the potential fecundity of female *B. dorsalis* is over 1000 eggs (Fletcher 1989).

The major means of movement and dispersal are transportation of infected fruit and adult flight (Fletcher 1989). Many *Bactrocera* species can fly 50–100 km (Fletcher 1989).

Fruit show the following symptoms of infestation: some necrosis around the puncture mark—'sting'—following oviposition, which causes decomposition of the fruit that appears as black or brown lesions. Premature fruit-drop from trees can occur (CAB International 2005).

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Bactrocera cucurbitae (Coquillett) [Diptera: Tephritidae] – melon fly

Synonyms and changes in combination:

Dacus cucurbitae Coquillett, 1899; *Chaetodacus cucurbitae* (Coquillett); *Dacus aureus* Tseng and Chu; *Dacus yuiliensis* Tseng & Chu; *Strumeta cucurbitae* (Coquillett); *Zeugodacus cucurbitae* (Coquillett).

Hosts:

This species is a very serious pest of cucurbit crops (CAB International 2005). According to Weems (1964) it has been recorded from over 125 plants, including members of families other than Cucurbitaceae. However, many of those records were based on casual observations of adults resting on plants or caught in traps set in non-larval host roosting trees.

Primary hosts are species of Cucurbitacaeae, as follows: *Cucumis melo* (melon) (Drew 1982; Allwood *et al*. 1999), *Cucurbita maxima* (giant pumpkin) (Tsuruta *et al*. 1997; Allwood *et al*. 1999), *Cucurbita pepo* (ornamental gourd) (Drew 1982; Allwood *et al*. 1999) and *Trichosanthes cucumerina* (snake gourd) (Tsuruta *et al*. 1997; Allwood *et al*. 1999).

Other hosts include: *Abelmoschus moschatus*, *Artocarpus heterophyllus* (jackfruit), *Benincasa hispida* (wax gourd), *Carica papaya* (papaw), *Citrullus colocynthis* (colocynth), *Citrullus lanatus* (watermelon), *Citrus hystrix*, *Citrus maxima* (pummelo), *Citrus sinensis* (navel orange), *Cucumis auguria* (gerkin), *Cucumis sativus* (cucumber), *Cucurbita moschata* (pumpkin), *Cydonia oblonga* (quince), *Cyphomandra betacea* (tree tomato), *Ficus carica* (fig), *Lagenaria siceraria* (bottle gourd), *Luffa acutangula* (angled luffa), *Luffa aegyptiaca* (loofah), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Momordica balsamina* (common balsamapple), *Momordica charantia* (bitter gourd), *Passiflora edulis* (passionfruit), *Persea americana* (avocado), *Phaseolus vulgaris* (common bean), *Prunus persica* (peach), *Psidium guajava* (guava), *Sechium edule*, *Sesbania grandiflora* (agati), *Syzygium samarangense* (water apple), *Trichosanthes cucumerina* var. *anguinea* (snakegourd), *Vigna unguiculata* (cowpea), *Ziziphus jujuba* (common jujube) (CAB International 2005). Mango is not listed as a host in Allwood *et al*. (1999).

Plant part(s) affected:

Fruit (Peña and Mohyuddin 1997; Srivastava 1997; CAB International 2005)

Distribution:

B. cucurbitae is widely distributed in Asia, but also occurs in Africa, North America and Oceania regions (CAB International 2005). It was introduced to Hawaii in the late 19th century (Clausen 1978). In Asia, *B. cucurbitae* is recorded from Afghanistan (IIE 1995); Bangladesh (CAB International 2005); Brunei Darussalam (Waterhouse 1993); Cambodia (IIE 1995); China (CAB International 2005); India (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Delhi, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal) (CAB International 2005; IIE 1995); Indonesia, Iran, Laos, Malaysia, Myanmar, Nepal, Oman, Pakistan, Philippines, Saudi Arabia (CAB International 2005); Singapore (IIE 1995); Sri Lanka, Thailand, United Arab Emirates and Viet Nam (CAB International 2005). In addition to Asia, CAB International (2005) includes the following countries in its distribution: in Africa this species is found in Cameroon, Côte d'Ivoire, Egypt, Gambia, Guinea, Kenya, Mali, Mauritius, Réunion, Seychelles, Somalia and Tanzania. In the USA, this species occurs in Hawaii and in Oceania it is known from Guam, Kiribati, Nauru, Northern Mariana Islands, Papua New Guinea, Bougainville and the Solomon Islands.

Biology:

Studies in Taiwan and India indicated that adult *B. cucurbitae* flies have been observed to 'roost' in mango trees, as well as citrus and guava, where they feed on honey dew produced by aphids and mealybugs (Lall and Singh 1969; Lee 1972) or the flowers (pollen/nectar) and juices of damaged plants (Severin *et al*. 1914). In India *B. cucurbitae* roosting occurs from December to mid February, during which time the females do not oviposit (Lall and Singh 1969). Adults migrate from roosting sites to cucurbits for oviposition (Lall and Singh 1969; Lee 1972).

Where suitable host plants are not present it is likely that flies would migrate in search of suitable reproductive habitat. Adults may disperse over 2 km but do not move significant distances when suitable larval hosts and adult roosting sites are available (Peck *et al*. 2005). Longevity of *B. cucurbitae* females has been recorded as a maximum of 222 days (Vargas and Carey 1990) and the mean generation time is 72 days (Vargas and Carey 1990).

B. cucurbitae is a very serious pest of cucurbit crops. It can attack flowers as well as fruit, and additionally, will sometimes attack stem and root tissue. In Hawaii, pumpkin and squash fields (varieties of *Cucurbita pepo*) have been known to be heavily attacked before fruit had even set, with eggs being laid into unopened male and female flowers, and larvae even developing successfully in the taproots, stems and leaf stalks (Back and Pemberton, 1914).

Measured on papaya *B. cucurbitae* has a higher mean generation time (72 days), lower net reproductive rate (Ro = 80.8) and lower intrinsic rate of increase (Rm = 0.06) than *Ceratitis capitata* or *B. dorsalis* (Vargas and Carey 1990).

Successful eradication of *B. cucurbitae* has been implemented in Japan (Kuba *et al*. 1996) and Naru (Allwood *et al*. 2003)

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Bactrocera latifrons (Hendel) [Diptera: Tephritidae] – solanum fruit fly.

Synonyms and changes in combination:

Bactrocera (Bactrocera) latifrons (Hendel), *Chaetodacus antennalis* Hendel, *Chaetodacus latifrons* Hendel, *Dacus latifrons* Hendel, *Dacus parvulus* Hendel.

Hosts:

In Taiwan, this species has been reported from *Litchi chinensis*, *Lycopersicon pimpinellifolium*, *Solanum* sp. *Solanum incanum*, *Solanum indicum* and *Ziziphus jujube* (Liquido *et al*. 1994). It has been recorded attacking mango in Thailand (Karnkowski *et al*. 2003), Malaysia (Liquido *et al*. 1994) and India (Srivastava 1997).

Other hosts include: *Capsicum annuum* (bell pepper), *Capsicum frutescens* (chilli), *Lycopersicon esculentum* (tomato), *Physalis peruviana* (cape gooseberry), *Solanum melongena* (aubergine), *Solanum nigrum* (black nightshade), *Solanum pseudocapsicum* (Jerusalem cherry), *Solanum torvum* (turkey berry) (CAB International 2005).

Plant part(s) affected:

Fruit (Peña and Mohyuddin 1997; Srivastava 1997; CAB International 2005)

Distribution:

Bactrocera latifrons is native to South and Southeast Asia. It has been recorded in Brunei Darussalam, China, India, Indonesia, Laos, Malaysia, Pakistan, Singapore, Sri Lanka, Taiwan, Thailand and Vietnam (CAB International 2005). In ~1983 it was introduced to Hawaii where it has since established on all major islands in the Hawaiian chain (Liquido *et al*. 1994).

Biology:

The eggs of *Bactrocera oleae* were described in detail by Margaritis (1985) and those of *B. latifrons* are probably similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis 1985). Eggs of *B. latifrons* are laid below the skin of the host fruit, and generally hatch within a day. Third instar larva are medium-sized, with a length of 7.0-8.5 mm and a width of 1.2-1.5 mm (White and Elson-Harris 1994). The pupae are barrel-shaped with most larval features unrecognizable. They are white to yellow-brown in colour and usually about 60-80% of the length of the larva (CAB International 2005). Adults are predominantly black or dark fuscous (CAB International 2005).

Eggs are laid below the skin of the host fruit. These hatch within a few days (mean 2.3) and the larvae feed for a little over a week (mean 8.5 days). Pupation occurs in the soil under the host plant for little over a week (mean 10.2 days). Adults occur throughout the year and females begin oviposition after 6-17 days, and continue laying eggs for 6-117 days (Vargas and Nishida 1985). The average incubation period and egg hatchability of *B. latifrons* is 1.19 days and 82.5% respectively. There are three larval instars, and the total duration of the life cycle is about 18 days (Kumar and Agarwal 2003). Duration of immature stages ranged between 15-47 days at temperatures between 16 and 32 ^{o}C (Vargas *et al*. 1996). In the laboratory, female longevity ranged from 15-80 days, and male longevity from 12-61 days. The highest net reproductive rate occurred at 24 ^{o}C (Vargas *et al*. 1997).

Bactrocera latifrons has a 20 day larval/pupal development time, and live for an average of 64 days as an adult. Females lay an average of 256 eggs over a period of about 50 days in the presence of suitable host plants (Vargas and Nishida 1985). These data suggest that the flies have the potential to reach high population numbers.

In Hawaii, *B. latifrons* is found at elevations between 10 and 955 m above sea level, with average annual rainfall of 50-125 cm (Liquido *et al*. 1994). In Hawaii, population numbers of *B. latifrons* appeared to increase during winter and early spring (Liquido *et al.* 1994). Liquido *et al*. (1994) showed that *B. latifrons* out competed *B. dorsalis*, *B. cucurbitae* and *Ceratitis capitata* in its Solanaceous hosts but not in its non-Solanaceous hosts.

The major means of movement and dispersal are transportation of infected fruit and adult flight (Fletcher 1989). Many *Bactrocera* spp. can fly 50–100 km (Fletcher 1989). In a mark-release-recapture study, *B. latifrons* was found to spread up to 500m after about 4 weeks (Peck and McQuate 2004).

Bactrocera latifrons is considered a fruit fly of economic importance in Hawaii, where a lot water disinfestation treatment has been developed (Jang *et al.* 1999). Liquido *et al.* (1994) recommended that the status of *B. latifrons* as a fruit fly of lesser economic importance be re-evaluated and its potential threat to agriculture be carefully examined. They recommended that proper measures be taken to include this fruit fly species in detection programs and its infestation biology should be examined in potential and putative hosts under commercial cultivation.

Bactrocera species in general can be attacked as larvae either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Liquido *et al*. (1994) reported low rates of parasitism for *B. latifrons* larvae. For a summary table of recorded parasitoids of *B. latifrons*, see Liquido *et al*. (1994).

This species is not attracted to either cue lure or methyl eugenol, however, alpha-ionol has been identified as a male lure for *B. latifrons* (McQuate and Peck 2001).

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Bactrocera tau (Walker) [Diptera: Tephritidae] – pumpkin fruit fly.

Synonyms and changes in combination:

Dacus tau Walker; *Bactrocera hageni* (Hendel); *Bactrocera* (*Zeugodacus*) *tau* (Walker); *Dacus hageni* (de Meijere); *Chaetodacus tau* (Walker); *Dacus caudatus* var. *nubilus* (Hendel); *Dacus nubilus* (Hendel); *Dasyneura tau* (Walker); *Zeugodacus nubilus* (Hendel).

Hosts:

This species appears to show a preference for attacking the fruits of Cucurbitaceae, but it has also been reared from the fruits of several other plant families (CAB International 2005). Due to the recent separation of previously confused species, the host data given below were taken from a recently published host catalogue that was largely based on a 1990s survey carried out in Thailand and Malaysia (Allwood *et al*. 1999). Hosts include; *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Cucurbita maxima* (giant pumpkin), *Luffa acutangula* (angled luffa), *Momordica charantia* (balsam apple) (CAB International 2005); *Mangifera indica* (mango) (Peña and Mohyuddin 1997); *Momordica cochinchinensis* (kankrol), *Trichosanthes dioica* (potol), *Benincasa hispida* (bottle gourd), *Trichosanthes anguina* (snake gourd) (Huque 2006).

Plant part(s) affected:

Fruit (Peña and Mohyuddin 1997; Srivastava 1997; CAB International 2005).

Distribution:

Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, India, Indonesia, Laos, Malaysia, Myanmar, Singapore, Taiwan, Thailand, Viet Nam (CAB International 2005).

Biology:

The eggs of *B. tau* are likely to be similar to those of *B. olae* (Gmelin); eggs are 0.8 mm long and 0.2 mm wide and white to yellow-white in colour (Margaritis 1985; CAB International 2005). The third instar larvae are medium-sized, 7.5-9.0 mm in length and 1.0-1.5 mm in width (White and Elson–Harris 1994). The pupae are barrel-shaped with most larval features unrecognisable. They are white to yellow-brown in colour, and about 60-80% the length of the larva (CAB International 2005).

As with all *Bactrocera* species, the eggs are laid below the skin of the host fruit. These hatch within a day or 2 days and the larvae feed for another week or more. Pupation occurs in the soil under the host plant for a week or more but may be delayed for several weeks under cool conditions. Adults occur throughout the year and begin mating after about 2 weeks (Christenson and Foote 1960; CAB International 2005).

Liu and Lin (2001) investigated the development and reproduction of *B. tau* on various hosts. The developmental time of the immature stage was 19-20 days at 28 °C. Female fecundity ranged between 665 and 911 eggs per female, with oviposition beginning on the 12th day after female emergence. Mean generation time varied between 44 and 52 days (Liu and Lin 2001). Developmental times for *B. tau* on pawpaw are approximately 1 day for eggs, 5-14 days for larvae, and 9 days for pupae. There was a pre-copulatory period of 14-15 days. In Taiwan there are two peaks of *B. tau* population in a year, the first peak around June and the second in December, although the fly can be found all-year-round (Chen 2001). There is one generation per year in Gansu, China, and the species over-winters as mature larvae (Zhou *et al*. 1993). Eggs are laid in clusters 8-14, and the number of larvae per fruit ranges from 10 to 40, depending on host (Borah and Dutta 1996).

Developmental time decreases with increasing temperature, up to 35 ºC. The theoretical low developmental threshold temperatures of eggs, larvae and pupae are 9.1, 2.4 and 10.3 ºC respectively. Chang and Ying (2000) state that larvae develop over 30 days at 10 ºC and 8 days at 30 ºC. Pupation takes about 25 days at 15 ºC and 7 days at 30 ºC (Chang and Ying 2000). The longevity of adults is more than six months at temperatures between 15 and 25 ºC, and up to 121 days at 30 ºC (Liu and Lin 2000).

Adult flight and the transport of infected fruit are the major means of movement and dispersal to previously uninfected areas. Many *Bactrocera* species can fly 50-100 km (Fletcher 1989). The major phytosanitary risk is from the import of fruit containing larvae, either as part of cargo, or through the smuggling of fruit in airline passenger baggage or mail (CAB International 2005).

In order to successfully pupate tephritid larvae prefer moist soils (Hulthen and Clarke 2006). Larvae which pupate in transit are likely to suffer desiccation moisture loss which is known to cause mortality in several other species (Hulthen and Clarke 2006).

Bactrocera species can be attacked as larvae by either parasitoids or vertebrates eating fruit, however, parasitoids appear to have little effect on the populations of most fruit flies (CAB International 2005). There are no known biological control programs for *B. tau*.

Bactrocera tau is considered to be a fruit fly of economic importance in Malaysia. Control is achieved by cover spraying with insecticides, spot sprays of protein baits, orchard sanitation and fruit wrapping (Vijaysegaran and Loke 2000). These control methods are considered to be sufficient for production of fruit for domestic consumption, but not for export fruit to countries which consider fruit flies to be quarantine pests (Vijaysegaran and Loke 2000).

A bait spray consists of a suitable insecticide (e.g. malathion) mixed with a protein bait. Both males and females of fruit flies are attracted to protein sources emanating ammonia and so insecticides can be applied to just a few spots in an orchard and the flies will be attracted to these spots (CAB International 2005). Protein baits have been successfully developed for mango fruit flies (including *B. tau*) in Sri Lanka (Ekanayake and Bandara 2003). The suppression of egg laying in *B. tau* by the use of boric acid and a neem pesticide has been investigated in India (Verma and Nath 2003a; 2003b). Males of *B. tau* are attracted to cue lure, and on a small scale many farmers use male suppression as a control technique (CAB International 2005).

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Armoured scales

Abgrallaspis cyanophylli Signoret, 1869 [Hemiptera: Diaspididae] – Cyanophyllum scale, red scale

Aonidomytilus albus Cockerell [Hemiptera: Diaspididae] – Tapioca scale

Lepidosaphes laterochitinosa Green [Hemiptera: Diaspididae]

Parlatoria pseudaspidiotus Lindinger, 1905 [Hemiptera: Diaspididae] – Vanda orchid scale

Unaspis acuminata Green [Hemiptera: Diaspididae] – Unaspis scale

Synonyms and changes in combination:

Abgrallaspis cyanophylli: *Aspidiotus cyanophylli* Signoret, 1869; *Fucaspis cyanophylli* Signoret; *Hemiberlesia cyanophylli* Signoret.

Aonidomytilus albus: *Mytilaspis albus* Cockerell; *Mytilaspis albus* Cockerell; *Mytilaspis alba*; Cockerell; *Coccomytilus albus* Leonardi; *Lepidosaphes alba* Fernald; *Mytilaspis coccomytibus dispar* Vayssière; *Mytilaspis* (*Coccomytilus*) *dispar* Vayssière; *Lepidosaphes dispar* Sasscer; *Coccomytilus dispar* Takahashi; *Aonidomytilus albus* Ferris; *Mytilococcus albus* Lindinger; *Lepidosaphes* (*Aonidomytilus*) *albus* Merrill.

Lepidosaphes laterochitinosa: *Lepidosaphes bladhiae* Takahashi, 1931; *Parainsulaspis bladhiae* Borchsenius, 1963; *Parainsulaspis laterochitinosa* Borchsenius, 1963; *Lepidosaphes spinulosa* Beardsley, 1966.

Parlatoria pseudaspidiotus: *Parlatoria mangiferae* Marlatt; *Parlatorea mangiferae* Lindinger; *Leucaspis mangiferae* Wester; *Genaparlatoria mangiferae* MacGillivray; *Genaparlatoria pseudaspidiotus* MacGillivray; *Aonidia pseudaspidiotus* Cockerell; *Parlatoria pseudaspidiotus* Ferris; *Parlatoria* (*Genaparlatoria*) *pseudaspidiotus* Merrill; *Pinnaspis pseudaspidiotus* Reyne.

Unaspis acuminata: *Chionaspis acuminata* Green; *Unaspis acuminata* MacGillivray.

Hosts:

Abgrallaspis cyanophylli: *Acalypha hispida* (chenille plant), *Annona squamosa* (sugar apple), *Annona* sp. (custard apple), *Artocarpus altilis* (breadfruit), *Bauhinia* sp., *Barringtonia* sp., *Camellia sinensis* (tea), *Capsicum ovatum*, *Ceiba pentandra* (kapok tree), *Cinnamomum verum* (cinnamon), *Clerodendrum* sp., *Coccoloba uvifera* (Jamaican kino, sea-grape), *Cocos nucifera* (coconut), *Coffea arabica* (arabica coffee), *Coffea* sp. (coffee), *Coleus* sp., *Cordyline fruticosa* (palm lily), *Dioscorea alata* (greater yam), *Dioscorea* spp. (yam), *Elettaria cardamomum* (cardamom), *Eriobotrya japonica* (loquat), *Eugenia* sp., *Ficus* sp. (fig), *Guettarda speciosa* (beach gardenia), *Hevea brasiliensis* (rubber tree), *Hibiscus syriacus* (rose-of-Sharon), *Jatropha curcas* (Barbados-nut), *Macadamia tetraphylla* (rough-shell Queensland nut), *Mangifera indica* (mango), *Manihot esculenta* (cassava), *Musa* × *paradisiaca* (banana), *Musa* sp. (banana), *Persea americana* (avocado), *Piper methysticum* (kava kava), *Plumeria rubra* f. *acutifolia* (Mexican frangipani), *Psidium guajava* (guava), *Swietenia macrophylla* (Honduras mahogany), *Theobroma cacao* (cocoa), *Toona ciliata* (Australian red cedar) (Williams and Watson 1988); *Nerium* sp. (oleander) (CAB International 2005).

Aonidomytilus albus: *Atriplex* sp., *Carica papaya* (papaya), *Chrysanthemum* sp., *Croton bonplandianus*, *Flourensia*, *Harrisia*, *Jatropha gossypifolia*, *Jatropha* sp., *Malvastrum americanum*, *Mangifera indica* (mango), *Manihot aipi*, *Manihot esculenta*, *Manihot utilissima*, *Mimosa* sp. *Salvia* sp., *Sechium* sp., *Sida carpinifolia*, *Solanum melongena*, *Solanum* sp., *Solanum torvum*, *Suaeda*, *Turnera ulmifolia* (Ben-Dov *et al. 20*05).

Lepidosaphes laterochitinosa: *Agalma lutchuense*, *Alstonia scholaris*, *Ardisia crenata*, *Ardisia japonica*, *Ardisia sieboldii*, *Ardisia* sp., *Areca catechu*, *Artocarpus communis* (breadfruit), *Asparagus* sp., *Barringtonia asiatica*, *Bladhia sieboldi*, *Bladhia* sp., *Bruguiera hexangula*, *Bruguiera* sp., *Camellia sinensis* (tea), *Castanea* sp., *Casuarina* sp., *Cestrum* sp., *Citrus* sp., *Cocos nucifera* (coconut), *Coelogyne* sp., *Cycas circinalis seemanii*, *Cycas circinalis*, *Cycas* sp., *Epipremnum mirabile*, *Eurya japonica*, *Eurya* sp., *Garcinia* sp., *Glochidion* sp., *Heptapleurum octophyllum*, *Heterosmilax japonica*, *Hevea* sp., *Hyophorbe verschaffeltii*, *Illicium anisatum*, *Illicium philippinense*, *Machilus kusanoi*, *Maesa* sp., *Mangifera indica* (mango), *Manihot esculenta*, *Osmanthus fragrans*, *Plumeria acuminata*, *Psidium* sp., *Ravenala* sp., *Rhizophora mucronata*, *Schefflera octophylla*, *Smilax china*, *Smilax glabra*, *Smilax* sp., *Ternstroemia gymnanthera*, *Vitis* sp., *Vitis vinifera* (grapevine) (Ben-Dov *et al*. 2005).

Parlatoria pseudaspidiotus: *Aerides* sp., *Caryopteris incana*, *Cattleya* sp., *Commiphora berryi*, *Cymbidium* sp., *Cyrtopodium punctatum*, *Dendrobium* sp., *Euphorbia antiquorum*, *Mangifera indica* (mango), *Trichoglottis philippinensis*, *Vanda hookeriana*, *Vanda jaquiem*, *Vanda* sp., *Vanda teres* (Ben-Dov *et al*. 2005).

Unaspis acuminata: *Ardisia* sp., *Bassia latifolia*, *Bassia* sp., *Carissa* sp., *Citrus* sp., *Cycas revoluta*, *Dipterocarpus*, *Euonymus resoluta*, *Euonymus*, *Evodia* sp., *Picus*, *Leea* sp., *Mangifera indica* (mango), *Morinda*, *Severinia buxifolia*, *Turpinia formosana* (Ben-Dov *et al*. 2005).

Plant part(s) affected:

For the listed armoured scales, the plant parts affected include leaves, stems and fruit (Smith *et al.* 1997; Srivastava 1997; CAB International 2005).

Distribution:

Abgrallaspis cyanophylli: Cook Islands, Fiji, French Polynesia (Williams and Watson 1988); Georgia, India (CAB International 2005); Kiribati, New Caledonia, Papua New Guinea, Tonga, Tuvalu, Vanuatu, Western Samoa (Williams and Watson 1988). This species has also been recorded in Australia (New South Wales, Queensland, Tasmania), but not in Western Australia (AICN 2004).

Aonidomytilus albus: Angola, Antigua and Barbuda, Argentina, Aruba, Bahamas, Barbados, Brazil, British Virgin Islands, China, Colombia, Cuba, Dominica, Dominican Republic, French Guiana, Ghana, Grenada, Guadeloupe, Guyana, Haiti, Hong Kong, India, Jamaica, Kenya, Madagascar, Malawi, Malaysia, Martinique, Mauritius, Mexico, Mexico, Montserrat, Mozambique, Nigeria, Puerto Rico and Vieques Island, Saint Croix, Saint Kitts and Nevis Islands, Saint Lucia, Saint Vincent and the Grenadines, Somalia, Sri Lanka, Taiwan Tanzania, Trinidad and Tobago, U.S. Virgin Islands, Uganda, United States of America (Ben-Dov *et al. 20*05).

Lepidosaphes laterochitinosa: China, Guam, Japan, Malaysia, Northern Mariana Islands, Palau, Philippines, Ponape Island, Taiwan, United Kingdom Wake Island (Ben-Dov *et al.* 2005).

Parlatoria pseudaspidiotus:

Barbados, Bonin Islands, Cameroon, China, Colombia, Costa Rica, Fiji, Germany, Guam, Guyana, Hawaiian Islands, India, Indonesia, Italy, Jamaica, Japan, Malaysia, Myanmar, Pakistan, Panama, Papua New Guinea, Philippines, Puerto Rico and Vieques Island, Singapore, South Africa, Sri Lanka, Sudan, Suriname, Tahiti, Taiwan, Thailand, Trinidad and Tobago, United Kingdom, United States of America, Vietnam, Western Samoa (Ben-Dov *et al. 20*05).

Unaspis acuminata: China, India, Sri Lanka, Taiwan, Thailand (Ben-Dov *et al. 20*05).

Biology:

Diaspidids are strongly sexually dimorphic. Diaspididae reproduction is usually sexual but parthenogenesis may occur in some species (Rosen 1990); relatively few species are oviparous, most being ovoviviparous or viviparous (Koteja 1990a). There are two immature instars in the female, which has no pupal stage. The male has 2 feeding larval instars followed by two non-feeding stages (pre-pupa and pupa) before a winged adult emerges (Koteja 1990b).

Diaspidids display division of function between different developmental stages within their life cycle. The first instar crawler developmental stage is the dispersive stage, with the role of locating a suitable feeding site; aiding this process they may travel to the top of a plant and spread their legs for wind dispersal (Greathead 1990). Crawlers may be dispersed on birds' feet, insects, animals or man (directly or indirectly via transport on infected plant materials) (Dreistadt *et al.* 1994; Beardsley and Gonzalez 1975). Moderate to high humidity, without precipitation, favours crawler survival (Watson 2005).

Crawlers locating a suitable feeding site will settle, feed and moult to form the second instar (Beardsley and Gonzalez 1975). The second instar larvae are sessile, lacking legs and are the main feeding stage. Subsequently the second instar female moults to the sessile adult stage, with feeding and reproduction roles. In sexual reproduction, adult females mate soon after the last moult. In viviparous and ovoviviparous species feeding continues during the reproductive period which may occur over several weeks or months. In contrast some oviparous species stop feeding before the short period of oviposition begins (Koteja 1990b). Male development continues, beyond the second instar, under the protective scale cover produced by the second instar (the final feeding stage for the male) (Foldi 1990). The second instar moults into a pre-pupa with small wing buds, which moults into a pupa (with larger wing buds), and finally the pupa moults into a functional winged adult male, which rests beneath the scale cover before emerging to seek a mate. Adult males lack mouthparts for feeding and they are short-lived. The sex ratio in diaspidid scale insects is usually about 1:1, but there are examples of strongly biased ratios that may be due to environmental conditions or a population structure that favours inbreeding, or due to maternal age (Watson 2005).

Most species produce 50–150 eggs per female (but some produce as few as 10 or as many as 600), at a rate of 1–10 laid per day, according to species and conditions. Eggs are laid under the protective scale cover, from which the crawlers later disperse.

Diaspididae do not excrete honeydew. They are therefore neither associated with sooty mould growths, nor are they normally attended by ants. Any sooty mould or ants in the vicinity are associated with other honeydew-excreting insects nearby, e.g. Pseudococcidae, Coccidae or Margarodidae.

The armoured scales *Abgrallaspis cyanophylli*, *Aonidomytilus albus* are both listed as significant economic pest in Miller and Davidson (1990). *A.* cyanophylli has been assessed previously (DAFF 2004).

<u>*Abgrallaspis cyanophylli*</u>: The cyanophyllum scale is widely distributed in the tropical and subtropical regions. It is polyphagous causing damage to various ornamentals (Davidson and Miller 1990), as well as horticultural crop plants (CAB International 2005). *Abgrallaspis cyanophylli* has been reported to cause damage on avocado trees in Israel (Gerson and Zor 1973), guava in Fiji (Lever 1945) and tea in Papua New Guinea (Williams and Watson 1988).

In northern Taiwan *A. cyanophylli* is one of the most important pests of tea (Shiao 1979). A single female may lay up to 60 eggs with a 93% hatch rate and five overlapping generations per year (Shiao 1979). In laboratory studies the survival rate at 25 ^{o}C was

75.9% and at 30 ^{o}C it was only 44.7% (He *et al*. 1998). The nymphal stage varied from 37.0 to 64.5 days between 20 and 28^{o}C. The number of crawler offspring per female was greatest at 28^{o}C, and the optimal survival rate occurred at 75% humidity (He *et al*. 1998). Population size may be influenced by temperature, rainfall, parasites and pathogens (Shiao 1979). *Abgrallaspis cyanophylli* has been the subject of several biological control studies (Gaprindashvili 1975; Ponsonby and Copland 1995; 2000).

Aonidomytilus albus: The species is considered to have spread from the New World with the dissemination of cassava planting sticks (CAB International 2005). *Aonidomytilus albus* is a serious pest of cassava in East and West Africa, Argentina, Brazil, Colombia, India, Madagascar, Mexico, Taiwan, Thailand, West Indies and USA (Bellotti 1978; Miller and Davidson 1990; CAB International 2005).

First instars walk or are carried by wind to new feeding sites (CAB International 2005). Dry conditions increase plant susceptibility to attack and favour the dissemination of crawlers which may drown or be swept off the host in wet conditions (CAB International 2005). Females begin to lay eggs about two days after reaching maturity (Anantanarayanan *et al*. 1957). Eggs hatch after 3–4 days and develop into mature adults over a period of 20–25 days (Lal and Pillai 1981).

New infections are predominantly initiated by the first instar crawler which typically spreads downwind to plants in close proximity. This stage is short-lived, especially in the absence of a host. Dispersal over longer distances requires human or animal assistance (CAB International 2005).

Lepidosaphes laterochitinosa: The biology and ecology of this species have not been reported. The natural enemies of this species have not been studied, further limiting assessment of its capacity for economic and environmental impact if introduced. However, species within the genus *Lepidosaphes* are identified as pests of significant economic significance. For example, *L. beckii* is a polyphagous species that has been recorded from hosts belonging to 45 genera in 11 plant families (Davidson and Miller 1990), and its host range may well be wider. *Lepidosaphes beckii* is one of the most important pests of *Citrus* wherever it is grown (Williams and Watson 1988).

Parlatoria pseudaspidiotus: This species is reported as a pest of *Mangifera indica* (Lee 1988; Ben-Dov *et al*. 2005). Balachowsky (1953) described *P. pseudoaspidiotus* as damaging on orchids cultivated under glass; introduction might threaten orchid production. However, Miller and Davidson (1990) considered it a non-serious pest in a global compilation of economically significant armoured scale pests. The natural enemies of this species have not been studied, further limiting assessment of its capacity for economic and environmental impact if introduced.

The biology and ecology of this species have not been extensively reported. Generally, crawlers are the primary dispersal stage for armoured scales as is dispersal by wind or animal contact. However, mortality due to abiotic factors is high in this stage. Sessile adults and eggs may be dispersed through human transport of infested plant material.

Unaspis acuminata: The biology and ecology of this species have not been reported. The natural enemies of this species have not been studied, further limiting assessment of its capacity for economic and environmental impact if introduced. However, species within the genus *Unaspis* are identified as pests of significant economic significance. For example, the polyphagous *Unaspis citri*, attacks plant species belonging to 9 genera in 7 plant families (Davidson and Miller 1990), including *Citrus* spp. *Unaspis yanonensis* is the most important pest of *Citrus* in Japan (Rosen 1990), and Foldi, (2001) lists it as of economic importance causing widespread damage to *Citrus* in the French Riviera.

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Soft scales

Protopulvinaria pyriformis (Cockerell, 1905) [Hemiptera: Coccidae] - Pyriform scale

Milviscutulus mangiferae (Green, 1889) [Hemiptera: Coccidae] - Mango shield scale

Synonyms and changes in combination:

Protopulvinaria pyriformis: *Pulvinaria* (*Protopulvinaria*) *pyriformis* Cockerell, 1894; *Protopulvinaria pyriformis* Cockerell, 1894; *Pulvinaria newsteadi* Leonardi, 1898; *Pulvinaria plana* Lindinger, 1911; *Protopulvinaria piriformis* Lindinger, 1912; *Protopulvinaria piriformis* Brain, 1920; *Protopulvinaria piriformes* Gomez-Menor Ortega, 1929; *Protopulvinaria agalmae* Takahashi, 1933; *Protopulvinaria pyiformis* Tao, 1978; *Pulvinaria phriformis* Pollard & Alleyne, 1986.

Milviscutulus mangiferae: *Lecanium mangiferae* Green, 1889; *Coccus mangiferae* (Green); *Lecanium psidii* Green, 1904; *Saissetia psidii* (Green); *Lecanium wardi* Newstead, 1922; *Coccus wardi* (Newstead); *Lecanium desolatum* Green, 1922; *Lecanium ixorae* Green, 1922; *Protopulvinaria mangiferae* (Green); *Coccus ixorae* (Green); *Coccus kuraruensis* Takahashi, 1939; *Protopulvinaria ixorae* (Green); *Coccus desolatum* (Green); *Kilifia mangiferae* (Green); *Udinia psidii* (Green).

Hosts:

Protopulvinaria pyriformis: *Adhatoda vasica, Agalma lutchuense, Altidesma bunius, Amomis, Antidesma bunius, Apollonias barbujana, Aralia, Araujia sericofera, Bauhinia chamioni, Bauhinia vahlii, Brassaia actinophylla, Canna indica, Caprifolium, Carica papaya* (papaya), *Carissa grandiflora, Choisya ternata, Cinnamomum camphora* (caphor laurel), *Cinnamomum cassia, Cinnamomum zeylanicum, Citrus aurantium* (bitter orange), *Clerodendrum, Cymbidium, Diospyros erianthi, Dizygotheca, Dracaena durante, Elaeocarpus elliptica, Elaeocarpus serratus, Epidendrum, Eucalyptus, Eugenia jambolana, Fatsia japonica, Ficus, Hedera canariensis, Hedera helix* (holly), *Hibiscus sinensis, Gardenia fortunei, Gardenia jasminoides, Ilex canariensis, Ilex perado, , Ipomoea, Lagerstroemia indica, Laurus azorica, Laurus canariensis, Laurus nobilis, Lonicera etrusca, Malpighia glabra, Mangifera indica* (mango), *Musa cavendishi, Myrica* spp., *Myricaria, Myrtus communis, Nerium, Ocotea foetens, Passiflora, Peltophyllum peltarum, Persea americana* (avocado), *Persea borbonia, Persea gratissima, Pittosporum tobira, Plumeria tricolor, Psidium guajava* (guava), *Punica, Schefflera octophylla, Tetrapanax papyriferum, Trachelospermum jasminoides, Veronica, Viburnum tinus* (Ben-Dov *et al*. 2005).

Milviscutulus mangiferae: *Alstonia spectabilis, Ananas, Artocarpus altilis, Artocarpus heterophyllus, Artocarpus integra, Artocarpus integrifolia, Bischofia javanica, Bixa* *orellana*, *Blighia sapida*, *Breynia cernua*, *Brunfelsia nitida*, *Campnosperma brevipetiolata*, *Caladium*, *Carica papaya* (papaya), *Champereia manillana*, *Cinnamomum cassia*, *Cinnamomum zeylanica*, *Citrus limon* (lemon), *Citrus sinensis* (orange), *Cocos nucifera* (coconut), *Codiaeum variegatum*, *Cordia myxa*, *Cordyline fruticosa*, *Cordyline terminalis, Decaspermum, Dendrobium spectabile, Elaeocarpus, Epipremnum, Eucalyptus citriodora*, *Eucalyptus deglupta*, *Eugenia aquea*, *Eugenia axillaris*, *Eugenia caryophyllata*, *Eugenia jambolona*, *Eugenia jambos*, *Eugenia malaccensis*, *Eugenia parkeri*, *Ficus gibbosa*, *Ficus glandulifera*, *Ficus septica*, *Ficus theophrastoides*, *Ficus tinctoria*, *Flagellaria*, *Gardenia florida*, *Gliricidia*, *Gluta turtur*, *Gnetum gnemon*, *Guioa*, *Gymnacranthera*, *Gynotroches axilaris*, *Hibiscus*, *Ixora coccinea*, *Jambosa*, *Jasminum trifoliatum*, *Litsea zeylanica*, *Malpighia glabra*, *Mangifera indica* (mango), *Merremia*, *Meryta macrophylla*, *Monstera deliciosa*, *Morinda citrifolia*, *Myristica moschate*, *Palaquium formosanum*, *Parathesis cubana*, *Persea americana* (avocado), *Pimelodendron amboinicum*, *Platanocephalus chinensis*, *Platanocephalus morindaefolius*, *Plumeria*, *Pometia pinnata*, *Pseudolmedia havanensis*, *Psidium friedrichsthalianum*, *Psidium guajava* (guava), *Psychotria elyptica*, *Psychotria rubra*, *Rapanea quianensis*, *Rhizophora apiculata*, *Rhizophora mucronata*, *Rhodomyrtus tomentosa*, *Schefflera*, *Strelitzia*, *Terminalia brassii*, *Terminalia catappa*, *Terminalia complanata*, *Timonius*, *Thevetia peruviana*, *Uvaria rufa*, *Vanilla*, *Vitex pubescens*, *Wedelia biflora* (Ben-Dov *et al.* 2005).

Plant part(s) affected:

For the listed soft scales, the plant parts affected include leaves and fruit (Smith *et al*. 1997; Peña and Mohyuddin 1997; USDA 2001).

Distribution:

<u>*Protopulvinaria pyriformis*</u>: Argentina, Azores, Bermuda, Canary Islands, Chile, Colombia, Comoros, Costa Rica, Cuba, Dominican Republic, France, Greece, Grenada, Guyana, Israel, Italy, Jamaica, Japan, Madeira Islands, Mauritius, Mexico, Peru, Portugal, Puerto Rico and Vieques Island, Saint Lucia, South Africa, Spain, Taiwan, Trinidad and Tobago, U.S. Virgin Islands, United States of America, Vietnam, Zimbabwe (Ben-Dov *et al.* 2005).

<u>*Milviscutulus mangiferae*</u>: Antigua and Barbuda, Bangladesh, Brazil, Colombia, Comoros, Costa Rica, Côte d'Ivoire, Cuba, Dominican Republic, Ecuador, El Salvador, Fiji, Ghana, Guyana, Honduras, Hong Kong, India, Indonesia, Israel, Jamaica, Japan, Kenya, Madagascar, Malaysia, Martinique, Mauritius, Mexico, Nicaragua, Pakistan, Palau, Panama, Papua New Guinea, Philippines, Puerto Rico, Réunion, Seychelles, Singapore, Solomon Islands, South Africa, Sri Lanka, Taiwan, Tanzania, Thailand, Tonga, United States of America, U. S. Virgin Islands, Venezuela, Viet Nam, Western Samoa (Ben-Dov *et al*. 2005).

Biology:

Protopulvinaria pyriformis: Adult females of *P. pyriformis* are 2–4 mm long, very flat and heart-shaped. Nymphs and young adults are transparent yellowish, and older females are yellowish-brown, with broad reddish, mottled marginal bands. Very old adults are uniformly brown. During egg laying, a short white ovisac is produced along the posterior margin, which lifts the abdomen of the adult about 2 mm off the surface of the leaf (Diaz *et al.* 2005; Gill 1988). *Protopulvinaria pyriformis* reproduces parthenogenetically and males are very rare (Ben-Dov and Hodgson 1997).

Two generations of *P. pyriformis* are common throughout its distribution, with the entire life cycle of the species normally spent on the lower leaf surface. The scale produces abundant honeydew, and sooty mould is subsequently found on all parts of the host plant. Affected leaves dry out and fall, reducing the growth of the plant. Sap removal, host debilitation, honeydew production and sooty mould can be major economic effects. *Protopulvinaria pyriformis* is considered to be an economic pest of Avocado in South Africa (de Villiers 1989), and Florida (Gill 1988); Mango in the Canary Islands, Israel (Ben-Dov and Hodgson 1997), and Florida (Gill 1988). Successful chemical methods in controlling out breaks of *P. pyriformis* have included oils and organophosphorus insecticides (Ben-Dov and Hodgson 1997)

Various natural enemies have been recorded for *P. pyriformis.* In Spain, *Microterys flavus* was able to control up to 90% of the scale infestation during the summer (Diaz *et al.* 2005). In Israel, various natural enemies attack *P. pyriformis*, but they are unable to curb heavy infestations. Hyperparasitoids such as *Marietta javensis* and *Pachyneuron concolor* sometimes cause considerable reductions in the populations of the primary parasitoids. Additionally, encapsulation of the parasitoid eggs prevents their successful development and may interfere with efficient biocontrol of the pest. For good overview of natural enemies see Ben-Dov and Hodgson (1997). If second, and subsequent, generations of soft scales become established on host plants, they are likely to persist indefinitely and to spread progressively over time. This spread would be assisted by wind dispersal, vectors and by the movement of plant material. Gravid females and crawlers may be moved within and between plantations by birds, on human clothing and in the hair of mammals. Crawlers can be dispersed by wind currents over considerable distances (Greathead 1997).

Milviscutulus mangiferae: *Milviscutulus mangiferae* adults are elongate (2.5–4.0 mm long), irregularly pyriform, thin and flat, in shape, with triangular anal plates. Adult males of *M. magniferae* have well developed functional legs (Giliomee 1997), as do first instar nymphs which exhibit considerable mobility on hosts (Williams 1997). Adults are yellowish green to brown in colour; larvae are translucent green. This species is reported to predominantly reproduce parthenogenically. There is a low occurrence of males; not greater than 1 percent of the population (Otanes 1936; Avidov and Zaitzov 1960). Under optimum conditions, the species is reported to be capable of producing three generations a year with development from hatching to maturity lasting 40–80 days; the pre-hatching period fluctuates between 30 and 113 days. First instar nymphs permanently attach and commence feeding on plant parts including fruit. Therefore, they may be difficult to remove or detect during fruit sorting, especially at low population levels (Taverner and Bailey 1995). Development of a complete generation lasts 2.5–6.5 months. Female life span is reported to average 2–3.5 months. Progeny per female reportedly increased in summer averaging 65 in spring and winter, and 100 in summer. Conversely, natural mortality of nymphs and young was 86 percent during winter and spring and 49 percent in summer (Avidov and Zaitzov 1960).

Milviscutulus mangiferae has previously been assessed (DAFF 2004), and is considered polyphagous with ornamental plants and other species of economic importance as hosts (Kosztarab 1997; Ben-Dov *et al.* 1997). The species is reported as a pest of economic significance on mango in Israel (Wysoki 1997), South Africa (Kamburov 1987) and the Philippines (Otanes 1936). It also significantly affects lemon trees in Taiwan (Takahashi 1939); and palms in the Seychelles where its presence has resulted in pre-mature leaf-fall, branch dieback and even tree death (Vesey-Fitzgerald 1953).

Sooty mould is reported to develop on honeydew excreted by *M. mangiferae*. In Israel, this is reported most often in summer, as the scale population peaks in October, when trees may be completely blackened. Scale populations of 600 per leaf have been recorded. Sooty mould interferes with plant respiration and photosynthesis, resulting in premature leaf-fall, poor flowering/fruiting and decline in vigour of the host. A significant economic impact results from the reduced quality of fruit covered with sooty moulds (Avidov and Zaitzov 1960).

Soft scales are parasitised by species of the chalcidoid families Encyrtidae and Aphelinidae, and a few species belonging to other families (Hayat 1997). For example, in the 1930s a severe infestation of *M. mangiferae* on mango, in Florida, was reported to be moderated by *Cephalosporium lecanii*, but a spray of oil emulsion/soap solution applied to both surfaces of the leaves was recommended to completely kill the scales and loosen mould (Berger 1938). Infestation by *M. mangiferae* on coconut palms in the Seychelles, during the 1940s was reportedly brought under control by *Chilocorus nigritus* (Vesey-Fitzgerald 1953). In Israel, *M. mangiferae* was parasitized by *Microterys frontatus* (Merc.) and *Coccophagus eritreaensis* Comp. However, parasitism was usually low, reaching about 20 percent during spring (Avidov and Zaitzov 1960). Attendance of the aggressive ant, *Oecophylla smaragdina* (Fabricius), is reported to reduce the rate of parasitization on *M. mangiferae* in Papua New Guinea (Buckley and Gullan 1991).

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Mealybugs

Planococcus lilacinus (Cockerell) [Hemiptera: Pseudococcidae] – Coffee mealybug

Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae] – Citriculus mealybug

Pseudococcus jackbeardsleyi Gimpel & Miller [Hemiptera: Pseudococcidae] – Jack Beardsley mealybug

Rastrococcus spinosus (Robinson) [Hemiptera: Pseudococcidae] – Philippine mango mealybug.

Synonyms and changes in combination:

<u>Planococcus lilacinus</u>: *Pseudococcus tayabanus* Cockerell, 1905; *Dactylopius crotonis* Green, 1906 (nomen nudum); *Dactylopius coffeae* Newstead, 1908; *Pseudococcus coffeae* (Newstead); *Dactylopius crotonis* Green, 1911; *Pseudococcus crotonis* (Green); *Pseudococcus deceptor* Betrem, 1937; *Tylococcus mauritiensis* Mamet, 1939; *Planococcus crotonis* (Green); *Planococcus tayabanus* (Cockerell).

<u>Pseudococcus cryptus</u>: *Pseudococcus citriculus* Green 1922; *Planococcus cryptus* Silva *et al*., 1968; *Pseudococcus spathoglottidis* Lit 1992; *Pseudococcus mandarinus* Das & Ghose 1996.

<u>Pseudococcus jackbeardsleyi</u>: previously known in the Philippines as *P. elisae* (e.g. in Lit and Calilung 1994). However, Gimpel and Miller (1996) discovered that the species previously identified as *P. elisae* actually included two cryptic species, and described *P. jackbeardsleyi*.

<u>Rastrococcus spinosus</u>: *Phenacoccus spinosus* Robinson, 1918; *Puto spinosus* (Robinson); *Ceroputo spinosus* (Robinson).

Hosts:

<u>Planococcus lilacinus</u>: The host range of *P. lilacinus* is extremely wide. It attacks over 65 genera of plants in 35 families, including Anacardiaceae, Asteraceae, Euphorbiaceae, Fabaceae, Leguminosae and Rutaceae (Ben-Dov *et al*. 2005). *Planococcus lilacinus* attacks *Theobroma cacao* (cocoa), *Psidium guajava* (guava), *Coffea* spp. (coffee), *Mangifera indica* (mango) (Ben-Dov *et al*. 2005), and other tropical and sub-tropical fruits and shade trees (IIE 1995).

<u>Pseudococcus cryptus</u>: *Ananas sativa*, *Annona muricata*, *Areca catechu*, *Artocarpus altilis*, *Artocarpus incisa* (breadfruit), *Artocarpus odoratissimus*, *Avicennia officinalis*, *Bauhinia purpurea*, *Calophyllum inophyllum*, *Citrus aurantifolia* (lime), *C. aurantium*, *C. grandis*, *C. limon* (lemon), *C. paradisi* (grapefruit), *C. reticulata* (mandarin), *C. sinensis*

(orange), *Cocos nucifera* (coconut), *Coelogyne dayana*, *Coffea arabica* (Arabian coffee), *Coffea liberica*, *Crinum asiaticum*, *Cyrtostachys renda*, *Dillenia indica*, *Elaeis guineensis*, *Eugenia malaccensis*, *Garcinia kydia*, *Garcinia mangostana* (mangosteen), *Glycine max*, *Hevea brasiliensis* (rubbertree), *Hibiscus tiliaceus*, *Lansium domesticum*, *Litchi chinensis* (lychee), *Mangifera indica* (mango), *Melastoma melobothricum*, *Melastoma normale*, *Millettia niuewenhuisii*, *Moringa oleifera*, *Musa sapientum*, *Myristica fragrans*, *Nephelium lappaceum*, *Ocotea pedalifolia*, *Osbornia ocdonta*, *Pandanus upoluensis*, *Passiflora foetida*, *Persea americana* (avocado), *Phalaenopsis amatilis*, *Phoenix dactylifera*, *Piper methysticum*, *Psidium guajava* (guava), *Punica granatum*, *Raphioperdalum bellatulum*, *Rhizophora apiculata*, *Ryparosa fasciculata*, *Spathoglottis plicata*, *Strychnos vanpurkii*, *Tamarindus indica*, *Vanda teres*, *Vitis vinifera* (grapevine) (Ben-Dov *et al*. 2005).

<u>Pseudococcus jackbeardsleyi</u>: *Acalypha wilkesiana*, *Aeschynomene americana* (forage legume), *Aglaonema commutatum*, *Aglaonema simplex*, *Alpinia purpurata* (red ginger), *Ananas comosus* (pineapple), *A. cherimola* (custard apple), *A. muricata* (sour sop), *A. squamosa* (sweet sop), *Apium graveolens* (celery), *Bidens bipinnate*, *Blighia sapida* (akee apple), *Cajanus cajan* (pigeon pea), *Cajanus indicus* (pigeon pea), *Capsicum fructescens* (sweet pepper), *Carica papaya* (paw paw), *Cereus peruvianus* (cactus), *Chrysophyllum cainito*, *Citrus aurantiifolia* (Mexican lime), *Citrus paradisi* (grape fruit), *Coccinia grandis* (scarlet gourd), *Coffea arabica* (coffee), *Cordia curassavica*, *Coryphanta cubensis*, *Cucumis melon* (oriental melon), *Cucurbita pepo* (zucchini), *Cymbopogon citratus* (lemon grass), *Dendrobium tortile* (orchid), *Ficus decora* (rubber plant), *Ficus tricolour*, *Gardenia jasminoides* (cape jasmine), *Gossypium barbadense* (cotton), *Haematoxylum campechianum*, *Hibiscus cannabinus* (kenaf), *Hibiscus esculentus* (okra), *Hoya carnosa* (ornamental flower plant), *Hura crepitans* (sandbox tree), *Ipomoea batatas* (sweet potato), *Jatropha curca*, *Lantana camara* (lantana), *Litchi chinensis* (litchi), *Lycopersicon esculentum* (tomato), *Mangifera indica* (mango), *Manihot esculenta* (manioc), *Melochia tomentosa*, *Moringa oleifera* (drumstick), *Mormolyca balsamina*, *Musa paradasiaca* (banana), *Musa sapientum* (banana), *Nephelium lappaceum* (rambutan), *Nerium oleander* (Mediterranean shrub), *Phaseolus limensis* (lima bean), *Physalis peruviana* (cape gooseberry), *Physalis pubescens* (ground cherry), *Piper nigrum* (pepper), *Psidium guava* (guava), *Pueraria javanica*, *Punica granatum* (pomegranate), *Rhipsalis mesembrianthemoides*, *Sechium edule* (chayote), *Solanum melongena* (eggplant), *Solanum tuberosum* (potato), *Tamarindus indica* (tamarind), *Theobroma cacao* (cocoa), *Vitis*, *Zea mays* (maize), *Zingiber* (ginger) (Ben-Dov *et al*. 2005).

<u>Rastrococcus spinosus</u>: *Anacardium occidentale* (cashew), *Antidesma nitidum*, *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Calophyllum* sp., *Citrus* sp., *Cocos nucifera* (coconut), *Ficus ampelas*, *Garcinia mangostana* (mangosteen), *Hevea brasiliensis* (rubber tree), *Lansium domesticum* (langsat), *Mangifera indica* (mango), *Mangifera odorata* (kuwini), *Nypa fruticans* (mangrove palm), *Plumeria robusta*, *Psidium*

guajava (guava), *Syzygium aqueum* (water apple), *Tabernaemontana* sp. (Ben-Dov *et al*. 2005).

Plant part(s) affected:

The listed mealybug species may affect the whole mango tree, including the fruit (CAB International 2005).

Distribution:

Planococcus lilacinus: *P. lilacinus* occurs mainly in the Palaearctic, Malaysian, Oriental, Australasian and Neotropical regions, and is the dominant cocoa mealybug in Sri Lanka and Java (Entwistle 1972). Williams (1982) reported that the species was probably introduced into the South Pacific from Southern Asia. According to Le Pelley (1968), the species does not occur above 1000 m.

In Asia, *P. lilacinus* is recorded from Bangladesh, Brunei Darussalam, Cambodia, China, India, Indonesia, Japan, Laos, Malaysia, Maldives, Myanmar, Philippines, Sri Lanka, Taiwan, Thailand, Viet Nam and Yemen (CAB International 2005). For a full distribution listing, refer to CAB International (2005).

Pseudococcus cryptus: *P. cryptus* is widely distributed in South East Asia, tropical Africa, mideastern Mediterranean and South America.

Afghanistan, American Samoa, Andaman Islands, Argentina, Bangladesh, Bhutan, Brazil, British Indian Ocean Territory, Brunei, Cambodia, China, Costa Rica, El Salvador, Federated States of Micronesia, Hawaiian Islands, India, Indonesia, Iran, Israel, Japan, Kenya, Laos, Malaysia, Maldives, Mauritius, Nepal, Palau, Paraguay, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, U.S. Virgin Islands, Viet Nam, Western Samoa, Zanzibar (Ben-Dov *et al.* 2005).

Pseudococcus jackbeardsleyi: Aruba, Bahamas, Barbados, Belize, Brazil, Canada, Colombia, Costa Rica, Cuba, Dominican Republic, El Salvador, Federated States of Micronesia, Galapagos Islands, Guatemala, Haiti, Hawaiian Islands, Honduras, Jamaica, Martinique, Mexico, Panama, Philippines, Puerto Rico, Singapore, Taiwan, Thailand, Trinidad and Tobago, U.S. Virgin Islands, United States of America, Venezuela (Ben-Dov *et al.* 2005).

Rastrococcus spinosus: Bangladesh, Brunei, India, Indonesia, Cambodia, Laos, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, Thailand, Viet Nam (Ben-Dov *et al*. 2005).

Biology:

Mealybugs injure the host plant by sucking sap through their tubular stylets, and excreting large amounts of sugary honeydew onto fruit and leaves. Heavy infestations usually begin on the underside of the terminal shoots, with infestations spreading to young shoots, flowers, fruits as population size increases (MTFIS 2004), therefore damaging plants directly. Sooty mould fungus growth on the honeydew can render the fruit unmarketable and reduce the photosynthetic efficiency of leaves and cause leaf drop. Many mealybug species pose particularly serious problems to agriculture when introduced into new areas of the world where their natural enemies are not present (CAB International 2005). Mealybugs *P. lilacinus* and *R. spinosus* have been previously assessed (DAFF 2004).

<u>*Planococcus lilacinus*</u>: Adult female *P. lilacinus* are broadly oval to rotund, with a length of 1.2–3.1 mm and width of 0.7–3.0 mm. The body is yellowish and covered by a wax coating and the mid-dorsal line is wide but indistinct (CAB International 2005).

Female *P. lilacinus* studied in India produced an average of 252 nymphs in their lifetime; under warm humid conditions the nymphs took an average of 47 days to develop (Mukhopadhyay and Ghose 1999). On cauliflower in India, females lay up to 150 eggs, which hatch within 24 hours. The nymphal period lasts 20–25 days (Loganathan and Suresh 2001).

Planococcus lilacinus causes severe damage to young trees by killing the tips of branches and roots of many economically important species (USDA 2001). These crops include citrus, guava, coffee, custard apple and mango. Cocoa crops all over the Oriental region are also affected (Ben-Dov *et al*. 2005). Dense colonies can form patches on fruit and the honeydew produced attracts ants and may result in the development of sooty mould (CAB International 2005).

The climatic conditions in the tropical regions of Asia and eastern Africa where *P. lilacinus* is found (USDA 2001) are similar to those in areas of Australia. Therefore this species may survive and establish in Australia, if it were introduced. The importance of this species in India has warranted its control using chemicals and biological control agents on several commodities (Krishnamoorthy and Mani 1998; Mani and Krishnamoorthy 2000; CAB International 2005).

<u>*Pseudococcus cryptus*</u>: No specific details on the biology of *Pseudococcus cryptus* are available. However, life history of a similar species of mealybug, *Planococcus citri* (Risso), is outlined below.

Adult female mealybugs of *P. citri* are white, about 3 mm long, and covered with a white, fluffy wax. White wax filaments surround the body margin, with the last pair up to one quarter the length of the female body. Males are tiny, gnat-like insects with one pair of fragile wings and non-functional mouthparts. They are short-lived (Smith *et al*. 1997).

Pale yellow eggs are laid in an elongated, loose, cottony egg sac extending beneath and behind the female; 300–600 eggs are laid over 1–2 weeks, and these eggs hatch in about a week (Smith *et al*. 1997). Very young nymphs (crawlers) are flat, oval and yellow. They develop through several stages (instars) over several weeks before reaching sexual maturity. There are three moults for females and four for males. Winged males emerge from a tiny fluffy cocoon and fly to the female mealybug to mate (Drees and Jackman 1999). The complete life cycle takes about 6 weeks during the summer and there are 3–6 generations per year (Smith *et al*. 1997).

During winter, citrus mealybugs shelter in cracks in the branches or trunk, or in leaf axils. Young mealybugs move onto citrus fruit in late spring and usually settle under the calyx or between touching fruit (Smith *et al*. 1997). Mealybugs produce honeydew, resulting in heavy growths of sooty mould (Smith *et al*. 1997).

Following the introduction of *P. cryptus* into Israel in 1937, it was biologically controlled with the encyrtid *Clausenia purpurea* Ishii, prior to its recurrence in newer varieties of citrus (Blumberg *et al*. 1999). Other natural enemies which attack nymphs and adults include the following parasitoids: *Anagyrus pseudococci*; *Cryptanusia luzonica*; *Paraplatycerus citriculus* and *Promuscidea unfasciativentris*; and following predators: *Amblyseius swirskii*; *Brumoides suturalis*; *Chilocorus nigrita*; *Diadiplosis hirticornis*; and *Pseudoscymnus dwipakalpa* (CAB International 2005).

<u>*Pseudococcus jackbeardsleyi:*</u> Nymphs of *P. jackbeardsleyi* are light-yellow with oval, flattened and smooth bodies. Once feeding has begun, the mealybugs secrete a white waxy material that covers the body. Both males and females have three larval stages. The females change little in appearance throughout their life-cycle, except to grow in size. Males go through a pupal phase, where they enclose themselves in a white case in which they develop into an adult male (Metcalf and Flint 1962; Mau and Kessing 1993). The adult female mealybug is pinkish in colour, oval and about 2.8 mm in length. Females are wingless throughout their life. The adult male mealybug is a tiny, two-winged insect. Males do not feed and die soon after mating. Eggs are laid within a compact, cottony, waxy sac beneath the abdomen of the female, and are usually found at the base of stems and leaves (Metcalf and Flint 1962; Mau and Kessing 1993).

Egg production lasts for 1–2 weeks, and the female dies soon after, alternatively unmated females in related spp. may live up to 80 days. Short-tailed mealybugs such as *P. jackbeardsleyi* generally lay 300–600 eggs per female. The eggs usually hatch in about 10 days and the first instars escape from the ovisac and crawl on the host searching for a suitable feeding site. First-instar larvae are sometimes transported by wind (Mau and Kessing 1993; CAB International 2005). Adult males can often be seen in flight early in the morning or late in the day when winds are generally calm. *P. jackbeardsleyi* generally have from one to nine generations a year, depending on the weather conditions and species. The completion on one generation usually takes about one month under glasshouse conditions (Mau and Kessing 1993; CAB International 2005).

Mealybugs usually occur in protected areas on the host plant, such as the undersides and or axils of leaves, as well as crevices on the trunk. *Pseudococcus jackbeardsleyi* occurs on a wide variety of fruit, vegetable and ornamental hosts. Although it has never been reported as a serious pest, its wide range of economic hosts and its ability to expand the geographical range make it an ideal candidate as a future pest (CAB International 2005). This mealybug could be injurious to a host plant in the absence of suitable natural enemies (Williams and Watson 1988). Although no natural enemies have been reported in the literature, it is likely that this species has several. Mealybugs are usually associated with Chalidoidea parasites and Coccinellid predators. Other natural enemies may include fungi, lacewings, flies and mites (CAB International 2005). There is no information on possible chemical control of this mealybug, but the application of soaps and detergents are sometimes affective against mealybug pests (Mau and Kessing 1993).

<u>*Rastrococcus spinosus*</u>: Adult female *R. spinosus* have no wings and are covered with a thick layer of white wax. They measure about 3.9 mm long and 2.5 mm wide. The male is 1.6 mm long with a pair of wings. There are long filaments of wax on all sides of their bodies, with the longest being at their rear (MTFIS 2004).

Females lay eggs in a white, waxy egg sac. After hatching, the first instar crawlers move away and eventually settle on suitable feeding sites. The crawlers are the main dispersal stage and may be carried by wind or on animals. The mealybug may also be carried over longer distances on infested planting material. Females moult three times and males four times before turning into adults (MTFIS 2004). On mango, the total development time for females and males is 28–32 and 30–32 days respectively (Ullah *et al.* 1992). Infestations on mango usually begin on the underside of leaves on terminal shoots. The mealybugs spread to young shoots and flowers as their population increases. Heavily infested leaves turn yellow, dry up and eventually fall off. The mealybug produces large amounts of honeydew that attracts sooty mould, reducing photosynthesis. The honeydew and sooty mould may also make fruits unmarketable (MTFIS 2004).

In Pakistan, *Rastrococcus spinosus* is considered as an important pest of mangoes, and has also been recorded on oleander, banana, guava, orange and other plants (Mahmood *et al.* 1980). It is recorded to be harmful to the young growth, flowers and mango fruit in the Philippines (Otanes 1936). *Rastrococcus spinosus* has been found in US ports-of-entry on *Lansium* and *Tabernaemontana* from the Philippines and Singapore (Miller *et al.* 2005).

Control measures for *R. spinosus* on mango include spraying with soap and water, and the removal of ants which transport the mealybug from tree to tree (Otanes 1936). Some insecticides are effective against this mealybug, including Salithion, fenitrothion, carbaryl, dimethoate, methyl-parathion and phosphamidon (Ausaf and Ahmed 1973). The natural enemies of *R. spinosus* include the lacewing *Odontochrysa ramburi* and the lepidopteran *Spalgis epeus* (CAB International 2005).

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Mango aphid

Toxoptera odinae (van der Goot, 1917) [Hemiptera: Aphididae]

Synonyms and changes in combination:

Toxoptera adivae Shiraki, 1952; *Toxoptera araliae* Matsumura, 1917; *Toxoptera ficicola* Takahashi, 1921; *Toxoptera hameliae*, Theobald, 1929; *Toxoptera mokulen*, Shinji, 1922; *Toxoptera rutae*, Shinji, 1922; *Toxoptera sansho*, Shinji, 1922; *Toxoptera schlingeri*, Tao, 1961; *Toxoptera setariae*, Rusanova, 1942; *Toxoptera somei*, Essig & Kuwana, 1918; *Toxoptera spathodeae*, van der Goot, 1918; *Toxoptera taranbonis*, Matsumura, 1917 (Remaudière and Remaudière, 1997).

Hosts:

Anacardium occidentale (cashew nut), *Anacardium* sp., *Aralia* sp., *Berberis* sp. (barberry), *Bidens* sp. (burmarigold), *Cassia fistula* (golden shower), *Cassia* sp. (senna), *Cinchona* sp., *Citrus aurantium* (sour orange), *Citrus* sp., *Coffea* sp. (coffee), *Croton* sp., *Datura fastuosa*, *Dioscorea* sp. (yam), *Duranta repens* (pigeonberry), *Erythrina indica* (Indian coral tree), *Fagopyrum* sp., *Gardenia florida* (cape jasmine), *Hamiltonia suaveolens*, *Heinsia* sp., *Hibiscus esculantus*, *Hibiscus rosa-sinensis* (China rose), *Jasminum* sp. (jasmine), *Kalopanax* sp., *Lannea* sp., *Leea* sp., *Maesa chisea*, *Maesa* sp., *Magnolia* sp. (magnolia), *Mangifera indica* (mango), *Momordica charantia* (bitter gourd), *Musa* sp. (banana), *Mussaenda* sp., *Pittosporum* sp., *Polyscias* sp., *Pyrus communis* (European pear), *Rhododendron* sp. (rhododendron), *Rhus semialata*, *Rhus* sp., *Senecio* sp. (groundsel), *Stephania* sp., *Stercula* sp., *Symplocos spicata*, *Tagetes patula (French marigold)*, *Tetrapanax* sp. *Thea sinensis* (tea), *Todelia aculeata*, *Viburnum foetidum*, *Zanthoxylum ornatum*, *Ziziphus* sp. (Mondal *et al*. 1976; Blackman and Eastop 1984; Martin 1989).

Plant part(s) affected:

Leaves, flowers, fruit and young shoots (Mondal *et al*. 1976; Shukla and Prasad 1983; BAPHIQ 2004).

Distribution:

Burundi, China, India, Indonesia, Japan, Kenya, Korea (Republic), Laos, Malaysia, Nepal, the Philippines, South Africa, Sri Lanka, Taiwan, Thailand (Mondal *et al*. 1976; Blackman and Eastop 1984; Martin 1989).

Biology:

The wingless stage is small to medium-sized, pale, grey-brown to reddish brown (Mondal *et al*. 1976; Blackman and Eastop 1984). The head is brown, and antennae have six segments (Mondal *et al*. 1976). The winged stage has a reddish-brown to dark brown abdomen (Blackman and Eastop 1984). Both winged and wingless stages are approximately 1.3-2.4 mm in length (Mondal *et al*. 1976; Blackman and Eastop 1984). *Toxoptera odinae* reproduces asexually (Blackman and Eastop 1984).

Over 4000 spp. of aphids have been described (Dixon 1987), and most generally feed on phloem from plant stems and leaf veins (Carver *et al*. 1991). Many tropical woody shrub species are hosts for this aphid species, and winged adults are gregarious, aggregating on undersides of leaves of host plants along the main veins, or occuring as dense colonies on young shoots, especially along the mid ribs and stout veins (Mondal *et al*. 1976; Blackman and Eastop 1984). *Toxoptera odinae* usually attacks young leaves, although moderately old leaves can also be attacked (Mondal *et al*. 1976). Individuals are often tended by ants (Mondal *et al*. 1976; Blackman and Eastop 1984). Heavy infestations occasionally cause curling of young leaves (Mondal *et al*. 1976). Mango aphids excrete honeydew, causing the growth of sooty mould which can hinder photosynthesis (Shukla and Prasad 1983).

Chemical control of mango aphid using methyl demeton, dimethoate and monocrotophos has been effective (Shukla and Prasad 1983). *Toxoptera odinae* has not been implicated in the transmission of any plant viruses (Blackman and Eastop 1984).

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Cocoa tussock moth

Orgyia australis postica (Walker, 1855) [Lepidoptera: Lymantriidae]

Synonyms and changes in combination:

Lacida postica (Walker); *Notolophus australis posticus* (Walker); *Notolophus postica* (Walker); *Notolophus posticus* (Walker); *Orgyia postica* (Walker); *Orgyia ceylanica* Nietner, 1862; *Orgyia ocularis* Moore; *Orgyia posticus* (Walker) (CAB International 2005).

Hosts:

Amherstia nobilis, *Camellia sinensis* (tea), *Cinchona*, *Cinnamomum*, *Coffea* (coffee), *Durio zibethinus* (durian), *Erythrina* spp., *Euphorbia longana* (longan), *Garcinia mangostana* (mangosteen), *Glycine max* (soyabean), *Hevea brasiliensis* (rubber), *Lablab purpureus* (hyacinth bean), *Leucaena leucocephala* (leucaena), *Litchi chinensis* (lichi), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Nephelium lappaceum* (rambutan), Orchidaceae (orchids), *Populus deltoides* (poplar), *Pyrus communis* (European pear), *Ricinus communis* (castor bean), *Rosa* (roses), *Syzygium cumini* (black plum), *Theobroma cacao* (cocoa), *Vigna radiata* (mung bean), *Vitis vinifera* (grapevine), *Ziziphus jujuba* (common jujube) (CAB International 2005).

Plant part(s) affected:

Fruit, leaf, stalk (CAB International 2005).

Distribution:

Bangladesh, Brunei Darussalam, China, India, Indonesia, Japan, Laos, Malaysia, Myanmar, Papua New Guinea, Philippines, Sri Lanka, Taiwan, Thailand, Vietnam (CAB International 2005).

Biology:

The eggs of *O. australis postica* are pillbox-shaped, pale whitish-brown, with a darker ring encircling a depressed top (CAB International 2005). The larva is yellowish, with sparse brown hairs, and with one dorsal and two lateral brown bands. The head is red. The pupa is stout, glossy black with numerous small tufts of short hairs (CAB International 2005).

The adult male has a wingspan of 21–30 mm. The head, thorax, abdomen and forewings are brown. The wing apex is slightly tinged with grey and the hind wings dark brown. The flightless female is brownish grey, thickly haired, with rudimentary wings (CAB International 2005).

Males are in flight from January to July in Sumatra and in April and May in Taiwan (CAB International 2005). The flightless females cling to the exterior of their cocoons and call males to them. Oviposition is generally on the cocoon, with up to 60% of eggs producing larvae (Sanchez and Laigo 1968). Adults of *O. australis postica* live for about 5 days (Su 1985; Cheng *et al.* 2001).

The eggs hatch after 5–7 days at the optimal temperature of 25 ºC (Su 1985; Cheng *et al.* 2001). At this temperature, females laid an average of 152 eggs each on soybean leaves in the laboratory (Su 1985). However, on cocoa leaves in the field, females have been observed to lay an average of 230 eggs each (Sanchez and Laigo 1968).

Depending on temperature, the larvae take 16-64 days to develop; the fastest development occurring at 25–30 ^{o}C (Cheng *et al.* 2001). The number of larval instars may vary depending on the host plant (Su 1987). Female larvae generally have four instars, and the male larvae three instars. As such, female larval development usually takes longer than male development. However, female pupal development is accelerated when compared to males, so the adults appear together (Gu *et al.* 1992). Pupation takes place in a flimsy cocoon on either leaves or stems. The female and male pupal stages last 4–5 and 6–7 days, respectively (Sanchez and Laigo 1968).

In Uttar Pradesh, India, widespread defoliation of mango has been reported, as well as fruit damage that rendered the fruit unsuitable for sale (Gupta and Singh 1986). Outbreaks also occurred in Lucknow, India (Fasih *et al.* 1989). *Orgyia australis postica* is a serious pest of cocoa, and can cause total defoliation, killing or stunting the tree (Sanchez and Laigo 1968). In Taiwan it is a major pest of cultivated grapevines and roses (CAB International 2005).

Nuclear polyhedrosis viruses cause considerable larval mortality in the Philippines (Sanchez and Laigo 1968). The parasitoids *Exorista* sp. and *Brachymeria lasus* have been recorded from India (Fasih *et al*. 1989), although *B. lasus* may be a hyperparasite. In Bangladesh, *Brachymeria jambolana* was found to be a hyperparasite or secondary parasite of a tachinid of the genus *Carcelia*, a primary parasite of *O. australis postica* (CAB International 2005).

Insecticides are also available for the control of this pest. For example, when 2nd and 3rd instar larvae were treated with CME-134 [teflubenzuron], 96–100% mortality resulted. Mortalities for 4th-instar and 5th-instar larvae were 75.0% and 55.5% respectively (Su 1985).

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Mango thrips; grapevine thrips

Rhipiphorothrips cruentatus Hood, 1919 [Thysanoptera: Thripidae: Panchaetothripinae]

Synonyms and changes in combination:

Rhipiphorothrips karna Ramakrishna 1928.

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) (CAB International 2005); *Areca catechu* (arecanut) (More *et al.* 2003); *Jatropha curcas* (Rani and Sridhar 2002); *Eugenia malaccensis* (malay apple) (Wen 1989); *Rosa indica* var. iceberg (Aslam *et al* 2001).

Plant part(s) affected:

The mango thrips affects fruit and leaves of mango trees (CAB International 2005).

Distribution:

Afghanistan, Bangladesh, China, India, Myanmar, Oman, Pakistan, Sri Lanka, Taiwan, Thailand (CAB International 2005).

Biology:

The female mango thrips are between 1.2 and 1.5 mm long, blackish-brown in colour, yellow legs and antennal segments yellow, and pale forewings with yellowish veins. Male mango thrips are similar to females in appearance but with pronotum and abdomen yellow. The nymphs are white when they hatch from the eggs, but they soon develop red markings similar to those of other Panchaetothripinae.

Sexual reproduction is normal in *R. cruentatus*, but parthenogenesis is said to be common in India. The life cycle is temperature-dependent, with more eggs being produced and life cycle lengths reduced at high temperatures. In India, adults emerge from a quiescent, pupal-like phase in March, whereas in southern Taiwan the species continues to breed throughout the year although at varying rates (CAB International 2005).

On wax apple in Taiwan, females each laid about 13 eggs. The egg stage lasted 13.0 days, and the 4 nymphal instars 4.7, 4.5, 1.3 and 2.0 days respectively (Chiu 1984). Mango thrips over-winter as pupae, either on the plant or in the soil. On grapevine in India, adults mate 2–10 days after emergence, the males and females surviving up to 7 and 20 days later respectively. The pre-oviposition period varies from 6 to 14 days. The eggs are laid in slits on the lower surface of the vine leaves. There are 5–8 generations annually (Rahman and Bhardwaj 1937).

They survived exposure to 4 ^{o}C for 1 hour, but not for 5 hours. Males were less resistant to cold than females (Rahman and Bhardwaj 1937).

Rhipiphorothrips cruentatus feeds by sucking the contents from individual plant cells. On mango in Taiwan, injury was caused by puncturing and sucking sap from the epidermis of leaves and fruits. Affected areas turned dark or developed scars; leaves became blackened on their growing points, curled and finally dropped (Ikisan 2000). In extreme cases, there was almost complete defoliation. Feeding punctures served as sources of entry for fungal attack (Lee and Wen 1982).

In India, *R. cruentatus* is one of the most important insect pests of grapevines. Attacked leaves turn brown and fall prematurely, and the grape berries develop a corky surface when attacked (Rahman and Bhardwaj 1937). In Taiwan, wax apple or water apple (*Syzygium samarangense*) has been severely attacked (Chiu 1984), although several other crops have also been damaged including mango and guava, leading to yield reductions and to loss of market value (Chang 1995).

The natural enemies of *R. cruentatus* are known to be important in controlling populations (CAB International 2005). In India, *Ceranisus maculatus* has been observed to be an important parasitoid of *R. cruentatus*, with an average of 159 parasitized pupae per grapevine leaf. *Rhipiphorothrips cruentatus* was also parasitized by the Eulophid, *Thripodenus maculatus* (Rahman and Bhardwaj 1937). Similarly, 77% parasitism by a *Ceranisus* species has been noted in Taiwan (Chiu 1984; Chang 1995). Other insects attacking these thrips are the workers of the *Polistine* wasp, *Polistes divaceus* on rose bushes in India, and the lygaeid bug *Geocoris ochropteus* (CAB International 2005).

In India, carbaryl has been applied for the control of *R. cruentatus* on grapevine (Batra *et al*. 1986), and in Pakistan, dimethoate and deltamethrin were applied against these thrips on mangoes (Khuhro *et al*. 1987). In Taiwan, spraying cyhalothrin, deltamethrin and carbosulfan was effective in controlling grapevine thrips on wax apple (Wen 1989). A recent study on the efficacy of different insecticides on *R. cruentatus* infesting grapevine showed that several sprays were effective, including deltamethrin, fenvalerate, dimethoate, endosulfan and malathion (Lakra and Dahiya 2000).

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Mango scab

Elsinoë mangiferae Bitanc. & Jenkins [Dothideales: Elsinoaceae]

Synonyms and change in combination:

Sphaceloma mangiferae [anamorph] Bitanc. & Jenkins

Hosts:

Mangifera indica (mango) (CAB International 2005).

Plant part(s) affected:

Leaves, growing points, inflorescence, and fruits/pods (CAB International 2005).

Distribution:

Australia (Northern Territory, Queensland), Brazil, Canada, China, Cuba, Dominican Republic, Haiti, India, Jamaica, Kenya, Nepal, Panama, Philippines, Puerto Rico, Taiwan, United States of America (CAB International 2005).

Biology:

Members of the genus *Elsinoë* are biotrophs. There are no reports of *E. mangiferae* infecting plants other than mango. The fungus and the disease have been described in Bitancourt and Jenkins (1946).

There has been very little work carried out on mango scab since an initial study in Florida, USA (Ruehle and Ledin 1955). To some extent extrapolation from work with other species of *Elsinoë* can be applied, but much of the information is based on observations in the rural area around Darwin, Australia (Condé *et al*. 1997). The conidia of *Elsinoë* can only infect young tissue of the leaves, stem, flower, fruit stalk and young fruit. Mango scab, in common with the anthracnose fungus, is spread by rain splash and periods of free water are needed to produce conidia and for the germination of these conidia to produce new infections. It is only during wet weather that the characteristic, pale-brown growth of the conidiophores and conidia on active lesions has been found. Under extremely wet and gusty conditions, but in a sheltered situation, the disease was observed to spread 4.25 m. In unsheltered situations, spread over longer distances would be expected. Mango scab is not seed transmitted (CAB International 2005).

E. mangiferae produces two types of spores: ascospores (the sexual stage) and conidia (the asexual stage). The asexual stage is sometimes referred to by a different name: *Sphaceloma mangiferae*. In the original study of this fungus (Bitancourt and Jenkins 1946) the ascospore state was only rarely found and it was concluded that the asexual conidia were responsible for the bulk of infections. Scientific identification of mango scab is best based on a combination of the symptoms with isolation of the fungus in culture (CAB International 2005).

The symptoms of mango scab are extremely diverse depending on factors such as the plant part affected, cultivar, age of tissue at infection, inoculum potential, water and mineral nutrition (expressed as plant vigour and lushness) and possibly the amount and distribution of free water. Only young tissue is susceptible to infection, for instance fruit is no longer susceptible after it reaches about half size. The occurrence of all symptoms is dependent on the availability of free water when the tissue is at the susceptible stage. Some of the symptoms can be confused with physical or insect injury or infection with other diseases (Condé *et al*. 1997).

In Darwin, Australia, the most noticeable symptom is on the fruit (Condé *et al*. 1997). Initially small black lesions form on the newly set fruit. These lesions can be easily confused with the black lesions of anthracnose and heavily affected fruits fall off the tree. Lesions on the fruit of the cultivar Kensington Pride, which remain on the tree, develop into light-brown scabs or scar tissue, either as small scabs or as large, irregular scar tissue when the lesions coalesce. As scabs develop they consist of scar tissue with a central scab which can, in some cases, be lifted off. Anthracnose infection does not produce this type of scar tissue on the fruit. If there are only a few fruits affected the disease can be confused with abrasion injury. More diverse lesions occur on the cultivar Irwin, which is popular in Darwin, Australia. These lesions range from small black spots, which could be mistaken for spray injury, to small and large scarred areas, the large areas being accompanied with a depressed distortion of the fruit. The scarred areas in all cultivars could be mistaken for damage caused by insect injury. However, with mango scab, there is no indication of any chewing to the fruit and significant numbers of potentially damaging insects will not be found. Of the two cultivars investigated in some detail in the Darwin area, Irwin has been found to incur greater damage than Kensington Pride. Unlike anthracnose, mango scab lesions do not develop into a soft rot as the fruit matures.

The most common symptom on stem tissue is the occurrence of numerous slightly raised, grey, oval to elliptical lesions. If conditions are somewhat dry, the lesions will be smaller and black. Lesions on the inflorescence or frutescence may initially appear similar to those of anthracnose, however, on closer inspection or microscopic examination they are seen to be raised structures in contrast to the non-raised lesions of anthracnose. Another symptom consisting of large, light-tan, corky areas, resembling the scar tissue caused by insect injury, has been observed on stems.

A wide range of symptoms has been observed on the leaves although these symptoms are largely overshadowed by the more dramatic damage on the fruits. Common symptoms are: brown necrotic spots with halos; edge lesions associated with hydathodes; corky lesions on the lower leaf surfaces; or elongated, dark lesions along main veins under the leaf. Other symptoms on leaves are lesions with central scabs and numerous small lesions about 0.1 mm diameter along secondary veins. Leaves often appear distorted due to the effects of marginal or edge lesions and other lesions on the growth and expansion of the leaf (CAB International 2005).

In nurseries a similar range of symptoms (shot hole, numerous small necrotic lesions, distorted leaves) occurs on the leaves as occurs in orchards but these tend to be more prominent on the young growth. Defoliation is common in severe infections. Small, black or elongated, grey scab lesions are also found on young stem tissue (CAB International 2005).

Various symptoms of mango scab can be confused with other conditions, for example anthracnose, *Amblypelta* damage to fruit and leaves, contact injury to fruit or leaves, algal infection and damage caused by *Monolepta* species to fruit. For this reason, one or a few scarred fruit, or a few mid-vein leaf lesions are not definitive of scab in the field. A larger number of scarred fruit is indicative of the disease. Microscopic examination is necessary to separate mango scab from other causes. In dry situations, leaf lesions tend to be fewer, smaller and black and could easily pass unnoticed (CAB International 2005).

Scientific identification of mango scab is best based on a combination of the symptoms with isolation of the fungus in culture. *E. mangiferae* produces a characteristic, slow-growing, small, dense, dark, volcano-shaped colony in common with other species of *Elsinoë*. Conidia are useful to some extent but are not particularly distinctive in size and shape and may be similar to the conidia of the common saprobic species of *Cladosporium*, although these have a distinctive thickened scar. Furthermore, the conidia may be difficult to find, being produced only when the leaves are exposed to prolonged periods of wet weather (e.g. rain, heavy fogs) (CAB International 2005).

Isolation of *E. mangiferae* in culture is best from young tissue. It is virtually impossible to obtain the fungus from older tissues due to the build-up of endophytes/saprobes as tissues mature (CAB International 2005).

If controlled, mango scab should cause little economic damage. Without chemical control, losses as high as 90% have been observed in one orchard during an investigation in 1996 and 1997 in Darwin, Australia (BD Condé, NT Department of Primary Industry and Fisheries, Darwin, Australia, unpublished data) (CAB International 2005).

In severe scab infections on trees or nursery stock, it may be beneficial to prune away old infected stems to reduce the levels of inoculum. Copper fungicides (oxychloride, hydroxide or oxide) need to be applied from at least flower bud emergence to flowering, and then after the fruit has set till the fruit are half-grown, in order to protect the fruit from infection. Copper fungicides mixed with certain other chemicals can cause phytotoxic burning symptoms on mango tissue (Condé *et al.* 1997). Experiments in Darwin, Australia, indicate that the use of copper fungicides alone will not cause damage to flowering or fruit set. Where copper sprays are used against flowering anthracnose, mango scab may be undetectable (CAB International 2005).

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