Australian Government

Department of Agriculture, Fisheries and Forestry

Mangosteen fruit from Thailand

Draft Import Risk Analysis Report

August 2003

Foreword

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GLOSSARY OF TERMS AND ABBREVIATIONS

ALOP	appropriate level of protection
AQIS	Australian Quarantine and Inspection Service
Area	an officially defined country, part of a country or all or parts of several countries
Biosecurity Australia	an operating group within the Australian Government Department of Agriculture, Fisheries and Forestry
Control (of a pest)	suppression, containment or eradication of a pest population
the Department	Australian Government Department of Agriculture, Fisheries and Forestry
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
Entry potential	likelihood of the entry of a pest
Establishment	the 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	not dried, deep-frozen or otherwise conserved
ICA	Interstate Certification Assurance
ICON	AQIS Import Conditions database
Introduction	entry of a pest resulting in its establishment
Introduction potential	likelihood of the introduction of a pest
IPPC	International Plant Protection Convention, as deposited in 1951 with FAO in Rome and as subsequently amended
IRA	import risk analysis
ISPM	International Standard for Phytosanitary Measures
National Plant Protection Organisation (NPPO)	official service established by a government to discharge the functions specified by the IPPC
Non-quarantine pest	pest that is not a quarantine pest for an area

OIE	Office International des Epizooties
Official	established, authorised or performed by a National Plant Protection Organisation
Official control (of a regulated pest)	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
PBPM	Plant Biosecurity Policy Memorandum
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	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	the process of evaluating biological or other scientific evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it
Phytosanitary measure	any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests
PRA	pest risk analysis
PRA area	area in relation to which a pest risk analysis is conducted
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 non-quarantine pest	a non-quarantine pest whose presence in plants for planting affects the intended use of those plants with an economically unacceptable impact and which is therefore regulated with the territory of the importing contracting party
Spread	expansion of the geographical distribution of a pest within an area

Spread potential	likelihood of the spread of a pest
SPS	Sanitary and Phytosanitary
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
WTO	World Trade Organization

EXECUTIVE SUMMARY

This *Draft Import Risk Analysis (IRA) Report* contains the following:

- information on the background to this IRA, Australia's framework for quarantine policy and import risk analysis, the international framework for trade in plants and plant products, and Australia's current policy for importation of fresh mangosteens;
- an outline of the methodology and results of pest categorisation, risk assessment and risk management;
- draft phytosanitary import conditions for fresh mangosteen fruit from Thailand;
- further steps in the IRA process; and
- a summary of stakeholder comments received on the Technical Issues Paper and Biosecurity Australia's response.

The risk assessment identified five arthropod pests as requiring risk management measures to reduce the risk to an acceptable level.

This draft IRA report concludes that the risks associated with the importation of fresh mangosteen fruit from Thailand can be managed by applying a combination of risk management measures, specifically:

- registration of export orchards and packinghouses;
- harvesting of mature fruit with unbroken skin for freedom from fruit flies;
- pressurised air/water blast for management of mealybugs;
- pre-export inspection by Thailand's Agricultural Regulatory Division (ARD);
- packing, labelling and storage compliance;
- phytosanitary certification by ARD; and
- on-arrival inspection by the Australian Quarantine and Inspection Service (AQIS).

Details on these proposed risk management measures, including their objectives, are provided within this draft IRA report. Details are also provided on how these measures may be implemented through the draft import conditions. Biosecurity Australia invites comments on the technical and economic feasibility of the proposed risk management measures and import conditions, in particular, comments on their appropriateness and any alternatives that stakeholders consider would achieve the identified objectives.

BIOSECURITY FRAMEWORK

INTRODUCTION

This section outlines:

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

AUSTRALIAN LEGISLATION

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

Some key provisions are set out below.

Quarantine Act: Scope

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

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

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

> *A reference in this Act to a level of quarantine risk is a reference to:*
>
> *(a) the probability of:*
>
> *(i) a disease or pest being introduced, established or spread in Australia or the Cocos Islands; and*
>
> *(ii) the disease or pest causing harm to human beings, animals, plants, other aspects of the environment, or economic activities; and*
>
> *(b) the probable extent of the harm.*

Section 5D of the *Quarantine Act 1908* includes harm to the environment as a component of the level of quarantine risk.

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

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

Quarantine Proclamation

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

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

> *Things a Director of Quarantine must take into account when deciding whether to grant a permit for importation into Australia*
>
> *(1) In deciding whether to grant a permit to import a thing into Australia or the Cocos Islands, or for the removal of a thing from the Protected Zone or the Torres Strait Special Quarantine Zone to the rest of Australia, a Director of Quarantine:*
>
> *(a) must consider the level of quarantine risk if the permit were granted; and*
>
> *(b) must consider whether, if the permit were granted, the imposition of conditions on it would be necessary to limit the level of quarantine risk to one that is acceptably low; and*
>
> *(ba) for a permit to import a seed of a kind of plant that was produced by genetic manipulation -- must take into account any risk assessment prepared, and any decision made, in relation to the seed under the Gene Technology Act; and*
>
> *(c) may take into account anything else that he or she knows that is relevant.*

Development of Biosecurity Policy

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

Import risk analyses are a significant contribution to the information available to the Director of Animal and Plant Quarantine - a decision maker for the purposes of the Quarantine Proclamation. Import risk analysis is conducted within an administrative process – known as the IRA process (described in the *IRA Handbook*[1])

[1] Biosecurity Australlia (2003) *Import Risk Analysis Handbook*, Department of Agriculture, Fisheries and Forestry.

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

AUSTRALIA'S INTERNATIONAL RIGHTS AND OBLIGATIONS

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

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

The SPS Agreement provides for the following:

- The right of WTO Member countries to determine the level of sanitary and phytosanitary protection (its appropriate level of protection, or ALOP) they deem appropriate;
- An importing Member has the sovereign right to take measures to achieve the level of protection it deems appropriate to protect human, animal or plant life or health within its territory;
- An SPS measure must be based on scientific principles and not be maintained without sufficient scientific evidence;
- An importing Member shall avoid arbitrary or unjustifiable distinctions in levels of protection, if such distinctions result in discrimination or a disguised restriction on international trade;
- An SPS measure must not be more trade restrictive than required to achieve an importing Member's ALOP, taking into account technical and economic feasibility;
- An SPS measure should be based on an international standard, guideline or recommendation where these exist, unless there is a scientific justification for a measure which results in a higher level of SPS protection to meet the importing Member's ALOP;
- An SPS measure conforming to an international standard, guideline or recommendation is deemed to be necessary to protect human, animal or plant life or health, and to be consistent with the SPS Agreement;

- Where an international standard, guideline or recommendation does not exist or where, in order to meet an importing Member's ALOP, a measure needs to provide a higher level of protection than accorded by the relevant international standard, such a measure must be based on a risk assessment; the risk assessment must take into account available scientific evidence and relevant economic factors;
- Where the relevant scientific evidence is insufficient, an importing Member may provisionally adopt SPS measures on the basis of available pertinent information. In such circumstances, Members shall seek to obtain the additional information necessary for a more objective assessment of risk and review the SPS measure accordingly within a reasonable period of time;
- An importing Member shall accept the measures of other countries as equivalent, if it is objectively demonstrated that the measures meet the importing Member's ALOP.

AUSTRALIA'S APPROPRIATE LEVEL OF PROTECTION (ALOP)

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

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

ALOP can be illustrated using a 'risk estimation matrix' Table 1. The cells of this matrix describe the product of likelihood[2] and consequences — termed 'risk'. When interpreting the risk estimation matrix, it should be remembered that, although the descriptors for each axis are similar ('low', 'moderate', 'high' etc), the vertical axis refers to *likelihood* and the horizontal axis refers to *consequences*.

[2] The terms "likelihood" and "probability" are synonymous. "Probability" is used in the *Quarantine Act 1908* while "likelihood" is used in the WTO SPS Agreement. These terms are used interchangeably in this IRA Report.

Table 1 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

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

Risk Management and SPS Measures

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

Australia bases its national measures on international standards where they exist and where they deliver the appropriate level of protection from pests and diseases. However, where such standards do not achieve Australia's level of biosecurity protection, or relevant standards do not exist, Australia exercises its right under the SPS Agreement to take appropriate measures, justified on scientific grounds and supported by risk analysis.

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

IMPORT RISK ANALYSIS

Description

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

Undertaking IRAs

Biosecurity Australia may undertake an IRA if:

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

Environment and human health

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

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

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

The IRA Process in summary

The process consists of the following major steps:

Initiation: This is the stage where the identified need for an IRA originates.

Scheduling and Scoping: At this stage, Biosecurity Australia considers all the factors that affect scheduling. Consultation with States, Territories and other Commonwealth agencies is involved. There is opportunity for appeal by stakeholders at this stage.

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

Reporting: Here, the results of the IRA are communicated formally. There is consultation with States and Territories. The Executive Manager of Biosecurity Australia then delivers the biosecurity policy recommendation arising from the IRA to the Director of Animal and Plant

Quarantine. There is opportunity for appeal by stakeholders at this stage.

POLICY DETERMINATION

The Director of Animal and Plant Quarantine makes the policy determination, which is notified publicly.

METHOD FOR PEST RISK ANALYSIS

The technical component of an IRA for plants or plant products is termed a 'pest risk analysis', or PRA. Biosecurity Australia conducts a PRA in accordance with the International Standard for Phytosanitary Measure (ISPM) 11 *Pest Risk Analysis for Quarantine Pests.* A summary of the requirements of ISPM 11 is given in this section plus descriptions of the methodology used to meet these requirements in this IRA. This summary is given to provide a description of the methodology used for this IRA and to provide a context for the technical information that is provided later in this document.

A PRA comprises three discrete stages

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

The *initiation* of a risk analysis involves the identification of the pest(s) and pathways of concern that should be considered for analysis. *Risk assessment* comprises pest categorisation, assessment of the probability of introduction and spread, and assessment of the potential consequences (including environmental consequences). *Risk management* describes the evaluation and selection of options to reduce the risk of introduction and spread of a pest.

STAGE 1: INITIATION

The aim of the initiation stage is to identify the pest(s) and pathways (e.g. commodity imports) which are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area. This PRA was initiated by a proposal from Thailand to export commercially produced fresh mangosteens into Australia for human consumption.

STAGE 2: PEST RISK ASSESSMENT

The process for pest risk assessment can be broadly divided into three interrelated steps:

- Pest categorisation
- Assessment of probability of entry, establishment and spread
- Assessment of potential consequences (including environmental consequences).

Pest risk assessment needs to be only as complex as is technically justified by the circumstances. ISPM 11 allows a specific PRA to be judged against the principles of necessity, minimal impact, transparency, equivalence, risk analysis, managed risk and non-discrimination.

Pest categorisation

Pest categorisation is a process to examine for each pest whether the criteria in the definition of a quarantine pest are satisfied. That is, whether the pests identified in Stage 1 (Initiation of the PRA) are 'quarantine pests' or not.

The categorisation of a pest as a quarantine pest includes the following primary elements:

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

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

  Where a vector is involved, the vector may also be considered a pest to the extent that it is associated with the causal organism and is required for transmission of the pest.
- *Presence or absence in the endangered area*. The pest should be absent from all or part of the endangered area.
- *Regulatory status*. If the pest is present but not widely distributed in the PRA area, it should be under official control or be expected to be under official control in the near future.
- *Potential for establishment and spread in the PRA area*. Evidence should be available to support the conclusion that the pest could become established or spread in the PRA area. The PRA area should have ecological/climatic conditions including those in protected conditions suitable for the establishment and spread of the pest where relevant, host species (or near relatives), alternate hosts and vectors should be present in the PRA area.
- *Potential for consequences in the endangered area*. There should be clear indication that the pest is likely to have an unacceptable consequence (including environmental consequences) in the PRA area.

Pest categorisation was carried out in two stages for this IRA.

In the Technical Issues Paper released in February 2003 (*Technical Issues Paper: Import Risk Analysis (IRA) for the importation of fresh mangosteen fruit from Thailand*) a list of pests of mangosteens in Thailand was categorised according to the presence or absence of each pest in Australia, and the association of each pest with mangosteen fruit. This step represents an assessment of the potential for entry of the identified pests.

The second stage of pest categorisation is documented in this report. This stage was based on the categorisation of each pest absent from Australia (or part(s) of Australia) and with potential for entry according to (a) its potential to establish or spread in Australia, and, (b) its potential for consequences. Categorisation of potential for establishment or spread and potential for consequences was dichotomous, and expressed using the terms 'feasible' / 'not feasible', and 'significant' / 'not significant', respectively. A summary of the results of pest categorisation for this IRA is given in the 'Pest Categorisation' section of this document.

Pests found to have potential for entry, establishment or spread and potential for consequences satisfy the criteria for a quarantine pest. Further background and methodology for the detailed assessments conducted on the quarantine pests is provided below.

Assessment of the probability of introduction or spread

Details on assessing the 'probability of entry', 'probability of establishment' and 'probability of spread after establishment' of a pest are given in ISPM 11. A synopsis of these details is given below, followed by a description of the qualitative methodology used in this IRA.

Pest introduction is comprised of both entry and establishment. Assessing the probability of introduction requires an analysis of each of the pathways with which a pest may be associated from its origin to its establishment in the PRA area. In a PRA initiated by a specific pathway, the probability of pest entry is evaluated for the pathway in question. The probabilities for pest entry with other pathways, if any, need to be investigated as well.

The assessment of probability of spread is based primarily on biological considerations similar to those for entry and establishment.

Probability of entry

The probability of entry of a pest depends on the pathways from the exporting country to the destination, and the frequency and quantity of the pests associated with them. The higher the number of pathways, the greater the probability of the pest entering the PRA area.

Steps identified in ISPM 11 relevant to PRA initiated by a pathway are:

- *Probability of the pest being associated with the pathway at origin* – e.g. prevalence in the source area, occurrence of life stages that would be associated with the commodity, volume and frequency of movement along the pathway, seasonal timing, pest management, cultural and commercial procedures applied at the place of origin.
- *Probability of survival during transport or storage* – e.g. speed and conditions of transport and duration of the life cycle, vulnerability of the life-stages during transport or storage, prevalence of the pest, commercial procedures applied.
- *Probability of pest surviving existing pest management procedures*
- *Probability of transfer to a suitable host* – e.g. dispersal mechanisms, whether the imported commodity is sent to few or many destination points in the PRA area, time of year at which import takes place, intended use of the commodity, risks from by-products and waste.

Probability of establishment

In order to estimate the probability of establishment of a pest, reliable biological information (life cycle, host range, epidemiology, survival, etc.) should be obtained from the areas where the pest currently occurs. The situation in the PRA area can then be compared with that in the areas where it currently occurs and expert judgement used to assess the probability of establishment. Examples provided in ISPM 11 of factors to consider are:

- 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
- Cultural practices and control measures.

Probability of spread after establishment

In order to estimate the probability of spread of the pest, reliable biological information should be obtained from areas where the pest currently occurs. The situation in the PRA area can then be carefully compared with that in the areas where the pest currently occurs and expert judgement used to assess the probability of spread. Examples provided in ISPM 11 of factors to consider are:

- 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
- Potential natural enemies of the pest in the PRA area.

Method for evaluating the probability of entry, establishment or spread in this IRA

Evaluation and reporting of likelihoods can be done qualitatively, semi-quantitatively or quantitatively. For qualitative evaluation, likelihoods assigned to steps in the scenarios are categorised according to a descriptive scale – e.g. ‘low’, ‘moderate’, ‘high’ etc – where no attempt has been made to equate descriptors with numeric values or scores. For semi-quantitative evaluation, likelihoods are given numeric ‘scores’ (e.g. 1, 2, 3), or probabilities and/or probability intervals (e.g. 0–0.0001, 0.0001–0.001, 0.001–0.01, 0.01–1). For quantitative evaluation, likelihoods are described in purely numeric terms.

Each of these three approaches to likelihood evaluation has its advantages and constraints and the choice of approach depends on both technical and practical considerations. For this IRA, likelihood was evaluated and reported qualitatively using the terms described in Table 2.

Table 2 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

Qualitative likelihoods can be assigned to individual steps or to the probability that all the steps will occur. If the likelihoods have been assigned to individual steps then some form of 'combination rule' is needed for calculating the probability that all steps will occur. For this IRA the likelihoods were combined using a tabular matrix, as shown in Table 3.

Table 3 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

In this IRA, qualitative likelihoods were assigned to the probability of entry (comprising an importation step and a distribution step), the probability of establishment and the probability of spread. In other IRAs it may be considered relevant to assign qualitative likelihoods to additional steps. This would depend on the complexity of the issue and the information that was available. For example, within the importation step, separate qualitative likelihoods could be assigned to the probabilities that source fruit is infested, that the pest survives packinghouse procedures and that it survives storage and transport.

The procedure for combining likelihoods is illustrated in Table 4. A likelihood is assigned to the probability of importation (low) and the probability of distribution (moderate) then they are combined to give the probability of entry (low). The likelihoods are combined using the 'rules' provided in Table 3. The probability of entry is then combined with the likelihoods assigned to the probability of establishment (high) and probability of spread (very low) to give the overall probability of entry, establishment and spread (very low).

Table 4 Qualitative evaluation of the imported fruit scenario

Step	Qualitative descriptor	Product of likelihoods
Probability of importation	Low	
Probability of distribution	Moderate	
...... ➔ Probability of entry	➔	Low
Probability of establishment	High .... ➔	Low
Probability of spread	V. Low	
...... ➔ Probability of entry, establishment and spread	➔	V. Low

Assessment of consequences

The basic requirements for the assessment of consequences are described in the SPS Agreement with Article 5.3 stating that:

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

Assessment of consequences is also referred to Annex A of the SPS Agreement in the definition of risk assessment:

> "*The evaluation of the likelihood of entry, establishment or spread of a pest or disease within the Territory of an importing Member according to the sanitary or phytosanitary measures which might be applied, and of the associated potential biological and economic consequences."*

Further detail on assessing these "relevant economic factors" or "associated potential biological and economic consequences" for plant-based analysis is given under the "potential economic consequences" section in ISPM 11[3]. This ISPM separates the consequences into "direct" and "indirect" and provides examples of factors to consider within each. These examples are listed below under the headings where they may be considered in an IRA. This is followed by a description of the methodology used in this IRA.

[3] A revised version of ISPM 11 was released in April 2003. The supplement on analysis of environmental risks endorsed by the ICPM has been integrated into ISPM 11 to produce ISPM No. 11 Rev. 1.

In this IRA, 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.

Direct pest effects

Plant life or health

Examples from ISPM 11 that could be considered for the direct consequences on plant life or health:

- Known or potential host plants
- Types, amount and frequency of damage
- Crop losses, in yield and quality
- Biotic factors (e.g. adaptability and virulence of the pest) affecting damage and losses
- Abiotic factors (e.g. climate) affecting damage and losses
- Rate of spread
- Rate of reproduction
- Control measures (including existing measures), their efficacy and cost
- Effect of existing production practices
- Environmental effects.

Any other aspects of the environment

Examples from ISPM 11 that could be considered for the direct consequences on any other aspects of the environment:

- Environmental effects *(listed as a general example in ISPM 11)*
- Reduction of keystone plant species
- Reduction of plant species that are major components of ecosystems (in terms of abundance or size), and endangered native plant species (including effects below species level where there is evidence of such effects being significant)
- Significant reduction, displacement or elimination of other plant species.

Indirect pest effects

Eradication, control etc

Examples from ISPM 11 that could be considered for the indirect consequences on eradication, control etc:

- Changes to producer costs or input demands, including control costs
- Feasibility and cost of eradication or containment
- Capacity to act as a vector for other pests

- Resources needed for additional research and advice.

Domestic trade & International trade

Examples from ISPM 11 that could be considered for the indirect consequences on domestic and international trade (the two are considered separately):

- Effects on domestic and export markets, including particular effects on export market access
- Changes to domestic or foreign consumer demand for a product resulting from quality changes.

Environment

Examples from ISPM 11 that could be considered for the indirect consequences on the environment:

- Environmental and other undesired effects of control measures
- Social and other effects (e.g. tourism)
- Significant effects on plant communities
- Significant effects on designated environmentally sensitive or protected areas
- Significant change in ecological processes and the structure, stability or processes of an ecosystem (including further effects on plant species, erosion, water table changes, increased fire hazard, nutrient cycling, etc)
- Effects on human use (e.g. water quality, recreational uses, tourism, animal grazing, hunting, fishing)
- Costs of environmental restoration.

Method for assessing consequences in this IRA

The relevant examples of direct and indirect consequences from ISPM 11 are considered for each of the broad groups (as listed above) and estimates of the consequences are assigned. The broad groups are shown in table form in the 'Risk Assessments for Quarantine Pests' section of this document.

The direct and indirect consequences are 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', of 'minor significance', significant' or 'highly significant':

- an '*unlikely to be discernible*' consequence is not usually distinguishable from normal day-to-day variation in the criterion;
- a consequence of '*minor significance*' is not expected to threaten economic viability, but would lead to a minor increase in mortality/morbidity or a minor decrease in production. For non-commercial factors, the 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;
- a '*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
- a '*highly significant*' consequence 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 were 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
	Local	*District*	*Regional*	*National*

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 were addressed in the order that they appeared in the list — for example, if the first rule did not apply, the second rule was considered. If the second rule did not apply, the third rule was considered and so on until one of the rules applied:

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

- Where the consequences of a pest with respect to all criteria is ‘B’, the overall consequences are considered to be ‘low’.
- Where the consequences of a pest with respect to one or more criteria is considered ‘B’, the overall consequences are considered to be ‘very low’.
- Where the consequences of a pest with respect to all criteria is ‘A’, the overall consequences are considered to be ‘negligible’.

STAGE 3: PEST RISK MANAGEMENT

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. 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. Pest risk management (in the analytical sense) is the process of identifying ways to react to a perceived risk, evaluating the efficacy of these actions, and identifying the most appropriate options.

Overall risk is determined by the examination of the outputs of the assessments of the probability of entry, establishment or spread and the consequence. If the risk is found to be unacceptable, then the first step in risk management is to identify possible phytosanitary measures that will reduce the risk to, or below, an acceptable level.

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 introduction of the pest.

Examples given of measures commonly applied to traded commodities include:

- *Options for consignments* – e.g. inspection or testing for freedom, 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.

The result of the pest risk management procedure will be either that no measures are identified which are considered appropriate or the selection of one or more management options that have been found to lower the risk associated with the pest(s) to an acceptable level. These management options form the basis of phytosanitary regulations or requirements.

Method for pest risk management

The unrestricted risk estimate for each pest is determined by combining the overall estimate for ‘entry, establishment and spread potential’ with the overall expected consequence using a risk estimate matrix (Table 1). The requirement for risk management is then determined by comparing the unrestricted risk estimate with Australia’s ALOP. Australia’s ALOP is represented in this matrix by the row of cells marked ‘very low risk’.

Where the estimate of unrestricted risk does not exceed Australia’s ALOP, risk management is not required. Where the unrestricted risk estimate exceeds Australia’s ALOP, risk management measures are required to reduce the risk to an acceptable level. Using this risk estimation matrix, risk management measures are required when the unrestricted risk estimate is low, moderate, high or extreme. Risk management measures are not required when the unrestricted risk estimate is very low or negligible.

Risk management measures are identified for each pest as required and are presented in the ‘Risk Management’ section of this document. The proposed import conditions based on these measures are presented in the ‘Draft Import Conditions’ section of this document.

PROPOSAL TO IMPORT MANGOSTEENS FROM THAILAND

BACKGROUND

Stakeholders were advised that an IRA for the importation of mangosteen from Thailand was being conducted by Biosecurity Australia in Plant Biosecurity Policy Memorandum (PBPM) 2002/06 of 18 February 2002.

Biosecurity Australia notified stakeholders of the availability of a Technical Issues Paper for this IRA in PBPM 2003/7 of 17 February 2003, and invited stakeholder comments. The Technical Issues Paper included background to the IRA and preliminary results of pest categorisation.

This draft IRA report summarises the information provided in the Technical Issues Paper and also includes the full pest risk assessment, the proposed risk management measures and the draft import conditions. Stakeholder comments were received to the Technical Issues Paper and these were considered in the preparation of this draft IRA report.

ADMINISTRATION

Timetable

The 'Further steps in the Import Risk Analysis process' section later in this document lists the steps for completion of this IRA.

Scope

This IRA considers quarantine risks that may be associated with the importation of fresh mangosteen (*Garcinia mangostana* L.) fruit from Thailand into Australia for human consumption. The produce will have been cultivated, harvested, packed and transported to Australia under commercial conditions.

AUSTRALIA'S CURRENT QUARANTINE POLICY FOR IMPORTS OF MANGOSTEEN

International arrangements

Fresh fruit — Imports of fresh mangosteen fruit into Australia for human consumption are not currently permitted from any country.

Non-tissue culture nursery stock — *In vivo* mangosteen nursery stock (e.g. whole plants, cuttings) may be imported from any country subject to the following requirements: an import permit, new packaging, packages labelled with the correct scientific name, specimens free from soil, disease symptoms and other extraneous contamination, inspection on arrival, methyl bromide fumigation and a minimum of nine months growth in a Government post-entry quarantine facility for visual disease screening.

Tissue culture nursery stock — *In vitro* mangosteen material may be imported from any country subject to the following requirements: an import permit, inspection on arrival and a minimum of nine months growth (out of tissue culture) in closed quarantine at a Government post-entry quarantine facility with disease screening.

Seed — Mangosteen seeds for sowing may be imported from any country subject to inspection on arrival and other requirements that include freedom from soil, live insects, plant material (e.g. fruit pulp, leaf or stem material), and contamination with prohibited seeds. Seeds must be packed in new containers that are clearly labelled with the scientific name.

Further details on import conditions for mangosteen are available in the AQIS Import Conditions database (ICON)[4].

Domestic arrangements

The Commonwealth Government is responsible for regulating the movement of plants and their products into and out of Australia, but the State and Territory Governments have primary responsibility 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.

Some states (i.e. New South Wales, Victoria, South Australia and Western Australia) accept that mangosteen with unbroken skin is a conditional non-host for Queensland fruit fly [*Bactrocera tryoni*] under the Interstate Certification Assurance (ICA)-13 scheme. ICA-13 covers approved fruit of durian, jaboticaba, jackfruit, longan, lychee, mangosteen, rambutan and pomegranate with unbroken skin (i.e. without any pre-harvest crack, puncture, pulled stem or other break of the skin that penetrates through to the flesh and has not healed with callus tissue) (QDPI, 2001).

[4] Available at http://www.aqis.gov.au/icon/

THE MANGOSTEEN INDUSTRY

Production of mangosteens in Australia

Production of mangosteen is an emerging tropical fruit industry in Australia. Grown in the Northern Territory and tropical Queensland, most of the market supply comes from 15–20 growers in north Queensland (Moody, 2000).

Table 6 Australian mangosteen industry statistics

Statistics	Mangosteen
Tree numbers	15,000
Farm numbers	60
Area of trees (ha)	72
Average number of trees per farm	250
Median number of trees per farm	80
Range of tree numbers per farm	6–1800

Source: O'Connor (2000)

There are approximately 15,000 trees planted in the Northern Territory and far north Queensland (Table 6) (O'Connor, 2000). Currently, there are approximately 40 growers (RTELPA and NTHA, 1997), with about 72 hectares planted (O'Connor, 2000). The fruiting season for each of the production areas is slightly different. The Northern Territory's season is from mid-October to mid-January (RTELPA and NTHA, 1997) and the Queensland season is from November to the end of January. In some years, two crops may be produced in north Queensland with further fruiting in April and May (Chay-Prove, 2001).

Currently, Australia does not export mangosteen fruit. The Australian mangosteen industry is seeking market access to New Zealand, the USA, the European Union and several other countries.

The global mangosteen industry

The mangosteen is a very popular tropical fruit in Asia. From its native home in the Sunda Islands of Indonesia and the Malay Peninsula in south-east Asia, the crop has spread to the New World and is now being grown in other tropical countries, including Sri Lanka, southern India, Madagascar, Ivory Coast, Puerto Rico, Trinidad, Brazil, Central America and Australia (Northern Territory and north Queensland) (Verheij and Coronel, 1991). Small mangosteen orchards have also been established in Hawaii, USA.

The major producing and exporting countries are Thailand, Malaysia, the Philippines and Indonesia. Most of the fruit in those markets comes from backyard trees or from trees planted as a component of mixed fruit orchards. Currently, the major producing countries are Thailand (130,000 t from 15,000 ha in 1995), Malaysia (27,000 t from 2,200 ha in 1987), the Philippines (2,270 t from 1,130 ha in 1987) and Indonesia (2,500 t in 1975) (Downton and Chacko, 1998).

Thailand is the major exporter of mangosteen fruit to international markets ($US5m). In other south-east Asian countries, the crop is becoming more important. The crop is mostly grown for domestic consumption although very small quantities may be exported, for example by Vietnam.

Producing areas in Thailand are in the south and south-east, from the eastern province of Chanthaburi, south to the Malaysian border. The five major producing areas listed by Thailand's Department of Agriculture include Rayong and Chanthaburi in the southeast and Chumpon, Surat Thani and Nakhorn Si Thammarat in the south. The fruiting season in Thailand is from May to September.

The mangosteen is strictly tropical. It cannot tolerate temperatures below 5°C nor temperatures above 38°C. Young seedlings are killed by temperatures below 7°C. The crop thrives bests in high atmospheric humidity, above 80%, and in areas with an annual rainfall of 1270 mm with short periods of drought. The crop thrives best in deep rich organic soils, sandy loam or laterite soils, and does best under shade or with good windbreaks.

Depending on the region where the crop is being grown, mangosteen can have two fruiting seasons a year, for example in Malaysia, Ivory Coast, Madagascar, Indonesia, Puerto Rico and Australia. In other countries, there is only one major fruiting season. Table 7 summarises the fruiting seasons in mangosteen producing countries.

Table 7 Summary of fruiting seasons in mangosteen producing countries

Country	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ref
Australia – NT													RTELPA & NTHA, 1997
Australia – North Qld													Chay-Prove, 2001
Brazil													RTELPA & NTHA, 1997
Côte d’Ivoire													Bordeaut & Moreuil, 1970
India (south)													Krishnamurthi *et al.*, 1964
Indonesia													Reza *et al.*, 1994
Madagascar													Bordeaut & Moreuil, 1970
Malaysia													Mohd Khalid & Rukayah, 1993
Myanmar (Burma)													Reza *et al.*, 1994
Papua New Guinea													Wiles, 1996
Philippines													DA-AMAS, 2000
Puerto Rico													Almeyda & Martin, 1976; Morton, 1987
Sri Lanka													Morton, 1987
Thailand													DAET, 1987
Trinidad													Bailey, 1963
Vietnam													Nguyen, 1998

PEST CATEGORISATION

For this IRA, pest categorisation was conducted using the method described in the 'Method for pest risk analysis' section of this document. Pests of mangosteens were categorised according to their presence or absence in Australia, their association with mangosteen fruit (compared with leaves, roots, etc.), their potential for entry, establishment or spread in the PRA area and their potential for consequences.

Following comments received from stakeholders to the Technical Issues Paper and further review of available literature, the list of potential quarantine pests was revised (Appendix 1). Three fruit fly species (*Bactrocera carambolae*, *B. dorsalis* and *B. papayae*) were added to the list of quarantine pests, making a total of seven arthropods. All weed species were removed from the pest categorisation following further consideration. Biosecurity Australia concluded that weeds are not commonly associated with this pathway as the structure of the fruit is not a receptacle for weed seeds.

Seven arthropod pests (Table 8) were considered to be associated with fresh mangosteen fruit and were further classified according to: (a) the potential to enter, establish or spread in Australia, and (b) the potential for consequences. All were found to have potential for entry, establishment or spread in the PRA area and have potential to cause consequences (Appendix 2).

Table 8 Quarantine pests for fresh mangosteen fruit from Thailand

Scientific name	Common name
ARTHROPODA	
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	Carambola fruit fly
Bactrocera dorsalis Hendel [Diptera: Tephritidae]	Oriental fruit fly
Bactrocera papayae Drew & Hancock [Diptera: Tephritidae]	Papaya fruit fly
Dolichoderus sp. [Hymenoptera: Formicidae]	Black ant
Dysmicoccus neobrevipes Beardsley [Hemiptera: Pseudococcidae]	Gray pineapple mealybug
Pseudococcus cryptus (Hempel) [Hemiptera: Pseudococcidae]	Cryptic mealybug
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	Black ant

RISK ASSESSMENTS FOR QUARANTINE PESTS

Detailed risk assessments were conducted for quarantine pests identified in the pest categorisation stage. Where pests shared similar biological characteristics, risk assessments were based on grouping of such pests (e.g. fruit flies). The proposed risk management measures were also developed for these groups.

In the context of the scope of this IRA, the risk assessments were conducted on the basis of the standard cultivation, harvesting and packing activities involved in the commercial production of mangosteen fruit i.e. in-field hygiene and management of pests (e.g. orchard control program), cleaning and hygiene during packing, and commercial quality control activities.

The groups are: fruit flies (3 species), mealybugs (2 species), and ants (2 species). For more details on the technical information used in the detailed risk assessments presented below, refer to the datasheets in Appendix 3.

FRUIT FLIES

Bactrocera carambolae (Drew & Hancock (carambola fruit fly), *Bactrocera dorsalis* (Hendel) (Oriental fruit fly), *Bactrocera papayae* Drew & Hancock (papaya fruit fly)

Introduction and spread potential

Probability of importation

The likelihood that fruit flies will arrive in Australia with the importation of fresh mangosteens from Thailand: **Very low**.

There is evidence to indicate that mangosteen is a non-host to many Tephritidae fruit fly species (Leach, 1997; Unahawutti and Oonthonglang, 2002). However, mangosteen has been recorded to be a host of *B. dorsalis* in Thailand by Burikam *et al*. (1991).

Studies conducted by Leach (1997) in Queensland have shown that mangosteen is a conditional non-host to papaya fruit fly [*B. papayae*] and Queensland fruit fly [*B. tryoni*] (Leach, 2003, pers. comm.) and that only damaged ripe fruits can be infested. Likewise *B. carambolae* can infest mangosteen fruit with damaged or broken skin (Vijaysegaran, 2003, pers. comm.).

Studies carried out on *B. dorsalis* in Thailand have shown that mangosteen is a conditional non-host to this pest (Unahawutti and Oonthonglang, 2002). A pest risk assessment conducted in Hawaii also indicated that mangosteen is a possible non-host for fruit flies (Follett, 1998).

Although *B. carambolae* has been reared from mangosteen, only one fruit fly has been reared out of 48 fruit samples collected (Allwood *et al*., 1999). There is no indication from this study whether the fruits were harvested by hand from the tree or picked from the ground. Fruits dropped on the ground may be bruised and have cracks which would allow the fruit fly to oviposit inside the fallen fruit. In Thailand, mangosteen fruits are individually harvested and placed immediately into bins, thus avoiding contact with the ground and reducing bruising and injury to the fruit.

Probability of distribution

The likelihood that fruit flies will be distributed as a result of the processing, sale or disposal of fresh mangosteens from Thailand, to the endangered area: **Moderate**.

Fruit infested with eggs are larvae are likely be distributed throughout Australia for retail sale. Adults, larvae and eggs are likely to be associated with infested waste. However, only damaged fruit are likely to be infested (Leach, 1997; Unahawutti and Oonthonglang, 2002). Even if damaged fruit are likely to be detected and removed from consignments due to quality concerns, fruit flies have the capacity to complete their development in discarded fruit. Eggs can produce larvae within stored fruit, at the point of sale or after purchase by consumers. Larvae can develop into adult flies, which are strong flyers and able to move directly from fruit into the environment to find a suitable host.

Probability of entry (importation × distribution)

The likelihood that fruit flies will enter Australia as a result of trade in fresh mangosteens from Thailand 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 distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **Moderate**.

For pests to establish and spread, a threshold limit must be reached. This threshold limit is the smallest number of pests capable of establishing a colony. One infested fruit is likely to contain many fruit fly larvae e.g. clutch sizes of 3-30 eggs have been recorded for *B. dorsalis* (Fletcher, 1989). However, the larval load on/in mangosteen fruit is likely to be considerably lower.

Surviving female flies must be successful in locating suitable mating partners and fruiting hosts to lay eggs. The mating behaviour of *B. dorsalis* requires that males gather to form aggregations or leks (Shelly and Kaneshiro, 1991). Females fly to such male aggregations to increase their chances of mating. However, there will be a limited number of males available to form a lek, therefore reducing the probability of a successful mating. Shelly (2001) reported that *B. dorsalis* females were observed more frequently at larger leks (of 18 males or more). There are likely to be plenty of suitable hosts for fruit fly species around the vicinity of the port of entry and other suburban areas around Australia. *B. carambolae* and *B. papayae* are members of the *B. dorsalis* complex of fruit flies (CAB International, 2002), and would have similar mating behaviour to *B. dorsalis*.

There have been exotic fruit fly incursions in Australia, all of which have been eradicated. *B. papayae* was detected near Cairns, northern Queensland in 1995. The infested area covered 4,500 km², some of which is dense tropical rainforest (Allwood, 1995). It was eradicated from Queensland by implementing an eradication programme using male annihilation and protein bait spraying that cost AUD$35 million (SPC, 2002). This example demonstrates that fruit fly species from the *B. dorsalis* complex can establish in Australia.

Probability of spread

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**.

Fruit flies possess many characters that facilitate successful colonisation. These include the high reproductive rate, longevity of adult flies, broad environmental tolerances and host range of both commercial and wild species, which are widespread in Australia. The infested area for the *B. papayae* incursion in Australia covered 4,500 km², some of which is dense tropical rainforest (Allwood, 1995). *B. carambolae* and *B. dorsalis* would have a similar capacity to spread in Australia due to their close biological relationship to *B. papayae* as members of the *B. dorsalis* complex, and in view of their wide host range.

Probability of entry, establishment and spread

The overall likelihood that fruit flies will enter Australia as a result of trade in fresh mangosteens from Thailand, 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 and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of fruit flies: **High**.

Criterion	Estimate
Direct consequences	
Plant life or health	**D** — Fruit flies can cause direct harm to a wide range of plant hosts and are estimated to have consequences of minor significance at the national level.

Any other aspects of the environment	**A** — Fruit flies introduced into a new environment will compete for resources with the native species. They are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the local level.
Indirect consequences	
Eradication, control etc.	**E** — A control program would add considerably to the cost of production of the host fruit, costing between $200-900 per ha depending on the variety of fruit produced and the time of harvest (Anon., 1991). In 1995, the *B. papayae* (papaya fruit fly) eradication programme using male annihilation and protein bait spraying cost AUD$35 million (SPC, 2002). Fruit flies are estimated to have consequences of minor significance at the national level.
Domestic trade	**D** — The presence of fruit flies in commercial production areas will have a significant effect at the regional level due to any resulting interstate trade restrictions on a wide range of commodities.
International trade	**D** — Fruit flies are regarded as the most destructive horticultural pests in the world. While they can cause considerable yield losses in orchards and suburban backyards, the major consequence facing Australian horticultural industries is the negative effect they have on gaining and maintaining export markets. When the Papaya fruit fly outbreak occurred in north Queensland, Australia experienced trade effects that affected the whole country. Fruit flies are estimated to have consequences of minor significance at the national level.
Environment	**A** — Pesticides required to control fruit flies are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Low. The unrestricted risk estimate is determined by combining the overall 'probability of entry, establishment and spread' with the 'consequences' using the risk estimation matrix (Table 1).

MEALYBUGS

Dysmicoccus neobrevipes Beardsley (gray pineapple mealybug), *Pseudococcus cryptus* Hempel (cryptic mealybug)

Introduction and spread potential

Probability of importation

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

Mangosteen orchards in Thailand are infested by mealybug species and fruit sent to be packed for export are very likely to contain these pests as they can hide beneath the calyces (Lim *et al*., 1998), and are likely to survive storage and transportation.

Mealybugs are sessile, small (1.4-3 mm), and often inconspicuous and usually live around the sepal or under the calyx of the fruit in the period from flowering onwards. On mangosteen they generally remain anchored on the fruit beneath the calyces (Lim *et al*., 1998).

Probability of distribution

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

The pests are likely to survive storage and transportation.. For example, the pseudococcid species *Pseudococcus affinis* can survive for up 42 days storage at 0°C (Hoy and Whiting, 1997).

Adults and nymphs are likely to be associated with infested waste. Mealybugs can enter the environment in two ways: adults can be associated with discarded mangosteen skin, or crawlers can be blown by wind, or carried by other vectors, from mangosteen at the point of sale or after purchase by consumers. Long-range dispersal of these pests would require movement of adults and nymphs on infested vegetative material or fruit. Shorter-range dispersal would occur readily through the random movement of crawlers with wind currents or biological or mechanical vectors. Mealybugs imported with fruit are likely to be at non-mobile stages and can be transported by ants to a suitable host. Because all stages of mealybugs survive in the environment for some time, they could be transferred to a susceptible host because they are highly polyphagous.

Adult female mealybugs would need to be carried onto hosts by vectors such as people or other insects. Adult males are winged but fragile and short-lived and do not persist for more than several days (Kessing and Mau, 1992). Crawlers are small and less robust than adult females, but can be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988).

Probability of entry (importation × distribution)

The likelihood that mealybugs will enter Australia as a result of trade in fresh mangosteens from Thailand and be distributed in a viable state to the endangered area: **Moderate**.

The overall probability of entry is determined by combining the likelihoods of importation and distribution using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **High**.

The mealybugs are highly polyphagous and host plants are common in Australia e.g. citrus, mango, pineapple. The skin of infested fruit is likely to be discarded and thereby provide a pathway for mealybugs to establish on suitable hosts especially in the warmer subtropical and tropical regions of Australia.

This group of pests has a high reproductive rate. *D. neobrevipes* is known to reproduce sexually, and mating must occur for young to be produced. Unmated females of *D. neobrevipes* live for an average length of 148 days, while mated females an average of 95 days (Ito, 1938). Adult males are short-lived (Kessing and Mau, 1992). Females of *D. neobrevipes* produce between 350-1000 larvae during their lifetime (Kessing and Mau, 1992). The first instar larvae or 'crawlers' disperse to suitable feeding sites on their hosts or new plants. Nymphs are active during the first instar stage and can travel some distance to a new plant where they become sessile for the remaining nymphal (larval) instars. Crawlers can survive only about a day without feeding.

Probability of spread

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**.

Tropical or subtropical areas of Australia would be suitable for the spread of these mealybugs because they are recorded from these environments. Adults and nymphs can be moved within and between plantations with the movement of equipment and personnel, and crawlers can be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988). The relevance of natural enemies in Australia is not known.

Probability of entry, establishment and spread

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

The probability of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of mealybugs: **Low**.

Criterion	Estimate
Direct consequences	
Plant life or health	**C** — Mealybugs can cause direct harm to a wide range of plant hosts and have also been reported as disease vectors e.g. pineapple wilt disease (Rohrbach *et al*., 1988). Fruit quality can be reduced by the presence of secondary sooty mould. Mealybugs are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the regional level.
Any other aspects of the environment	**A** — Mealybugs introduced into a new environment will compete for resources with the native species. They are estimated to have consequences which are unlikely to be discernible at the national level and of minor

	significance at the local level.
Indirect consequences	
Eradication, control etc.	**B** — 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). Mealybugs are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the district level.
Domestic trade	**B** — The presence of these pests in commercial production areas can have a significant effect at the local level due to 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.
International trade	**B** — for *Dysmicoccus neobrevipes* **C** — for *Pseudococcus cryptus* The presence of these pests in commercial production areas of a wide range of commodities (e.g. citrus, mango) can have a significant effect at the local level due to any limitations to access to overseas markets where these pests are absent. Both species considered in this analysis feed on citrus. Australia exports citrus fruit worth $40-60 million to the USA from the Riverland-Sunraysia-Riverina (R-S-R) area. Extension of this area has also been negotiated for the USA market. Consideration for export of citrus from areas in Queensland and New South Wales to the USA market is also underway. *D. neobrevipes* has been reported from Florida (Miller and Miller, 2002) and therefore, will not be likely to affect citrus trade with the USA if it became established in Australia. *P. cryptus*, however, does not occur in the continental USA and, if it became established in the R-S-R and other possible export areas in Australia, would complicate citrus trade with the USA and might result in the reintroduction of fumigation for unidentifiable mealybugs or the necessity for pest survey to verify the mealybugs in the export citrus orchards.
Environment	**A** — Although additional pesticide applications would be required to control these pests on susceptible crops, this is not considered to impact on the environment. They are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Low. The unrestricted risk estimate is determined by combining the overall ‘probability of entry, establishment and spread’ with the ‘consequences’ using the risk estimation matrix (Table 1).

BLACK ANTS

Dolichoderus sp. and *Technomyrmex butteli* Forel

While black ants are not plant pests as such, they are associated with plant pests of mangosteen in Thailand. Therefore they are evaluated here, including the potential impacts on the environment. As this assessment is based on entry, establishment or spread, only mated females (queen) are considered, as workers are not capable of transforming into a queen and establishing new colonies (Shattuck, 2003, pers. comm.).

Introduction and spread potential

Probability of importation

The likelihood that black ants will arrive in Australia with the importation of fresh mangosteens from Thailand: **Low**.

Both genera are commonly found in the tropics and subtropics (Shattuck and Barnett, 2001), although generally in small numbers. Workers have been observed nesting under the fruit calyces. They are minute in size (2-4 mm) and can hide beneath the calyces of fruit.

There is a possibility that a single, mated *Technomyrmex* queen will form a colony under the fruit calyx as they are an opportunistic species. However, this is not the normal method of colonisation as queens of both genera prefer to search for a suitable nest site in the soil (Shattuck, 2003, pers. comm.), not under a fruit calyx. Queens are capable of forming a colony without worker ants and can survive for six months without feeding, as long as moisture is present (Shattuck, 2003, pers. comm.). However, queens of both genera are vulnerable to predation by other ants species and predators and have a low survival rate (Shattuck, 2003, pers. comm.).

Probability of distribution

The likelihood that black ants will be distributed as a result of the processing, sale or disposal of fresh mangosteens from Thailand, to the endangered area: **Moderate**.

Although both genera are commonly found in the tropics and subtropics (Shattuck and Barnett, 2001), they are highly adaptive and are likely to be cold hardy and survive cold storage and transportation. Upon arrival, the queen can remain on the fruit or carton before finding an alternate habitat as she can survive for six months without feeding, as long as moisture is present (Shattuck, 2003, pers. comm.). Males and female reproductives are winged and mating flights are the primary means of colony propagation for both genera (Shattuck, 2003, pers. comm.).

Probability of entry (importation × distribution)

The likelihood that black ants will enter Australia as a result of trade in fresh mangosteens from Thailand 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 distribution using the matrix of ‘rules’ for combining descriptive likelihoods (Table 3).

Probability of establishment

Comparative assessment of factors in the source and destination areas considered pertinent to the ability of the pest to survive and propagate: **Moderate**.

Both genera are highly adaptable as the ants can nest in both open and shaded situations and the genera are present in Australia (Shattuck and Barnett, 2001). Workers of *Dolichoderus* are general scavengers and also tend mealybugs to collect their honeydew. Both genera nest either in the soil or arboreally. *Technomyrmex* can be common in disturbed habitats and are known to survive in cool climates by living indoors (Shattuck and Barnett, 2001). The climate in Australia is suitable for the pests to establish, particularly in tropical and subtropical climates. Some *Technomyrmex* species are known to have worker-like males and queens (Terron, 1972). However, workers from either genera are not capable of transforming into a queen (Shattuck, 2003, pers. comm.). In general, at least 50-100 ants with a mated queen are needed to form a viable colony, but a queen is capable of forming a colony without worker ants (Shattuck, 2003, pers. comm.). Queens can survive for six months without feeding, as long as moisture is present (Shattuck, 2003, pers. comm.). A colony will die if the queen dies (Shattuck, 2003, pers. comm.).

Probability of spread

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**.

Mating flights are the primary means of colony propagation for both genera (Shattuck, 2003, pers. comm.). Satellite nests (or budding) is known to occur in *Technomyrmex* in which a portion of a colony becomes an autonomous unit (Shattuck, 2003, pers. comm.). Environmental triggers cause the simultaneous release of queens and males from the vast majority of nests of a given species in a given area (Shattuck and Barnett, 2001). Because of this, huge numbers of queens and males can be released on the same day, sometimes over hundreds of kilometres (Shattuck and Barnett, 2001). These mass emergences last only a few days, with the queens mating and attempting to establish new nests while the males generally die within several days of leaving their nests (Shattuck and Barnett, 2001).

Ants are capable of expanding naturally and steadily into new territories because of their high reproductive rate. Nests of black ants usually have more than one laying queen. Some species of *Technomyrmex* are known to have a high fecundity which, coupled with a rapid development of workers, can lead to an increased population in a relatively short timeframe.

Probability of entry, establishment and spread

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

The probability of entry, establishment and spread is determined by combining the likelihoods of entry, establishment and spread using the matrix of 'rules' for combining descriptive likelihoods (Table 3).

Consequences

Consideration of the direct and indirect consequences of black ants: **Low**.

Criterion	**Estimate**
Direct consequences	
Plant life or health	**B** — Black ants do not directly affect the health of the tree or fruit. They tend honeydew secreting pests, increasing their numbers and promote the proliferation of sooty moulds (Gullan, 1997). They are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the district level.
Any other aspects of the environment	**C** — Introduction of black ants into a new environment can be significant at the district level. Both species exhibit high adaptive ability, food searching and competitive ability and could have impacts on native fauna and flora, particularly in disturbed areas. Black ants introduced into a new environment may compete for resources with the native species.
Indirect consequences	
Eradication, control etc.	**B** — Both ants can increase the cost of pest control both in the field and during postharvest treatment and handling. It would also be costly to eradicate them. State authorities in Australia are in the process of eradicating the red imported fire ant by using low-toxic bait and chemical treatments (QPDI, 2002). Black ants are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the district level.
Domestic trade	**B** — The presence of these pests in commercial production areas can have a significant effect at the local level due to any resulting interstate trade restrictions on a wide range of commodities. These restrictions can lead to a loss of markets.
International trade	**B** — The presence of these pests in commercial production areas of a range of commodities (e.g. mangosteen) can have a significant effect at the local level due to 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 not considered to otherwise impact on the environment. They are estimated to have consequences which are unlikely to be discernible at the national level and of minor significance at the local level.

Unrestricted risk estimate

Very low. The unrestricted risk estimate is determined by combining the overall 'probability of entry, establishment and spread' with the 'consequences' using the risk estimation matrix (Table 1).

CONCLUSION: RISK ASSESSMENTS

The results of the risk assessments are summarised in Table 9. The results show that unrestricted risk estimates for fruit flies and mealybugs exceed Australia's ALOP. Hence, risk management measures are required for these pests. The proposed risk management measures are described in the following section.

Table 9 Results of the risk assessments

Scientific name	Common name	Probability of Entry	Probability of Establishment	Probability of Spread	Overall Probability of entry, establishment and spread	Consequences	Unrestricted Risk
Bactrocera carambolae	carambola fruit fly	Very low	Moderate	High	Very low	High	Low
Bactrocera dorsalis	Oriental fruit fly	Very low	Moderate	High	Very low	High	Low
Bactrocera papayae	papaya fruit fly	Very low	Moderate	High	Very low	High	Low
Dolichoderus sp.	black ant	Low	Moderate	High	Low	Low	Very low
Dysmicoccus neobrevipes	gray pineapple mealybug	Moderate	High	High	Moderate	Low	Low
Pseudococcus cryptus	cryptic mealybug	Moderate	High	High	Moderate	Low	Low
Technomyrmex butteli Forel	black ant	Low	Moderate	High	Low	Low	Very low

RISK MANAGEMENT

Pest risk management evaluates and selects options for measures to reduce the risk of entry, establishment or spread of quarantine pests assessed to pose an unacceptable level of risk to Australia via the importation of commercially produced mangosteens from Thailand (i.e. produced under standard cultivation, harvesting and packing activities).

Biosecurity Australia considers that the risk management measures proposed below are commensurate with the identified risks and invites technical comments on their economic and technical feasibility. In particular, technical comments are welcome on the appropriateness of the measures and any alternative measures that stakeholders consider would achieve the objective(s) identified for each of the measures.

The measures described below will form the basis of proposed import conditions for fresh mangosteens from Thailand, and are detailed in the section entitled 'Draft Quarantine Conditions'. The proposal for the use of the risk management measures described below does not preclude consideration of other risk management measures should they be proposed by stakeholders.

PROPOSED RISK MANAGEMENT MEASURES

There are 3 categories of measures proposed to manage the risks identified in the pest risk assessment:

- harvesting of mature fruit with unbroken skin for freedom from fruit flies
- pressurised air/water blast for management of mealybugs, and
- supporting operational maintenance systems and verification of phytosanitary status.

[1] Harvesting of mature fruit with unbroken skin for freedom from fruit flies

Bactrocera carambolae, *B. dorsalis* and *B. papayae* have been assessed to have an unrestricted risk estimate of low, and measures are therefore required 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 because clear visual external signs of infestation (particularly in recently infested fruit) may not be present. If infested fruit was not detected at inspection, fruit flies may enter, establish and spread. Harvesting of mature fruit with unbroken skin is proposed as a phytosanitary risk management measure for fruit flies.

Other postharvest disinfestation treatments (e.g. chemical dipping, methyl bromide fumigation) were identified as an in-principle option for these pests but were considered to be less economically and technically feasible than the proposed measure which is already successfully implemented in commercial production in Thailand.

Australia has conducted host status tests for papaya fruit fly (*B. papayae*) on mangosteen. Scientists from Thailand have also conducted similar studies with Oriental fruit fly (*B. dorsalis*). Results from both studies confirmed that mangosteen fruit at the mature stage (pink to maroon) with unbroken skin were a conditional non-host to these fruit fly species (Leach, 1997; Unahawutti and Oonthonglang, 2002).

In Australia, many states and territories have accepted Interstate Certification Assurance (ICA) arrangements for domestic trade of several horticultural commodities that are susceptible hosts to *B. tryoni* [Queensland fruit fly] infestations. ICA-13 allows interstate movement of approved fruits, which include mangosteen, based on mature fruit with unbroken skin.

It is concluded that mangosteen fruits for export to Australia would be required to be harvested at the mature stage (pink to maroon). Fruit is to comply with the following two requirements:

Mature	means mature fruit harvested at the pink to maroon stage.
Unbroken skin	means the skin has no pre-harvest crack, puncture, pulled stem or other break that penetrates through to the flesh and has not healed with callus tissue.

The objective of this measure is to remove fresh mangosteen fruits with pre-harvest cracks, stings, puncture or other breaks in the skin (indicating a potential wound site through which the fruit flies may deposit eggs within the fruit) from the export pathway. Adopting this measure is considered to reduce the risk associated with this group to an acceptable level.

[2] Pressurised air/water blast for management of mealybugs (treatment)

Mealybugs (*Dysmicoccus neobrevipes* and *Pseudococcus cryptus*) have been assessed to have an unrestricted risk estimate of low, and measures are therefore required to mitigate that risk. As these pests are cryptic and can hide beneath the fruit calyx, visual inspection alone is not considered to be an appropriate risk management option. If infested fruit was not detected at inspection, these mealybugs may enter, establish and spread. Pressurised air/water blast is proposed as a phytosanitary risk management measure for mealybugs.

Other postharvest chemical disinfestation treatments (e.g. methyl bromide fumigation, insecticide dip) were identified as an in-principle option for these pests but were considered to be less economically and technically feasible than the proposed measure which is already implemented in commercial production in Thailand.

All fruit is to be individually cleaned of mealybugs on the surface and underneath the calyx using either a pressurised air blast or a high-pressure water jet device. This must be completed in packinghouses that are registered with and audited by ARD (see measure 3B). Biosecurity Australia understands this measure is consistent with standard commercial practices in Thailand.

Cleaning of all fruit using a pressurised air blast or a high-pressure water jet device would reduce the likelihood of introduction of mealybugs on the mangosteen fruit by physically removing them from the fruit surface and/or beneath the fruit calyx.

A gun/nozzle connected to the hose from an electrically-driven air compressor is used in Thailand to blast air under the calyces of mangosteens found with insects present. This activity involves examination of every piece of fruit by the operator.

This method was observed by Australian scientists during a visit to Thailand in 2002 and found to be very successful in dislodging ants, mealybugs, thrips and plant debris. Adopting this measure is considered to reduce the risk associated with this group to an acceptable level.

[3] Operational 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 fresh mangosteen from Thailand 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.

The proposed system of operational procedures for the production and export of fresh mangosteen from Thailand to Australia consists of:

- Registration of export orchards,
- Packinghouse registration and auditing of procedures,
- Packaging and labelling compliance,
- Pre-export inspection by ARD,
- Phytosanitary certification by ARD,
- Specific conditions for storage and movement of produce,
- On-arrival quarantine clearance by AQIS.

[3A] Registration of export orchards

All mangosteens for export to Australia must be sourced from export orchards registered with Thailand's ARD. Copies of the registration records must be made available to AQIS if requested. The ARD is required to register export orchards prior to commencement of exports.

All export orchards are expected to produce commercial mangosteens under standard cultivation, harvesting and packing activities.

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

[3B] Packinghouse registration and auditing of procedures

All packinghouses involved in the export of mangosteen fruit to Australia need to be registered with ARD. The pressurised air/water blast for management of mealybugs is to be done within the registered packinghouses. Biosecurity Australia understands these measures to be consistent with standard commercial practices.

Packinghouses would be required to identify the individual orchard with a numbering system and identify fruit from individual orchards by marking cartons or pallets (i.e. one orchard per pallet) with the unique orchard number. The list of registered packinghouses must be kept by ARD and provided to AQIS prior to exports commencing with updates provided should packinghouses be added or removed from the list.

Registration of orchards and packinghouses is to include an audit program by ARD. An audit is to be conducted prior to registration and then done at least annually.

The objective of this procedure is to ensure that packinghouses at which the pressurised air/water blast is applied can be identified. This is to allow trace back to individual packinghouses and orchards in the event of non-compliance.

[3C] Packing and labelling

All packages of mangosteen for export would be free from contaminated plant materials including trash and weed seeds and would 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/). Trash refers to soil, splinters, twigs, leaves and other plant materials. Inspected and treated fruits would be required to be packed in new cartons. Packing material would be synthetic or 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 mangosteen must comply with the AQIS conditions (e.g. those in "Cargo containers: Quarantine aspects and procedures" (AQIS, 2003).

All boxes would be labelled with the orchard registration number and packinghouse registration number for the purposes of trace back in the event that this is necessary. The pallets should be securely strapped only after phytosanitary inspection has been carried out following mandatory postharvest 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 registered orchards.

The objectives of this procedure are to ensure that:

- The mangosteens exported to Australia are not contaminated by weeds or trash.
- Unprocessed packing material (which may vector pests identified as not on the pathway and pests not known to be associated with mangosteen) is not imported with the mangosteens.
- The packaged mangosteens are labelled in such as way to identify the orchard and packinghouse (see measure 3A).

[3D] Pre-export inspection by ARD

ARD will inspect all consignments in accordance with official procedures for all visually detectable quarantine pests and trash using sampling procedures developed by ARD in consultation with Biosecurity Australia/AQIS.

The objective of this procedure is to ensure that mangosteens exported to Australia do not contain quarantine pests or trash on the surface of the fruit and underneath the fruit calyx, and complies with packing and labelling requirements.

Records of the interceptions made during these inspections (live or dead pests, and trash) are to be maintained by ARD 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.

[3E] Phytosanitary certification by ARD

ARD is required to issue a Phytosanitary Certificate for each consignment upon completion of pre-export inspection and treatment. The objective of this procedure is to provide formal documentation to AQIS verifying that the relevant measures have been done offshore. Each Phytosanitary Certificate is to contain the following information:

Additional declarations

"The mangosteens in this consignment have been produced in Thailand in accordance with the conditions governing entry of fresh mangosteen fruits to Australia and inspected by ARD and found to be free of quarantine pests".

Distinguishing marks

The orchard registration number, packinghouse registration number, number of cartons per consignment, and container and seal numbers (as appropriate); (to ensure trace back to the orchard in the event that this is necessary).

Treatment

"The product in this consignment has been cleaned using a pressurised air/water blast."

A consignment is the quantity of mangosteen fruits covered by one Phytosanitary Certificate that arrives at one port in one shipment. All consignments would need to be shipped directly from one port or city in Thailand to a designated port or city in Australia.

[3F] Specific conditions for storage and movement of produce

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

Product for export to Australia that has been inspected and certified by ARD must be maintained in secure conditions that will prevent mixing with fruit for export to other destinations.

Security of the consignment is to be maintained until release from quarantine in Australia.

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

[3G] On-arrival quarantine clearance by AQIS

On arrival, each consignment would be inspected by AQIS and documentation examined for consignment verification purposes at the port of entry in Australia prior to release from quarantine. Sampling methodology would provide 95% confidence that there is not more than 0.5% infestation in a consignment.

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

Where consignments are found to be non-compliant with requirements on-arrival, the importer will be given the option to treat (if suitable treatments for the pests detected can be applied), re-export or destroy the consignment. If product continually fails inspection, AQIS reserves the right to suspend the export program and conduct an audit of the Thai mangosteen risk management systems. The program will continue only once Biosecurity Australia/AQIS is satisfied that appropriate corrective action has been taken.

Uncategorised pests

If an organism is detected on mangosteens from Thailand that has not been categorised, it will require assessment to determine its quarantine status and if 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.

DRAFT QUARANTINE CONDITIONS

The draft import conditions described below are based on the conclusions of the pest risk analysis contained in this draft IRA report. Specifically, they are based on the risk management measures proposed in the previous section. Each proposed risk management measure is covered in more detail below including the options of how they could be implemented.

The components of the draft quarantine conditions are summarised in dot point format below and Biosecurity Australia invites comments on their technical and economic feasibility. The proposed risk management measure that links with each component is given in brackets ( ).

- Import Condition 1. Registration of export orchards (links with risk management measure 3A)
- Import Condition 2. Packinghouse registration and auditing of procedures (3B)
- Import Condition 3. Harvesting of mature fruit with unbroken skin for freedom from fruit flies (1)
- Import Condition 4. Pressurised air/water blast for management of mealybugs (2)
- Import Condition 5. Packing and labelling (3C)
- Import Condition 6. Pre-export inspection by ARD (3D)
- Import Condition 7. Phytosanitary certification by ARD (3E)
- Import Condition 8. Storage (3F)
- Import Condition 9. On-arrival quarantine clearance by AQIS (3G)
- Import Condition 10. Audit and review of policy.

IMPORT CONDITION 1. REGISTRATION OF EXPORT ORCHARDS

All mangosteens for export to Australia must be sourced from export orchards registered with Thailand's ARD. Copies of the registration records must be made available to AQIS if requested. The ARD is required to register export orchards prior to commencement of exports.

All export orchards are expected to produce commercial mangosteens under standard cultivation, harvesting and packing activities.

IMPORT CONDITION 2. PACKINGHOUSE REGISTRATION AND AUDITING OF PROCEDURES

All packinghouses involved in the export of mangosteen fruit to Australia need to be registered with ARD. The pressurised air/water blast for management of mealybugs is to be done within the registered packinghouses. Biosecurity Australia understands these measures to be consistent with standard commercial practices.

Packinghouses would be required to identify the individual orchard with a numbering system and identify fruit from individual orchards by marking cartons or pallets (i.e. one orchard per pallet) with the unique orchard number. The list of registered packinghouses must be kept by ARD and provided AQIS prior to exports commencing with updates provided should packinghouses be added or removed from the list.

Registration of orchards and packinghouses is to include an audit program by ARD. An audit is to be conducted prior to registration and then done at least annually.

IMPORT CONDITION 3. HARVESTING OF MATURE FRUIT WITH UNBROKEN SKIN FOR FREEDOM FROM FRUIT FLIES

Mangosteen fruits for export to Australia would be required to be harvested at the mature stage (pink to maroon). Fruit is to comply with the following two requirements:

Mature	means mature fruit harvested at the pink to maroon stage.
Unbroken skin	means the skin has no pre-harvest crack, puncture, pulled stem or other break that penetrates through to the flesh and has not healed with callus tissue.

IMPORT CONDITION 4. PRESSURISED AIR/WATER BLAST FOR MANAGEMENT OF MEALYBUGS (TREATMENT)

All fruit is to be individually cleaned of mealybugs on the surface and underneath the calyx using either a pressurised air blast or a high-pressure water jet device. This must be completed in packinghouses that are registered with and audited by ARD. Biosecurity Australia understands this measure is consistent with standard commercial practices in Thailand.

IMPORT CONDITION 5. PACKING AND LABELLING

All packages of mangosteen for export would be free from contaminated plant materials including trash and weed seeds and would 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/). Trash refers to soil, splinters, twigs, leaves and other plant materials. Inspected and treated fruits would be required to be packed in new cartons. Packing material would be synthetic or 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 mangosteen must comply with the AQIS conditions (e.g. those in "Cargo containers: Quarantine aspects and procedures" (AQIS, 2003).

All boxes would be labelled with the orchard registration number and packinghouse registration number for the purposes of trace back in the event that this is necessary. The pallets should be securely strapped only after phytosanitary inspection has been carried out following mandatory postharvest 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 registered orchards.

IMPORT CONDITION 6. PRE-EXPORT INSPECTION BY ARD

ARD will inspect all consignments in accordance with official procedures for all visually detectable quarantine pests and trash using sampling procedures developed by ARD in consultation with Biosecurity Australia/AQIS.

The inspection procedures would ensure that mangosteen fruit is free from pests of quarantine concern to Australia, has no broken skin, is free of any contaminant plant material (leaves, twigs, seed, etc.) and soil, and is clean on the surface and underneath the calyx consistent with the level of cleanliness of fruit subjected to either a pressurised air blast or a high-pressure water jet device.

Consignments that do not comply with the above requirements will be rejected for export to Australia.

Records of the interceptions made during these inspections (live or dead pests, and trash) are to be maintained by ARD 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.

IMPORT CONDITION 7. PHYTOSANITARY CERTIFICATION BY ARD

ARD is required to issue a Phytosanitary Certificate for each consignment upon completion of pre-export inspection and treatment. Each Phytosanitary Certificate is to contain the following information:

Additional declarations

"The mangosteens in this consignment have been produced in Thailand in accordance with the conditions governing entry of fresh mangosteen fruits to Australia and inspected by ARD and found to be free of quarantine pests".

Distinguishing marks

The orchard registration number, packinghouse registration number, number of cartons per consignment, and container and seal numbers (as appropriate); (to ensure trace back to orchard in the event that this is necessary).

A consignment is the quantity of mangosteen fruits covered by one Phytosanitary Certificate that arrives at one port in one shipment. All consignments would need to be shipped directly from one port or city in Thailand to a designated port or city in Australia.

Treatment

"The product in this consignment has been cleaned using a pressurised air/water blast."

IMPORT CONDITION 8. STORAGE

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

Product for export to Australia that has been inspected and certified by ARD must be maintained in secure conditions that will prevent mixing with fruit for export to other destinations. For example, segregation of product for export to Australia in separate storage facilities, shrink-wrapping pallets in plastic, placing product in low temperature cold storage or directly transferring the packed product at the packinghouse into a shipping container, which would be sealed and not opened until the container reached Australia.

Security of the consignment is to be maintained until release from quarantine in Australia.

IMPORT CONDITION 9. ON-ARRIVAL QUARANTINE CLEARANCE BY AQIS

On arrival, each consignment would be inspected by AQIS and documentation examined for consignment verification purposes at the port of entry in Australia prior to release from quarantine. Sampling methodology would provide 95% confidence that there is not more than 0.5% infestation in a consignment.

Where consignments are found to be non-compliant with requirements on-arrival, the importer will be given the option to treat (if suitable treatments for the pests detected can be applied), re-export or destroy the consignment. If product continually fails inspection, AQIS reserves the right to suspend the export program and conduct an audit of the Thai mangosteen risk management systems. The program will continue only once Biosecurity Australia/AQIS is satisfied that appropriate corrective action has been taken.

Uncategorised pests

If an organism is detected on mangosteens from Thailand that has not been categorised, it will require assessment to determine its quarantine status and if 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.

IMPORT CONDITION 10. REVIEW OF POLICY

Biosecurity Australia reserves the right to review this policy after the first year of trade.

CONCLUSIONS

The findings of this draft IRA report are based on a comprehensive analysis of relevant scientific literature.

Biosecurity Australia considers that the risk management measures proposed in this draft IRA report will provide an appropriate level of protection against the pests identified in the risk assessment. Various risk management measures may be suitable to manage the risks associated with fresh mangosteens from Thailand and Biosecurity Australia will consider any other measures suggested by stakeholders that provide an equivalent level of phytosanitary protection.

In the course of preparing the draft IRA report, Biosecurity Australia received submissions on scientific issues raised in the Technical Issues Paper. A synopsis of submissions received in response to the Technical Issues Paper and Biosecurity Australia's response to the issues raised are included in this draft IRA report. Biosecurity Australia has considered all scientific issues raised in the stakeholder submissions and incorporated the comments as appropriate.

FURTHER STEPS IN THE IMPORT RISK ANALYSIS PROCESS[5]

The IRA process will now proceed through the following steps:

- Consultation with stakeholders on the Draft IRA Report[6]
  - – Stakeholders having 60 days to submit comments
- Preparation of the Final IRA Report
- Consideration of the Final IRA Report by the Executive Manager, Biosecurity Australia
- Consultation with State and Territory Government agencies
- Release of Final IRA Report and recommendation for a policy determination
  - – Stakeholders having 30 days from the publication of the recommendation for a policy determination to lodge an appeal in writing
  - – With determination of appeals, if required
- Final policy determination by the Director of Animal and Plant Quarantine and public notification
  - – Notification being made to the proponent/applicant, registered stakeholders and the WTO

Stakeholders will be advised of any significant variations to this process.

[5] The process described here differs from that in *The AQIS Import Risk Analysis Process Handbook*. This is the new process as outlined in Biosecurity Australia's *Import Risk Analysis Handbook* 2003, which will become effective on its publication.

[6] Contact details for stakeholder contributions are provided in the accompanying Plant Biosecurity Policy Memorandum (PBPM).

STAKEHOLDER COMMENTS ON THE TECHNICAL ISSUES PAPER AND RESPONSE FROM BIOSECURITY AUSTRALIA

Fruit flies

Stakeholder comments: that

a) fruit flies on mangosteen be considered further in the IRA

b) there is lack of information on studies conducted on the host status of mangosteen for *B. dorsalis*

c) use of conditional non-host status for mangosteen for *B. papayae* instead of non-preferred host status.

Biosecurity Australia has included *B. carambolae*, *B. dorsalis* and *B. papayae* for further consideration in the draft IRA report. Biosecurity Australia has used the term "non-preferred host" in negotiating access for our commodities overseas and our trading partners have accepted this term. Based on host studies carried out in Thailand on *B. dorsalis*, and on *B. papayae* in Queensland and information available on host range of *B. carambolae*, Biosecurity Australia considers that mangosteen is a conditional non-host for all three species and have proposed this as a risk management measure (see 'Risk Management' section). These measures are consistent with domestic trade on mangosteens (ICA-13).

Ants, soil and weeds under the fruit calyces

Stakeholder comments: that Biosecurity Australia gives due consideration to the presence of ants, soil and weeds under the fruit calyces (on the premise that Australian growers commonly find ants and soil on mangosteen fruit particularly after the rainy weather).

Biosecurity Australia understands that in Australia some growers allow fruits to fall to the ground and pick the mature, ripe fruits off the ground because of the high labour cost involved. In Thailand, the fruits are individually harvested using a bag connected to a pole and placed directly into plastic containers and do not come in contact with the ground. This practice reduces the risk of soil, weed seeds or ground dwelling insects being present beneath the fruit calyces (Appendices 1 and 2, Technical Issues Paper). Thai growers reported that fruit that fall onto the ground suffers skin damage and are not picked for the market (Appendix 1B, Technical Issues Paper).

Consideration of red tree ants in Thailand on the mangosteen pathway

Stakeholder comments: that red tree ants in Thailand have similar behaviour as the green tree ants in Australia (observed foraging on mangosteen in Australia) and are not considered in the IRA.

Biosecurity Australia understands that the red tree ant species is present in Thailand but has not been reported on mangosteen in Thailand and therefore is not included in this IRA.

Status of fungal species on the mangosteen fruit pathway

Statement comment: the only serious concern is that of *Gliocephalotrichum bulbilium* that causes serious rot of rambutan, apple in India and durian and this needs to be considered in the IRA. Of lesser concern is the unidentified species of *Graphium* recorded from fruit rot in Thailand.

Gliocephalotrichum bulbilium, *Phomopsis* sp., *Graphium* sp. and *Pestalotiopsis flagisetula* are associated with causing postharvest storage rots together with other fungi on mangosteen (Sangchote and Pongpisutta, 1998). *G. bulbilium*, *Phomopsis* sp. and *P. flagisetula* also affect other fruits such as rambutan (Visarathanonth and Ilag, 1987), and related durian species *Durio kutejensis* and *D. graveolens* (Sivapalan *et al*., 1998). *G. bulbilium* is also reported to cause a storage rot of apples in India as a result of fruit injury (Uddin *et al*., 1972). These fungi are weak pathogens or secondary invaders (Sivapalan *et al*., 1998), and cause postharvest problems related to latent field infection or injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth and Ilag, 1987). Postharvest secondary pathogens such as these are not considered to be quarantine pests.

Graphium has been reported to be the anamorph of pathogens that can cause serious diseases such as Dutch elm disease (causal agent is *Ophiostoma* (*Ceratocystis*) *ulmi*). Anamorphs of *Ophiostoma* include *Leptographium*, *Graphium*, *Hyalorhinocladiella*, *Sporothrix* and *Knoxdaviesia* (Mouton *et al*., 1994). Published literature suggests that *Ophiostoma* is usually found in cooler Mediterranean, sub-temperate and temperate areas of the world affecting woody plants including species of Pinaceae. *Graphium* sp. occur commonly on wood, dung, seeds, and plant debris (Ellis, 1971; Seifert and Okada, 1993).

Consideration of other insect pests recorded on mangosteen

Stakeholder comment: that species such as *Carpophilus dimidiatus*, *Taeniothrips usitatus*, and *Thrips florum* (syn. *T. hawaiiensis*) have been recorded on mangosteens (Yunus and Ho, 1980) and are present in Thailand (CAB International, 2002). None of these are listed in Appendix 4 of the Technical Issues Paper.

Biosecurity Australia has not found any evidence that *Carpophilus dimidiatus* and *Thrips florum* are present on mangosteen in Thailand, hence these two species are not considered in this IRA. *Carpophilus dimidiatus*, *Megalurothrips usitatus* (syn. *Taeniothrips usitatus*) and *Thrips florum* have been recorded on leaves of mangosteen in Malaysia (Yunus and Ho, 1980). They are not present on the fruit pathway. *Carpophilus dimidiatus* is present in Thailand, but has not been recorded on mangosteen (CAB International, 2002).

Taeniothrips usitatus was listed in Appendix 4 of the Technical Issues Paper under the valid name *Megalurothrips usitatus*. Biosecurity Australia understands that *Thrips hawaiiensis* (Morgan) and

Thrips florum Schmutz are regarded as two separate species by Mound (1996). Both species are present in Australia (Mound, 1996).

Consideration of fungal pathogens not present in Thailand

Stakeholder comment: that Biosecurity Australia should consider *Marasmiellus scandens* and *Marasmius crinis-equi* further because both pests have been reported from countries bordering Thailand and having similar tropical climates to Thailand. Both pests are known to have a wide host range and can be spread through contact with infected plant parts and airborne spores. Hyphae and fruiting bodies of these two pests can be both externally and internally borne, and infect leaves, stems, trunks and branches of host plants. The ability of these pathogens to spread by airborne basidiospores suggest that their entry via the fruit pathway in the form of basidiospore load on the fruit should be considered further.

Biosecurity Australia has not found any evidence that *Marasmiellus scandens* and *Marasmius crinis-equi* are present on mangosteen in Thailand, hence these two species are not considered in this IRA. *Marasmiellus scandens* and *Marasmius crinis-equi* have been recorded on the stem and shoots of mangosteen in Malaysia (Turner, 1971), not the fruit pathway. They have not been reported in Thailand.

Consideration of additional weed species

Stakeholder comment: that Biosecurity Australia should consider an additional 61 weed species that are all present in Thailand, or among the major weed pests in the country.

Specific consideration of weeds within IRAs is required only for certain commodities where it is considered feasible that weeds would commonly be associated with the pathway. For mangosteens, Biosecurity Australia does not consider that this is the case.

Use of Australian Government Department of Agriculture, Fisheries and Forestry Agriculture Counsellors in our overseas embassies to source information

Stakeholder comment: that they find it bizarre to use Australian Agriculture Counsellors in Seoul to source information on import conditions on mangosteen into Taiwan from Thailand, Biosecurity Australia should source directly from Taiwan.

Prior to the deployment as an Agriculture Counsellor in Beijing China, the counsellor in Seoul had responsibilities to cover China and Taiwan in addition to Korea. One of the many roles of our counsellor is to liaise with other government and private firms in the overseas market for issues pertaining to agricultural trade.

REFERENCES

Allwood, A.L. (1995). Outbreak of papaya fruitfly in North Queensland, Australia. Ag-Alert No. 14, 2 pp.

Allwood, A.L., Chinajariyawong, A., Drew, R.A.I., Hamacek, E.L., Hancock, D.L., Hengsawad, C., Jipanin, J.C., Jirasurat, M., Kong Krong, C., Kritsaneepaiboon, S., Leong, C.T.S. and Vijaysegaran, S. (1999). Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology, Supplement* 7: 1-92.

Almeyda, N. and Martin, F.W. (1976). *Cultivation of Neglected Tropical Fruits with Promise. Part 1. The Mangosteen*. Berkeley, California, USA: Agricultural Service, United States Department of Agriculture No. ARS-S-155, 18 pp.

Anon. (1991). The impact of fruit flies on Australian Horticulture. Report to the Honourable John Kerin, Minister for Primary Industries and Energy. Horticultural Policy Council, April 1991.

AQIS (Australian Quarantine and Inspection Service) (2003). Cargo Containers: Quarantine aspects and procedures. http://www.affa.gov.au/corporate_docs/publications/word/quarantine/border/cargo.doc

Bailey, L.H. (1963). *The Standard Encyclopaedia of Horticulture*. New York, USA: Macmillan Press.

Bordeaut, J. and Moreuil, C. (1970). Le mangoustanier, ses possibilities de culture in Côte d'Ivoire et a Madagascar. *Fruits d'outre Mer*. 25: 223-245. (In French).

Burikam, I., Sarnthoy, O. and Charernsom, K. (1991). A probit analysis of the disinfestation of mangosteens by cold treatment against the larval stages of the Oriental fruit fly (*Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Kasetsart Journal, Natural Sciences* 25(2): 251-255.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Chay-Prove, P. (2001). *Mangosteen: general crop management*. DPI Note, Department of Primary Industries Queensland.

DA-AMAS (Department of Agriculture - Agribusiness and Marketing Assistance Service, Philippines) (2000). Mangosteen Industry Situationer Report. http://www.da.gov.ph/agribiz/mangosteen.html.

DAET (Department of Agricultural Extension, Ministry of Agriculture and Cooperatives, Thailand) (1987). *Fruits in Thailand*. Thailand: Department of Agricultural Extension, Ministry of Agriculture and Cooperatives.

Downton, J. and Chacko, E.K. (1998). Mangosteen. In: Hyde, K.W. (ed.). *The New Rural Industries: A Handbook for Farmers and Investors*. Canberra, Australia: Rural Industries Research and Development Corporation (RIRDC), pp. 296-301.

Ellis, M.B. (1971). *Dematiaceous Hyphomycetes*. (Kew, Surrey, UK: Commonwealth Mycological Institute), 608 pp.

Fletcher, B.S. (1989). Life history strategies of tephritid fruit flies. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 195-208.

Follett, P. (1998). Country of Hawaii Agriculture – Treatments for Exporting Hawaiian Fruit. Information from Quarantine Updates, USDA-ARS Tropical Fruit, Vegetable & Ornamental Crop Research Laboratory, Hilo, Hawaii. Issue 1, 21 July 1998. http://www.hawaii-county.com/bigislandag/quarantine.html

Gullan, P.J. (1997). Relationships with ants. In: Ben-Dov, Y. and Hodgson, C.J. (eds). *Soft Scale Insects: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 7A. Amsterdam, Netherlands: Elsevier Science, pp. 351-374.

Hoy, L.E. and Whiting, D.C. (1997). Low-temperature storage as a postharvest treatment to control *Pseudococcus affinis* (Homoptera: Pseudococcidae) on Royal Gala apples. *Journal of Economic Entomology* 90(5): 1377-1381.

ISPM No. 2 (1996). *Guidelines for Pest Risk Analysis*. International Standards for Phytosanitary Measures, Publication No. 2. Secretariat of the International Plant Protection Convention. Food and Agriculture Organization of the United Nations.

ISPM No. 11 (2001). *Pest Risk Analysis for Quarantine Pests*. International Standards for Phytosanitary Measures, Publication No. 11. Secretariat of the International Plant Protection Convention. Food and Agriculture Organization of the United Nations.

Ito, K. (1938). Studies on the life history of the pineapple mealybug, *Pseudococcus brevipes* (Ckll.). *Journal of Economic Entomology* 31: 291-298.

Kessing, J.L.M. and Mau, R.F.L. (1992). Crop Knowledge Master. *Dysmicoccus neobrevipes* (Beardsley). http://www.extento.hawaii.edu/kbase/crop/Type/d_neobre.htm

Krishnamurthi, S., Rao, V.N.M. and Ravoff, A.A. (1964). A note on the flowers and floral biology in mangosteen (*Garcinia mangostana* L.). *South Indian Horticulture* 12(3/3): 99-101.

Leach, P.L. (1997). Determination the susceptibility of mangosteen, *Garcinia mangostana* L., to infestation by papaya fruit fly, *Bactrocera papayae* Drew and Hancock (Diptera: Tephritidae). An internal report for consideration by the Interstate Plant Health Regulatory Working Group. Brisbane, Australia: Queensland Department of Primary Industries, 5 pp.

Leach, P.L. (2003). Personal communication.

Lim, T.K., Diczbalis, Y., Landrigan, M. and McMahon, G. (1998). Mangosteen Quality Standards chart. Prepared by the Northern Territory Department of Primary Industry and Fisheries.

Miller, G.L. and Miller, D.R. (2002). *Dysmicoccus* Ferris and similar genera (Hemiptera: Coccoidea: Pseudococcidae) of the Gulf state region including a description of a new species and new United States records. *Proceedings of the Entomological Society of Washington* 104(4): 968-979.

Mohd Khalid, M.Z. and Rukayah, A. (1993). *Penanaman manggis*. (Mangosteen cultivation). Kuala Lumpur, Malaysia: Malaysian Agricultural Research and Development Institute (MARDI). (In Malay).

Moody, T. (2000). *Asian and Exotic Fruit – Mangosteen*. New South Wales Department of Agriculture. http://www.agric.nsw.gov.au/Hort/Fmrs/Asian_veg/mangostn.htm

Morton, J.F. (1987). Mangosteen. In: *Fruits of Warm Climates*. Miami Florida, USA: Julia F. Morton, pp. 301-304.

Mound, L.A (1996). Thysanoptera. In: Wells, A. (ed.). *Zoological Catalogue of Australia. Volume 26*. Psocoptera, Phthiraptera, Thysanoptera. Melbourne, Australia: CSIRO Publishing, pp. 249-332, 333-337 (App. I-III), 397-414 (Index).

Mouton, M., Wingfield, M.J. and van Wyk, P.S. (1994). Conidium development in anamorphs of *Ceratocystis* sensu lato: a review. *South African Journal of Science* 90(5): 293-298.

Nguyen, M. (1998). Some ideas on the export market of fresh and processed fruits in Vietnam. *Workshop on Commercialisation of Tropical Fruits in South Vietnam, SOFRI, Vietnam, 12-13 June 1998*, pp. 52-64.

O'Connor, P. (2000). *Overcoming the Tyranny of Distance*. Paper presented at the FRESH 2000 Conference - Cairns, Queensland. www.horticulture.com.au/admin/docs/fresh2000proceedingssession3.pdf

QDPI (Queensland Department of Primary Industries) (2001). ICA Operational Procedures - ICA-13 Unbroken Skin Condition of Approved Fruits. http://www.dpi.qld.gov.au/health/4145.html#13

QDPI (Queensland Department of Primary Industries) (2002). Fire Ants – Homepage. http://www.dpi.qld.gov.au/fireants/

Reza, M., Wijaya, M. and Tuherkih, E. (1994). *Pembibitan dan Pembudidayaan Manggis*. (Propagation and cultivation of Mangosteen). Penerbar Swadaya, 58 pp. (In Indonesian).

Rohrbach, K.G., Beardsley, J.W., German, T.L., Reimer, N.J. and Sanford, W.G. (1988). Mealybug wilt, mealybugs, and ants on pineapple. *Plant Disease* 72: 558-565.

RTELPA (Rambutan and Tropical Exotic Local Producers Association) and NTHA (Northern Territory Horticultural Association) (1997). *Australian Mangosteen Industry Strategic Plan*. RIRDC Project RTE-1A.

Sangchote, S. and Pongpisutta, R. (1998). Fruit rots of mangosteen and their control. Paper abstracts presented at the *7th International Congress of Plant Pathology*, held in Edinburgh, Scotland 9-16 August 1998. ICPP 98 Abstracts. http://www.bspp.org.uk/icpp98/

Seifert, K.A. and Okada, G. (1993). *Graphium* anamorphs of *Ophiostoma* species and similar anamorphs of other ascomycetes. In: Wingfield, M.J., Seifert, K.A. and Webber, J. (eds). *Ceratocystis and Ophiostoma: Taxonomy, Ecology and Pathology*. (St Paul, Minnesota, USA: American Phytopathological Society Press), pp. 27-41.

Shattuck, S.O. and Barnett, N.J. (2001). Australian Ants Online. The Guide to the Australian Ant Fauna. http://www.ento.csiro.au/science/ants/default.htm

Shelly, T.E. (2001). Lek size and female visitation in two species of tephritid fruit flies. *Animal Behaviour* 62(1): 33-40.

Shelly, T.E. and Kaneshiro, K.Y. (1991). Lek behavior of the Oriental fruit fly, *Dacus dorsalis*, in Hawaii (Diptera: Tephritidae). *Journal of Insect Behavior* 4(2): 235-241.

Sivapalan, A., Metussin, R., Hamdan, F. and Zain, R.M. (1998). Fungi associated with postharvest fruit rots of *Durio graveolens* and *D. kutejensis* in Brunei Darussalam. *Australasian Plant Pathology* 27(4): 274-277.

SPC (Secretariat of the Pacific Community) (2002). Pacific Fruit Fly Web – Asian Papaya Fruit Fly (*Bactrocera papayae* Drew and Hancock). 17 October, 2002. http://www.spc.int/pacifly/Species_profiles/B_papayae.htm

Terron, G. (1972). Observations sur les mâles ergatoïdes et les mâles ailés chez une fourmie du genre *Technomyrmex* Mayr (Hym., Formicidae, Dolichoderinae). *Ann. Fac. Sci. Cameroun* 10: 107-120. (In French).

Turner, G.J. (1971). Fungi and plant disease in Sarawak. *Phytopathological Papers No. 13*, 55 pp.

Uddin, J., Tandon, M.P. and Tandon, R.N. (1972). A storage rot of fruits of apple (*Malus sylvestris*). *Indian Phytopathology* 25(4): 593-595.

Unahawutti, U. and Oonthonglang, P. (2002). *Laboratory Study on the Possible Attack of the Oriental fruit fly (Diptera: Tephritidae) on Mangosteens*. Chattuchak, Bangkok: Department of Agriculture, Office of Crop Protection Research and Development, 15 pp.

Verheij, E.W.M. and Coronel, R.E. (eds). (1991). *Plant Resources of South-East Asia. No. 2. Edible fruits and nuts*. Wageningen, Netherlands: Pudoc, 446 pp.

Vijaysegaran, S. (2003). Personal communication.

Visarathanonth, N. and Ilag, L.L. (1987). Postharvest diseases of rambutan. In: Lam, P.F. and Kosiyachinda, S. (eds). *Rambutan: Fruit development, Postharvest Physiology and Marketing in ASEAN*. Kuala Lumpur, Malaysia: ASEAN Food Handling Bureau, pp. 51-57.

Wiles, G.C. (1996). Papua New Guinea: A potential exporter of tropical fruit to Asian markets. In: *Proceedings of the International Conference on Tropical Fruits Kuala Lumpur, Malaysia 23-26 July 1996*, pp. 47-60.

Yunus, A. and Ho, T.H. (1980). List of Economic Pests, Host Plants, Parasites and Predators in West Malaysia (1920-1978). *Ministry of Agriculture Malaysia, Bulletin No. 153*, 538 pp.

APPENDICES

APPENDIX 1: PEST CATEGORISATION FOR MANGOSTEENS FROM THAILAND

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
ARTHROPODA					
Acari [mites]					
Brevipalpus californicus (Banks, 1904) [Acarina: Tenuipalpidae]	citrus flat mite	Yes CAB International (2002)	Yes Astridge *et al*. (2000a); Halliday (1998); ICDB (2002)	Yes CAB International (2002)	No
Tetranychus urticae Koch [Acarina: Tetranychidae]	two-spotted spider mite	Yes IIE (1996); Waterhouse (1993)	Yes Astridge & Fay (2000); ICDB (2002); IIE (1996)	Yes CAB International (2002)	No
Diptera [flies]					
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	carambola fruit fly	Yes CAB International (2002), but not on mangosteen	No CAB International (2002)	Yes CAB International (2002)	**Yes**
Bactrocera dorsalis (Hendel, 1912) [Diptera:	Oriental fruit fly	Yes	No	Yes	**Yes**

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Tephritidae]		Burikam *et al*. (1991); IIE (1994); Waterhouse (1993)	Evenhuis (1989)	Burikam *et al*. (1991)	
Bactrocera papayae (Drew & Hancock) [Diptera: Tephritidae]	papaya fruit fly	Yes CAB International (2002); Drew & Romig (1996)	No – Eradicated CAB International (2002)	Yes CAB International (2002); only on damaged fruit (Leach (1997)	**Yes**
Drosophila (*Sophophora*) *melanogaster* [Diptera: Drosophilidae]	vinegar fly	Yes Okada (1977)	Yes Anderson & Gibson (1985); Davidson (1990); ICDB (2002); Worthen (1996)	No CAB International (2002)	No
Hemiptera [aphids, leafhoppers, mealybugs, psyllids, scales, whiteflies]					
Aspidiotus destructor Signoret, 1869 [Hemiptera: Diaspididae]	coconut scale	Yes APPPC (1987); CIE (1966); Waterhouse (1993)	Yes Astridge & Fay (2000); Chacko *et al*. (1995); CIE (1966) Not present in WA (AgWA, 2003)	No leaf (Yunus & Ho, 1980)	No
Coccus viridis (Green, 1889) [Hemiptera: Coccidae]	green coffee scale	Yes Ben-Dov *et al*.	Yes Ben-Dov (1994);	No leaf (Yunus & Ho,	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
		(2001); Waterhouse (1993)	Smith *et al*. (1997) Not present in WA (AgWA, 2003)	1980)	
Dysmicoccus neobrevipes Beardsley, 1959 [Hemiptera: Pseudococcidae]	gray pineapple mealybug	Yes Anon. (2000b); Waterhouse (1993)	No Williams (1985)	No? Anon. (2000b)	**Yes**
Greenidea sp. [Hemiptera: Aphididae]	aphid	Yes DOA (2000)	? – Genus is present in Australia Carver (2002) Not present in WA (AgWA, 2003)	No DOA (2000)	No
Icerya seychellarum (Westwood, 1855) [Hemiptera: Margarodidae]	Seychelles scale	Yes CIE (1955); Waterhouse (1993)	Yes CAB International (2002) Not present in WA (AgWA, 2003)	No CAB International (2002)	No
Planococcus citri (Risso, 1813) [Hemiptera: Pseudococcidae]	citrus mealybug	Yes CABI/EPPO (1999); Waterhouse (1993)	Yes Astridge (2000); Chay-Prove *et al*. (2000); ICDB (2002); Smith *et al*. (1997)	Yes Astridge (2000)	No
Planococcus minor (Maskell, 1897) [Hemiptera:	Pacific mealybug	Yes	Yes	No	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Pseudococcidae]		Anon. (2000b)	Williams (1985) Not present in WA (AgWA, 2003)	Ooi *et al*. (2002) leaf (Yunus & Ho, 1980)	
Pseudococcus cryptus Hempel, 1918 [Hemiptera: Pseudococcidae]	cryptic mealybug	Yes Anon. (2000b)	No Ben-Dov (1994)	Yes Anon. (2000b)	**Yes**
Toxoptera aurantii (Boyer de Fonscolombe, 1841)	camellia aphid	Yes APPPC (1987); Waterhouse (1993)	Yes Berlandier (1999); CIE (1961); Smith *et al*. (1997)	No CAB International (2002)	No
Hymenoptera [ants, bees]					
Dolichoderus sp. [Hymenoptera: Formicidae]	black ant	Yes Sudhi-Aromna (2002)	? – Genus is present in Australia Shattuck & Barnett (2001) Not present in WA (AgWA, 2003)	Yes Sudhi-Aromna (2002)	**Yes**
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	black ant	Yes Sudhi-Aromna (2002)	No Shattuck & Barnett (2001)	Yes Sudhi-Aromna (2002)	**Yes**
Lepidoptera [butterflies, moths]					
Acrocercops sp. [Lepidoptera: Gracillariidae]	leaf miner	Yes Anon. (2000a)	? – Genus is present in Australia	No Anon. (2000a)	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			Nielsen *et al*. (1996) Not present in WA (AgWA, 2003)		
Adoxophyes privatana Walker [Lepidoptera: Tortricidae]	apple leaf-curling moth	Yes DOA (2000)	No Nielsen *et al*. (1996)	No DOA (2000)	No
Aetholix flavibasalis (Guenée, 1854) [Lepidoptera: Pyralidae]	leaf roller	Yes DOA (2000)	Yes Nielsen *et al*. (1996) Not known if present in WA (AgWA, 2003)	No DOA (2000)	No
Archips micaceanus (Walker) [Lepidoptera: Tortricidae]	soyabean leaf roller	Yes DOA (2000); Waterhouse (1993)	No Nielsen *et al*. (1996)	No CAB International (2002); DOA (2000)	No
Dudua aprobola (Meyrick, 1886) [Lepidoptera: Tortricidae]	leaf roller	Yes DOA (2000)	Yes Nielsen *et al*. (1996) Not present in WA (AgWA, 2003)	No DOA (2000)	No
Eudocima fullonia (Clerck, 1764) [Lepidoptera: Noctuidae]	fruit-piercing moth	Yes Anon. (2000b)	Yes Common (1990); Nielsen *et al*. (1996)	Yes CAB International (2002)	No
Gatesclarkeana idia Diakonoff, 1973 [Lepidoptera: Tortricidae]	moth	Yes	No	No	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
		DOA (2000)	Nielsen *et al*. (1996)	DOA (2000)	
Homona difficilis Meyrick [Lepidoptera: Tortricidae]	leaf roller	Yes DOA (2000)	No Nielsen *et al*. (1996)	No DOA (2000)	No
Hyposidra talaca (Walker, 1860) [Lepidoptera: Geometridae]	leaf-eating looper	Yes DOA (2000)	Yes Common (1990); Nielsen *et al*. (1996)	No DOA (2000)	No
Lobesia genialis Meyrick [Lepidoptera: Tortricidae]	moth	Yes DOA (2000)	No Nielsen *et al*. (1996)	No DOA (2000)	No
Orgyia postica (Walker, 1855) [Lepidoptera: Lymantriidae]	cocoa tussock moth	Yes CAB International (2002); Waterhouse (1993)	No CAB International (2002)	No CAB International (2002); Waterhouse (1993)	No
Phyllocnistis citrella Stainton, 1856 [Lepidoptera: Gracillariidae]	citrus leaf miner	Yes IIE (1995); Waterhouse (1993)	Yes Smith *et al*. (1997); Wilson (1991); Woods (1995)	No CAB International (2002)	No
Stictoptera columba (Walker) [Lepidoptera: Noctuidae]	leaf-eating caterpillar	Yes Anon. (2000a); DOA (2000); Jumroenma *et al*. (2000)	Yes Nielsen *et al*. (1996) Not present in WA (AgWA, 2003)	No DOA (2000)	No
Stictoptera cucullioides Guenée, 1852 [Lepidoptera:	leaf-eating caterpillar	Yes	Yes	No	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
Noctuidae]		Anon. (2000a); Jumroenma *et al*. (2000)	Nielsen *et al*. (1996) Not present in WA (AgWA, 2003)	Ooi *et al*. (2002)	
Stictoptera signifera Walker [Lepidoptera: Noctuidae]	leaf-eating caterpillar	Yes Anon. (2000a); Jumroenma *et al*. (2000)	No Nielsen *et al*. (1996)	No Anon. (2000a); Jumroenma *et al*. (2000)	No
Thysanoptera [thrips]					
Megalurothrips usitatus (Bagnall, 1913) [Thysanoptera: Thripidae]	bean flower thrips	Yes Reyes (1994); Waterhouse (1993)	Yes Miyasaki *et al*. (1984); Mound (1996) Not present in WA (AgWA, 2003)	No CAB International (2002)	No
Scirtothrips dorsalis Hood, 1919 [Thysanoptera: Thripidae]	castor thrips	Yes DOA (2000); IIE (1986); Waterhouse (1993)	Yes Moulden (2002); Mound (1996)	No – only recorded on immature fruit DOA (2000)	No
Scirtothrips oligochaetus Karny [Thysanoptera: Thripidae]	mangosteen thrips	Yes DOA (2000)	No Mound (1996)	No – only recorded on immature fruit DOA (2000)	No
Selenothrips rubrocinctus Giard, 1901 [Thysanoptera: Thripidae]	red-banded thrips	Yes Strassen & Harten	Yes Astridge (2000);	Yes	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
		(1984)	Astridge *et al*. (2000b); Johnson & Parr (1999); Mound (1996)	Astridge (2000)	
NEMATODA					
Tylenchulus semipenetrans Cobb, 1913 [Tylenchida: Tylenchulidae]	citrus root nematode	Yes Chunram (1972)	Yes Anderson (1965), Colbran (1955); Meagher (1969); McLeod *et al*. (1994)	No Chawla *et al*. (1980)	No
ALGAE					
Cephaleuros virescens Künze [Protista]	algal leaf spot	Yes Lim & Sangchote (2003)	Yes Lim & Sangchote (2003)	No Lim & Sangchote (2003)	No
FUNGI					
Botryodiplodia theobromae Pat. [Mitosporic fungi: Coelomycetes]	fruit rot	Yes Banjerdcherdchu & Shana (1991); Lim & Sangchote (2003); Wisalthanon & Jermsiri (1998)	Yes CMI (1985); Shivas (1989)	Yes DOA (2000)	No
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. [Phyllachorales: Phyllachoraceae]	anthracnose	Yes Giatgong (1980);	Yes CAB International	Yes CAB International	No

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
		Khanmalee (1965); Lim & Sangchote (2003); Wisalthanon & Jermsiri (1998)	(2002); Cameron *et al*. (1989); Chakraborty *et al*. (1996); Sweetingham *et al*. (1995)	(2002)	
Colletotrichum sp. [Phyllachorales: Phyllachoraceae]	anthracnose; leaf blight	Yes Khanmalee (1965); Wisalthanon & Jermsiri (1998)	? – Genus is present in Australia CAB International (2002)	No DOA (2000)	No
Corticium koleroga (Cooke) Höhnel [Polyporales: Corticiaceae]	thread blight	Yes Wisalthanon & Jermsiri (1998)	Yes Chacko *et al*. (1995) No records found for WA (AgWA, 2003)	Yes Morton (1987)	No
Corticium salmonicolor (Berk. & Broome) [Polyporales: Corticiaceae]	pink disease	Yes IMI (1996)	Yes IMI (1996) No records found for WA (AgWA, 2003)	No CAB International (2002)	No
Gliocephalotrichum bulbilium Ellis & Hesseltine [Hypocreales: Nectriaceae]	fruit rot	Yes Sangchote & Pongpisutta (1998)	No APDD (2002) No records found for WA (AgWA,	Yes Sangchote & Pongpisutta (1998)	**Yes**

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			2003)		
Graphium sp. [Mitosporic fungi: Deuteromycetes]	fruit rot	Yes Pienpuck & Choobumroong (1988)	? – Genus is present in Australia CAB International (2002) No records found for WA (AgWA, 2003)	Yes DOA (2000)	**Yes**
Helminthosporium quaciniae [Mitosporic fungi: Hyphomycetes]	leaf spot	Yes Wisalthanon & Jermsiri (1998)	Yes Chacko *et al*. (1995) No records found for WA (AgWA, 2003)	No DOA (2000)	No
Pestalotiopsis flagisetulai Guba [Mitosporic fungi]	leaf spot	Yes Giatgong (1980); Lim & Sangchote (2003); Wisalthanon & Jermsiri (1998)	No APDD (2002) No records found for WA (AgWA, 2003)	Yes Wisalthanon & Jermsiri (1998)	**Yes**
Phomopsis sp. [Mitosporic fungi]	white pulp rot	Yes Banjerdcherdchu & Shana (1991); Lim & Sangchote (2003)	? – Genus is present in Australia CAB International (2002) Genus present in	Yes DOA (2000)	**Yes**

Scientific Name	Common name	Present in Thailand	Present in Australia	Associated with mangosteen fruit	Consider further
			WA (AgWA, 2003)		

References for Appendix 1

AgWA (Agriculture Western Australia) (2003). Stakeholder comments on Importation of mangosteen fruit from Thailand - Technical Issues Paper. E-mail response 23 May 2003.

Anderson, E.J. (1965). Plant-parasitic nematodes in fruit trees nurseries of New South Wales. *Proceedings of the Linnean Society of New South Wales* 90: 225-230.

Anderson, D.G. and Gibson, J.B. (1985). Variation in alcohol dehydrogenase activity *in vitro* in flies from natural populations of *Drosophila melanogaster*. *Genetica* 67(1): 13-19.

Anon. (2000a). *Recommendation on Insect and Zoological Pest Control: Mangosteen*. Bangkok, Thailand: Department of Agriculture, Entomology and Zoology Division. (In Thai).

Anon. (2000b). *Research report to increase yield and fruit quality of mangosteen. 1.3 Integrated control of mangosteen pests*. Bangkok, Thailand: Department of Agriculture. (In Thai).

APDD (Australian Plant Disease Database) (2002). http://npdd.nre.vic.gov.au/ihd/nre/research.htm

APPPC (Asia and Pacific Plant Protection Commission) (1987). Insect pests of economic significance affecting major crops of the countries in Asia and the Pacific region. *Technical Document, Asia and Pacific Plant Protection Commission, FAO*, No. 135, 56 pp.

Astridge, D. (2000). Insect fauna surveys on rambutan, durian and mangosteen in north Queensland. Queensland, Australia: Queensland Horticulture Institute, Department of Primary Industries Queensland, Mimeograph.

Astridge, D. and Fay, H. (2000). Personal communication.

Astridge, D., Fay, H. and Elder, R. (2000a). False spider mites in rare fruit. *DPI NOTE, Department of Primary Industries Queensland*, File No. HO193, Agdex 216/622.

Astridge, D., Fay, H. and Elder, R. (2000b). Red-banded Thrips in rare fruit. *DPI NOTE, Department of Primary Industries Queensland*, File No. HO205, Agdex 216/622.

Banjerdcherdchu, R. and Shana, J. (1991). Fruit rot of mangosteens caused by *Botryodiplodia* and how to control. In: *Proceedings of the 29th Agricultural Research Conference: Plants Section*. Bangkok, Thailand: Kasetsart University, pp. 297-305.

Berlandier, F.A. (1999). Aphids in lupin crops, their biology and control. *Farmnote F04499, Agriculture Western Australia*.

Ben-Dov, Y. (1994). *A Systematic Catalogue of the Mealybugs of the World (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with Data on Geographical Distribution, Host Plants, Biology and Economic Importance*. Andover, UK: Intercept Limited, 686 pp.

Ben-Dov, Y., Miller, D.R. and Gibson, G.A.P. (2001). ScaleNet. http://www.sel.barc.usda.gov/scalenet/scalenet.htm

Burikam, I., Sarnthoy, O. and Charernsom, K. (1991). A probit analysis of the disinfestation of mangosteens by cold treatment against the larval stages of the Oriental fruit fly (*Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae). *Kasetsart Journal, Natural Sciences* 25(2): 251-255.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

CABI/EPPO (1999). *Planococcus citri* (Risso). *Distribution Maps of Plant Pests, Map No. 43 (2nd revision)*. Wallingford, UK: CAB International, 8 pp.

Cameron, D.F., Chakraborty, S., Davis, R.D., Edye, L.A., Irwin, J.A.G., Manners, J.M. and Staples, I.B. (1989). A multi-disciplinary approach to anthracnose diseases of *Stylosanthes* in Australia. *Proceedings of the XVI International Grassland Congress, 4-11 October 1989, Nice, France*. Versailles, France: Association Francaise pour la Production Fourragere, Centre National de Recherche Agronomique, pp. 719-720.

Carver, M. (2002). E-mail communication with Wendy Lee on the presence of *Greenidea* genus in Australia. Australian National Insect Collection (ANIC), CSIRO Entomology, Canberra, 7 November 2002.

Chacko, E.K., Weibel, J. and Downton, W.J.S. (1995). Mangosteens. In: Coombs, B. (ed.). *Horticulture Australia: The Complete Reference of the Australian*

Horticultural Industry. Hawthorn East, Australia: Morescope Publishing, pp. 447-449.

Chakraborty, S., Thomas, M.R. and Ellis, N. (1996). A multivariate analysis of pathogenic variation in *Colletotrichum gloeosporioides* infecting the tropical pasture legume, *Stylosanthes scabra*. *Phytopathology* 86(3): 283-289.

Chawla, M.L., Samathanam, G.J. and Sharma, S.B. (1980). Occurrence of citrus nematode (*Tylenchulus semipenetrans* Cobb, 1913) on roots of mangosteen (*Garcinia mangostana*). *Indian Journal of Nematology* 10(2): 240-242.

Chay-Prove, P., Astridge, D. and Vawdrey, L. (2000). Mangosteen insect pest and disease management. *DPI NOTE, Department of Primary Industries Queensland*, Agdex 234/630, 3 pp.

Chunram, C. (1972). A list of plant parasitic nematodes in Thailand. *Plant Protection Service Technical Bulletin, Ministry of Agriculture, Bangkok, Thailand*, No. 1, 44 pp.

CIE (Commonwealth Institute of Entomology) (1955). *Icerya seychellarum* (Westw.). *Distribution Maps of Insect Pests*, *Series A, Map No. 52*. London, UK: Commonwealth Agricultural Bureaux, 2 pp.

CIE (Commonwealth Institute of Entomology) (1961). *Toxoptera aurantii* (Boy.). *Distribution Maps of Pests*, *Series A (Agricultural), Map No. 131*. London, UK: Commonwealth Agricultural Bureaux, 2 pp.

CIE (Commonwealth Institute of Entomology) (1966). *Aspidiotus destructor* Sign. *Distribution Maps of Pests*, *Series A (Agricultural), Map No. 218*. London, UK: Commonwealth Agricultural Bureaux, 2 pp.

CMI (Commonwealth Mycological Institute) (1985). *Botryodiplodia theobromae* Pat. *Distribution Maps of Plant Diseases, Map No. 561 (edition 1)*. Kew, Surrey, UK: Commonwealth Agricultural Bureaux, 2 pp.

Colbran, R.C. (1955). A preliminary survey of plant nematodes in Queensland. *Journal of the Australian Institute of Agricultural Science* 21: 167-169.

Common, I.F.B. (1990). *Moths of Australia*. Carlton, Australia: Melbourne University Press 535 pp.

Davidson, J.K. (1990). The genetic architecture of cold tolerance in natural populations of *Drosophila melanogaster* and *D. simulans*. *Australian Journal of*

Zoology 38(2): 163-171.

DOA (Department of Agriculture, Thailand) (2000). Information on pests of mangosteen in Thailand. Bangkok, Thailand: Department of Agriculture.

Drew, R.A.I. and Romig, M.C. (1996). Overview – Tephritidae in the Pacific and southeast Asia. In: Allwood, A.J. and Drew, R.A.I. (eds). *Management of Fruit Flies in the Pacific*. ACIAR Proceedings No. 76. Canberra, Australia: Australian Centre for International Agricultural Research (ACIAR), pp. 46-53.

Evenhuis, N.L. (ed.). (1989). *Catalog of the Diptera of the Australasian and Oceanian Regions*. Bishop Museum Special Publication 86. Honolulu, Hawaii and Leiden, Netherlands: Bishop Museum Press and E.J. Brill, 1155 pp.

Giatgong, P. (1980). *Host Index of Plant Diseases in Thailand (2nd edition)*. Mycology Branch Plant Pathology and Microbiology Division. Bangkok, Thailand: Department of Agriculture, Ministry of Agriculture and Cooperatives, 124 pp.

Halliday, R.B. (1998). Mites of Australia: A Checklist and Bibliography. *Monographs on Invertebrate Taxonomy. Volume 5*. Collingwood, Australia: CSIRO Publishing, 317 pp.

ICDB (Insect Collection Database) (2002). Insect Collection Database or Insect Reference Collection. Agriculture Western Australia.

IIE (International Institute of Entomology) (1986). *Scirtothrips dorsalis* Hood. *Distribution Maps of Pests, Series A (Agricultural), Map No. 475*. Wallingford, UK: CAB International, 2 pp.

IIE (International Institute of Entomology) (1994). *Bactrocera dorsalis* (Hendel). *Distribution Maps of Pests, Series A, Map No. 109 (3rd revision)*. Wallingford, UK: CAB International, 3 pp.

IIE (International Institute of Entomology) (1995). *Phyllocnistis citrella* Stainton. *Distribution Maps of Pests, Series A, Map No. 274 (2nd revision)*. Wallingford, UK: CAB International, 4 pp.

IIE (International Institute of Entomology) (1996). *Tetranychus urticae* Koch. *Distribution Maps of Pests, Series A, Map No. 562*. Wallingford, UK: CAB International, 6 pp.

IMI (International Mycological Institute) (1996). *Corticium salmonicolor* Berk. & Broome. *Distribution Maps of Plant Diseases, Map No. 122 (edition 5)*. Wallingford, UK: CAB International, 4 pp.

Johnson, P.R. and Parr, D. (1999). Mango growing in Western Australia. *Bulletin No. 4348, Agriculture Western Australia*.

Jumroenma, K., Sudhi-Aromna, S., Namruangsri, W. and Poonnachit, U. (2000). The problem of young leaf eating caterpillar and approach appropriate control on mangosteen. In: *The Twelfth Entomology and Zoology Division Conference 2000*. Bangkok, Thailand: Department of Agriculture, p. 60.

Khanmalee, S. (1965). Anthracnose of Mangosteens. Thesis for Bachelor of Science. Bangkok, Thailand: Kasetsart University, p. 39.

Leach, P.L. (1997). Determination the susceptibility of mangosteen, *Garcinia mangostana* L., to infestation by papaya fruit fly, *Bactrocera papayae* Drew and Hancock (Diptera: Tephritidae). An internal report for consideration by the Interstate Plant Health Regulatory Working Group. Brisbane, Australia: Queensland Department of Primary Industries, 5 pp.

Lim, T.K. and Sangchote, S. (2003). Diseases of Mangosteen. In: Ploetz, R.C. (ed.). *Diseases of Tropical Fruit*. Wallingford, UK: CAB International, pp. 365-372.

Meagher, J.W. (1969). Nematodes as a factor in citrus production in Australia. *Proceedings of the First International Citrus Symposium, Riverside, California* 2, pp. 999-1006.

McLeod, R., Reay, F. and Smyth, J. (1994). Plant nematodes of Australia listed by plant and by genus. Orange, Australia: NSW Agriculture, 201 pp.

Miyasaki, M., Kudo, I. and Iqbal, A. (1984). Notes on the thrips (Thysanoptera) occurring on the soybean in Java. *Kontyu, Tokyo* 52(4): 482-486.

Morton, J.F. (1987). Mangosteen. In: *Fruits of Warm Climates*. Miami Florida, USA: Julia F. Morton, pp. 301-304.

Moulden, J. (2002). A thrips survey of mango flowers in the Ord River Irrigation Area. Personal communication. Department of Agriculture, Western Australia.

Mound, L.A (1996). Thysanoptera. In: Wells, A. (ed.). *Zoological Catalogue of Australia. Volume 26*. Psocoptera, Phthiraptera, Thysanoptera. Melbourne, Australia: CSIRO Publishing, pp. 249-332, 333-337 (App. I-III), 397-414 (Index).

Nielsen, E.S., Edwards, E.D. and Rangsi, T.V. (eds). (1996). Checklist of the Lepidoptera of Australia. *Monographs on Australian Lepidoptera. Volume 4*. Melbourne, Australia: CSIRO Australia, 529 pp.

Okada, T. (1977). Family Drosophilidae. In: Delfinado, M.D. and Hardy, D.E. (eds). *A Catalog of the Diptera of the Oriental Region. Volume III. Suborder Cyclorrhapha (excluding division Aschiza)*. Honolulu, Hawaii, USA: University Press of Hawaii, pp. 342-387.

Ooi, P.A.C., Winotai, A. and Peña, J.E. (2002). Pests of minor tropical fruits. In: Peña, J., Sharp, J. and Wysoki, J. (eds). *Tropical Fruit Pests and Pollinators: Biology, Economic Importance, Natural Enemies and Control*. Wallingford, UK: CAB International, pp. 315-330.

Pienpuck, K. and Choobumroong, V. (1988). Pre harvest diseases of export fruit. *Annual Report. Plant Pathology and Microbiology Division*. Bangkok, Thailand: Department of Agriculture, pp. 96-105. (In Thai).

Reyes, C.P. (1994). Thysanoptera (Hexapoda) of the Philippine Islands. *The Raffles Bulletin of Zoology* 42(2): 239-241.

Sangchote, S. and Pongpisutta, R. (1998). Fruit rots of mangosteen and their control. Paper abstracts presented at the 7th International Congress of Plant Pathology, held in Edinburgh, Scotland 9-16 August 1998. ICPP 98 Abstracts. http://www.bspp.org.uk/icpp98/

Shattuck, S.O. and Barnett, N.J. (2001). Australian Ants Online. The Guide to the Australian Ant Fauna. http://www.ento.csiro.au/science/ants/default.htm

Shivas, R.G. (1989). Fungal and bacterial diseases of plants in Western Australia. *Journal of the Royal Society of Western Australia* 72(1-2): 1-62.

Smith, D., Beattie, G.A.C. and Broadley, R. (1997). *Citrus Pests and their Natural Enemies: Integrated Pest Management in Australia*. Information Series QI97030. Brisbane, Australia: Queensland Department of Primary Industries and Horticultural Research and Development Corporation, 263 pp.

Sudhi-Aromna, S. (2002). Personal communication.

Strassen, R. zur and Harten, A. van (1984). Gelbschhalenfaenge von Fransenflüglern aus Katoffelkulturen in Bangladesh (Insecta: Thysanoptera). *Senckenbergiana Biologica* 65(1-2): 75-95. (In German).

Sweetingham, M.W., Cowling, W.A., Buirchell, B.J., Brown, A.G.P. and Shivas, R.G. (1995). Anthracnose of lupins in Western Australia. *Australasian Plant Pathology* 24(4): 271.

Waterhouse, D.F. (1993). *The Major Arthropod Pests and Weeds of Agriculture in Southeast Asia*. ACIAR Monograph No. 21. Canberra, Australia: Australian Centre for International Agricultural Research (ACIAR), 141 pp.

Williams, D.J. (1985). *Australian Mealybugs*. London, UK: British Museum (Natural History), 431 pp.

Wilson, G.G. (1991). Notes on *Phyllocnistis citrella* Stainton (Lepidoptera: Phyllocnistinae) attacking four citrus varieties in Darwin. *Journal of the Australian Entomological Society* 30: 77-78.

Wisalthanon, N. and Jermsiri, J. (1998). Fruit tree diseases. *Technical Information, Analysis and Service Section. Agriculture Research and Development Centre No. 6*. Bangkok, Thailand: Department of Agriculture, p. 74. (In Thai).

Woods, W. (1995). Citrus leafminer. *Farmnote, Agriculture Western Australia*.

Worthen, W.B. (1996). Latitudinal variation in developmental time and mass in *Drosophila melanogaster*. *Evolution* 50(6): 2523-2529.

Yunus, A. and Ho, T.H. (1980). List of Economic Pests, Host Plants, Parasites and Predators in West Malaysia (1920-1978). *Ministry of Agriculture Malaysia, Bulletin No. 153*, 538 pp.

APPENDIX 2: POTENTIAL FOR ENTRY, ESTABLISHMENT OR SPREAD AND CONSEQUENCES

Scientific name	**Common name**	**Potential for entry[1], establishment or spread in the PRA area**		**Potential for consequences**		**Consider further?**
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
ARTHROPODS						
Diptera [flies]						
Bactrocera carambolae (Drew & Hancock) [Diptera: Tephritidae]	carambola fruit fly	Feasible	Wide host range (Allwood *et al.*, 1999). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**
Bactrocera dorsalis (Hendel) [Diptera: Tephritidae]	Oriental fruit fly	Feasible	Wide host range (Allwood *et al.*, 1999; Tsuruta *et al.*, 1997). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**
Bactrocera papayae (Drew & Hancock) [Diptera: Tephritidae]	papaya fruit fly	Feasible	Wide host range (Allwood *et al.*, 1999). Dispersed by infected fruit and adult flight (Fletcher, 1989). Strong flyer – adults can fly up to 50-100 km (Fletcher, 1989).	Significant	Primary economic impact would result from quarantine restrictions imposed by important domestic and foreign export markets, rather than from direct yield losses from infested fruit.	**Yes**

[1] Association of the pest with the mangosteen fruit pathway (see Appendix 1) was considered to be sufficient evidence of feasibe potential for entry.

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
Hemiptera [aphids, leafhoppers, mealybugs, psyllids, scales, whiteflies]						
Dysmicoccus neobrevipes Beardsley [Hemiptera: Pseudococcidae]	gray pineapple mealybug	Feasible	Wide host range (Ben-Dov, 1994) and high reproductive rates (Kessing & Mau, 1992). Adults females live an average length of 95-148 days (Ito, 1938; Kessing & Mau, 1992).	Significant	Can infest a wide range of plant species. Therefore, has potential to cause economic damage if introduced. Vector of green spot disease on pineapple leaves (Beardsley, 1993; Kessing & Mau, 1992).	**Yes**
Pseudococcus cryptus Hempel [Hemiptera: Pseudococcidae]	cryptic mealybug	Feasible	Wide host range (Ben-Dov, 1994).	Significant	Can infest a wide range of plant species. Therefore, has potential to cause economic damage if introduced.	**Yes**
Hymenoptera [ants, bees]						
Dolichoderus sp. [Hymenoptera: Formicidae]	black ant	Feasible	This species can establish and spread in the PRA area as the genus is present in Australia (Shattuck & Barnett, 2001). This species is highly adaptive, competitive and a general scavenger.	Significant	This species will compete for resources with native species. Can cause indirect damage through proliferation of honeydew secreting pests, leading to reduction of photosynthesis as a result of sooty mould development.	**Yes**
Technomyrmex butteli Forel [Hymenoptera: Formicidae]	black ant	Feasible	This species can establish and spread in the PRA area as the genus is present in Australia (Shattuck & Barnett, 2001). This species is highly adaptive, competitive and a general scavenger.	Significant	This species will compete for resources with native species. Can cause indirect damage through proliferation of honeydew secreting pests, leading to reduction of photosynthesis as a result of sooty mould development.	**Yes**

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
FUNGI						
Gliocephalotrichum bulbilium Ellis & Hesseltine [Hypocreales: Nectriaceae]	fruit rot	Feasible	Wood rotting fungus commonly found in woody substrates, plant debris, soil, manure, and polluted water (Anon., 2002).	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987).	No
Graphium sp. [Mitosporic fungi: Deuteromycetes]	fruit rot	Feasible	This species can establish and spread in the PRA area as the genus is present in Australia (CAB International, 2002).	Not significant	Causes postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987). The fact that this species has not been identified to species level and has only been reported once in a list of mangosteen diseases indicates its lack of economic importance.	No
Pestalotiopsis flagisetulai Guba [Mitosporic fungi]	leaf spot	Feasible	This species can establish and spread in the PRA area as susceptible hosts are present in Australia.	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest storage rots. Causes postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures	No

Scientific name	Common name	Potential for entry[1], establishment or spread in the PRA area		Potential for consequences		Consider further?
		Feasible/ not feasible	Comments	Significant/ not significant	Comments	
					during packaging, storage and transport (Visarathanonth & Ilag, 1987).	
Phomopsis sp. [Mitosporic fungi]	white pulp rot	Feasible	This species can establish and spread in the PRA area as the genus is present in Australia (CAB International, 2002).	Not significant	Weak pathogen or secondary invader (Sivapalan *et al*., 1998), causing postharvest problems related to injuries caused during harvesting, processing and high humidity and temperatures during packaging, storage and transport (Visarathanonth & Ilag, 1987).	No

References for Appendix 2

Allwood, A.L., Chinajariyawong, A., Drew, R.A.I., Hamacek, E.L., Hancock, D.L., Hengsawad, C., Jipanin, J.C., Jirasurat, M., Kong Krong, C., Kritsaneepaiboon, S., Leong, C.T.S. and Vijaysegaran, S. (1999). Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology, Supplement* 7: 1-92.

Anon. (2002). Mold Inspectors of Nevada, LCC. http://www.moldnv.com/f56.htm

Beardsley, J.W. (1993). The pineapple mealybug complex; taxonomy, distribution and host relationships. *Acta Horticulturae* 334: 383-386.

Ben-Dov, Y. (1994). *A Systematic Catalogue of the Mealybugs of the World (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with Data on Geographical Distribution, Host Plants, Biology and Economic Importance*. Andover, UK: Intercept Limited, 686 pp.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Fletcher, B.S. (1989). Life history strategies of tephritid fruit flies. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and*

Control. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 195-208.

Ito, K. (1938). Studies on the life history of the pineapple mealybug, *Pseudococcus brevipes* (Ckll.). *Journal of Economic Entomology* 31: 291-298.

Kessing, J.L.M. and Mau, R.F.L. (1992). Crop Knowledge Master. *Dysmicoccus neobrevipes* (Beardsley). http://www.extento.hawaii.edu/kbase/crop/Type/d_neobre.htm

Shattuck, S.O. and Barnett, N.J. (2001). Australian Ants Online. The Guide to the Australian Ant Fauna. http://www.ento.csiro.au/science/ants/default.htm

Sivapalan, A., Metussin, R., Hamdan, F. and Zain, R.M. (1998). Fungi associated with postharvest fruit rots of *Durio graveolens* and *D. kutejensis* in Brunei Darussalam. *Australasian Plant Pathology* 27(4): 274-277.

Tsuruta, K., White, I.M., Bandara, H.M.J., Rajapakse, H., Sundaraperuma, S.A.H., Kahawatta, S.B.M.U.C. and Rajapakse, G.B.J.P. (1997). A preliminary notes on the host-plants of fruit flies of the tribe Dacini (Diptera, Tephritidae) in Sri Lanka. *Esakia* 37: 149-160.

Visarathanonth, N. and Ilag, L.L. (1987). Postharvest diseases of rambutan. In: Lam, P.F. and Kosiyachinda, S. (eds). *Rambutan: Fruit development, Postharvest Physiology and Marketing in ASEAN*. Kuala Lumpur, Malaysia: ASEAN Food Handling Bureau, pp. 51-57.

APPENDIX 3: PEST DATASHEETS

3.1 *Bactrocera carambolae* (Drew & Hancock) [Diptera: Tephritidae]

Synonyms and changes in combination: *Bactrocera* sp. near *dorsalis* (A) (Hendel)

Common name(s): Carambola fruit fly.

Host(s): *Bactrocera carambolae* is a serious pest of *Averrhoa carambola* (carambola), however its total host list is extensive. This species is present in Thailand (Drew and Romig, 1996), but has not been reported to infest mangosteen in Thailand, although mangosteen has been reported to be a host by CAB International (2002).

Other recorded commercial hosts are: *Anacardium occidentale* (cashew), *Annona muricata* (soursop), *Arenga pinnata* (sugar palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Artocarpus integer* (chempedak), *Averrhoa bilimbi* (bilimbi), *Capsicum annuum* (bell pepper, capsicum), *Carica papaya* (pawpaw), *Chrysophyllum cainito* (star-apple), *Citrus aurantiifolia* (lime), *Citrus maxima* (pummelo), *Citrus limon* (lemon), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus* × *paradisi* (grapefruit), *Eugenia uniflora* (Brazil cherry), *Fortunella margarita* (oval kumquat), *Garcinia mangostana* (mangosteen), *Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Mangifera indica* (mango), *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Persea americana* (avocado), *Pouteria campechiana* (yellow sapote), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Rhizophora* sp., *Rollinia pulchrinervis*, *Syzygium aqueum* (water apple), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Thevetia peruviana* (yellow oleander) and *Ziziphus jujuba* (jujube) (Allwood *et al*., 1999; CAB International, 2002; Ranganath and Veenakumari, 1995; Ranganath *et al*., 1997; Yong, 1994).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: *B. carambolae* is widely distributed throughout Asia and is present in the Thai/Malay peninsular area. It is found in India (Drew and Hancock, 1994); Indonesia (Drew and Hancock, 1994; White and Hancock, 1997); Malaysia (Drew and Hancock, 1994; White and Hancock, 1997); Singapore (Drew and Hancock, 1994) and Thailand (Drew and Hancock, 1994). In the Western Hemisphere, this species has been recorded from French Guiana (Drew and Hancock, 1994); Guyana (IIE, 1994) and Suriname (Drew and Hancock, 1994).

Biology: The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis, 1985). Eggs of species related to *B. carambolae* are laid below the skin of the host fruit. They 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, 2002). Third instar larvae of *B. carambolae* are medium-sized, 7.5-9.5 mm long and 1.5-2 mm wide (White and Elson-Harris, 1994).

Pupariation is 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 about 60-80% length of larva. Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002). 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. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002).

Adults are predominantly black or dark fuscous, or a balanced mixture of black and yellow. When viewed dorsally, the thorax is predominantly dark with lateral yellow stripes before turning yellow posteriorly. The abdomen is oval in shape or parallel sided, tergites are separate with medial dark stripes (Carrol *et al*., 2002). Adults occur throughout the year and begin mating after about 8-12 days, they may live 1-3 months depending on temperature (up to 12 months in cool conditions) (Christenson and Foote, 1960).

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

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). 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 drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupariation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989).

References:

Allwood, A.L., Chinajariyawong, A., Drew, R.A.I., Hamacek, E.L., Hancock, D.L., Hengsawad, C., Jipanin, J.C., Jirasurat, M., Kong Krong, C., Kritsaneepaiboon, S., Leong, C.T.S. and Vijaysegaran, S. (1999). Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology, Supplement* 7: 1-92.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Carrol, L.E., White, I.M., Friedberg, A., Norrbom, A.L., Dallwitz, M.J. and Thompson, F.C. (2002 onwards). *Pest Fruit Flies of the World: Descriptions, Illustrations, Identification, and Information Retrieval*. Version: 8th August 2002. http://www.sel.barc.usda.gov/Diptera/tephriti/pests/adults/

Christenson, L.D. and Foote, R.H. (1960). Biology of fruit flies. *Annual Review of Entomology* 5: 171-192.

Drew, R.A.I. and Hancock, D.L. (1994). The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research, Supplement* 2: 1-68.

Drew, R.A.I. and Romig, M.C. (1996). Overview – Tephritidae in the Pacific and southeast Asia. In: Allwood, A.J. and Drew, R.A.I. (eds). *Management of Fruit Flies in the Pacific*. ACIAR Proceedings No. 76. Canberra, Australia: Australian Centre for International Agricultural Research (ACIAR), pp. 46-53.

Fletcher, B.S. (1987). The biology of Dacine fruit flies. *Annual Review of Entomology* 32: 115-144.

Fletcher, B.S. (1989). Life history strategies of tephritid fruit flies. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 195-208.

IIE (International Institute of Entomology) (1994). *Bactrocera carambolae* Drew & Hancock. *Distribution Maps of Pests, Series A, Map No. 546*. Wallingford, UK: CAB International, 2 pp.

Margaritis, L.H. (1985). Comparative study of the eggshell of the fruit flies *Dacus oleae* and *Ceratitis capitata* (Diptera: Trypetidae). *Canadian Journal of Zoology* 63(9): 2194-2206.

Ranganath, H.R. and Veenakumari, K. (1995). Notes on the Dacine fruit flies (Diptera: Tephritidae) of Andaman and Nicobar Islands. *The Raffles Bulletin of Zoology* 43: 235-238.

Ranganath, H.R., Suryanarayana, M.A. and Veenakumari, K. (1997). Papaya – a new host record of carambola fruit fly *Bactrocera* (*Bactrocera*) *carambolae* Drew and Hancock. *Insect Environment* 3: 37.

Wharton, R.H. (1989). Classical biological control of fruit-infesting Tephritidae. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 303-313.

White, I.M. and Elson-Harris, M.M. (1994). *Fruit Flies of Economic Significance: Their Identification and Bionomics*. Reprint with addendum. Wallingford, UK: CAB International, 601 pp.

White, I.M. and Hancock, D.L. (1997). The identity of *Trirhithrum nigrum* (Graham) and some new combinations in *Ceratitis* MacLeay (Diptera: Tephritidae). *Entomologist* 116(3-4): 192-197.

Yong, H.S. (1994). Host fruit preferences in two sympatric taxa of the *Bactrocera dorsalis* complex (Insecta: Diptera: Tephritidae). In: Yong, H.S. and Khoo, S.G. (eds). *Current Research on Tropical Fruit Flies and their Management*. Kuala Lumpur, Malaysia: The Working Group on Malaysian Fruit Flies, pp. 1-8.

3.2 *Bactrocera dorsalis* (Hendel, 1912) [Diptera: Tephritidae]

Synonyms and changes in combination: *Bactrocera conformis* Doleschall, 1858; *Bactrocera ferrugineus* Fabricius; *Chaetodacus dorsalis* Hendel; *Chaetodacus ferrugineus* Fabricius; *Chaetodacus ferrugineus dorsalis* Hendel; *Chaetodacus ferrugineus okinawanus* Shiraki, 1933; *Dacus dorsalis* Hendel, 1912; *Dacus ferrugineus* Fabricius; *Dacus ferrugineus dorsalis* Fabricius; *Dacus ferrugineus okinawanus* Shiraki; *Dacus ferrugineus* var. *dorsalis* Fabricius; *Musca ferruginea* Fabricius, 1794; *Strumeta dorsalis* Hendel; *Strumeta ferrugineus* Fabricius.

Common name(s): Oriental fruit fly.

Host(s): *Bactrocera dorsalis* is a very serious pest of a wide variety of fruits and vegetables throughout its range and damage levels can be anything up to 100% of unprotected fruit. In China, where the pest populations are definitely the true *B. dorsalis*, the major hosts are apple, guava, mango, peach and pear (*Pyrus communis*) (X.-J. Wang, unpublished data, 1988, as reported in White and Elson-Harris, 1994). 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, 2002).

Mangosteen has not been listed as a primary or secondary host of *B. dorsalis* in CAB International (2002). 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*. However, in the Californian Department of Food and Agriculture Exotic Fruit Fly Regulatory Response Manual, mangosteen is listed as a typical host of *B. dorsalis* (Hillard and Jordan, 2001).

Recorded commercial hosts are: *Aegle marmelos* (bael fruit), *Anacardium occidentale* (cashew nut), *Annona reticulata* (bullock's heart), *Annona squamosa* (sugar apple), *Areca catechu* (betelnut palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Capsicum annuum* (bell pepper), *Chrysophyllum cainito* (caimito), *Citrus maxima* (pummelo), *Citrus reticulata* (mandarin), *Coffea arabica* (arabica coffee), *Cucumis melo* (melon), *Cucumis sativus* (cucumber), *Dimocarpus longan* (longan), *Ficus racemosa* (cluster fig), *Litchi chinensis* (lychee), *Malus pumila* (apple), *Mangifera foetida* (bachang mango), *Mangifera 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), *Prunus avium* (gean), *Prunus cerasus* (sour cherry), *Prunus domestica* (plum, prune), *Prunus mume* (Japanese apricot), *Prunus persica* (peach), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Pyrus communis* (European pear), *Syzygium aqueum* (water apple), *Syzygium aromaticum* (clove), *Syzygium cumini* (jambolan), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Ziziphus jujuba* (jujube) and *Ziziphus mauritiana* (Chinese date) (Allwood *et al*., 1999; Tsuruta *et al*., 1997).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: The true *Bactrocera 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 (2002) also includes California and Florida, USA, in the distribution because the fly is repeatedly trapped there in small numbers. The distribution of *B. dorsalis* was mapped by IIE (1994). This species is a serious pest of a wide range of fruit crops in Taiwan, southern Japan, China and in the northern areas of the Indian subcontinent, and it has also been established in the Hawaiian Islands since about 1945 (Pemberton, 1946).

In Asia, *B. dorsalis* is recorded from Bangladesh (IIE, 1994); Bhutan (Drew and Hancock, 1994); Cambodia (Drew and Hancock, 1994; Waterhouse, 1993); China (Drew and Hancock, 1994); Guam (Waterhouse, 1993); Hawaii (Drew and Hancock, 1994); Laos (Drew and Hancock, 1994); Myanmar (Drew and Hancock, 1994); Nauru (Waterhouse, 1993) Nepal (Drew and Hancock, 1994); Pakistan (Drew and Hancock, 1994); Sri Lanka (Drew and Hancock, 1994); Thailand (Drew and Hancock, 1994; Waterhouse, 1993) and Vietnam (Drew and Hancock, 1994).

Biology: The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very 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, 2002). Third instar larvae of *B. dorsalis* are medium-sized, length 7.5-10 mm; width 1.5-2 mm (White and Elson-Harris, 1994).

Pupariation is 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 about 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. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002). Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002).

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 about 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 females of *B. dorsalis* is well over 1000 eggs (Fletcher, 1989).

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).

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). 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 drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989). However, Clausen (1978) reviewed the numerous releases that have taken place in Hawaii and these are listed under natural enemies. Clausen (1978) noted that any benefit was almost entirely due to

Fopius arisanus (as *Opius oophilus*) and gave the example of guava fruit attack being reduced from 100 to 22% as a result of reduction in *B. dorsalis* populations through the effects of parasitism. A number of parasitoids were also released in Guam against *B. dorsalis* (Waterhouse, 1993).

Due to difficulties in verifying the identifications of both parasitoids and (in some cases) the fruit fly hosts, no attempt has been made to catalogue all natural enemy records (CAB International, 2002). Major sources are listed in White and Elson-Harris (1994).

References:

Allwood, A.L., Chinajariyawong, A., Drew, R.A.I., Hamacek, E.L., Hancock, D.L., Hengsawad, C., Jipanin, J.C., Jirasurat, M., Kong Krong, C., Kritsaneepaiboon, S., Leong, C.T.S. and Vijaysegaran, S. (1999). Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology, Supplement* 7: 1-92.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Carrol, L.E., White, I.M., Friedberg, A., Norrbom, A.L., Dallwitz, M.J. and Thompson, F.C. (2002 onwards). *Pest Fruit Flies of the World: Descriptions, Illustrations, Identification, and Information Retrieval*. Version: 8th August 2002. http://www.sel.barc.usda.gov/Diptera/tephriti/pests/adults/

Christenson, L.D. and Foote, R.H. (1960). Biology of fruit flies. *Annual Review of Entomology* 5: 171-192.

Clausen, C.P. (1978). Tephritidae (Trypetidae, Trupaneidae). In: Clausen, C.P. (ed.). *Introduced Parasites and Predators of Arthropod Pests and Weeds: A World Review*. Agricultural Handbook, United States Department of Agriculture No. 480, pp. 320-335.

Drew, R.A.I. and Hancock, D.L. (1994). The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research, Supplement* 2: 1-68.

Fletcher, B.S. (1987). The biology of Dacine fruit flies. *Annual Review of Entomology* 32: 115-144.

Fletcher, B.S. (1989). Life history strategies of tephritid fruit flies. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 195-208.

Hillard, J. and Jordan, S. (2001). *Exotic Fruit Fly Regulatory Response Manual*. California Department of Food and Agriculture Plant Health and Pest Prevention Services, Pest Exclusion Branch, United States Department of Agriculture, Animal and Plant Health Inspection Services, Plant Protection and Quarantine. http://www.cdfa.ca.gov./phpps/pe/fruit_fly_manual.htm

IIE (International Institute of Entomology) (1994). *Bactrocera dorsalis* (Hendel). *Distribution Maps of Pests, Series A, Map No. 109 (3rd revision)*. Wallingford, UK: CAB International, 3 pp.

Margaritis, L.H. (1985). Comparative study of the eggshell of the fruit flies *Dacus oleae* and *Ceratitis capitata* (Diptera: Trypetidae). *Canadian Journal of Zoology* 63(9): 2194-2206.

Pemberton, C.E. (1946). A new fruit fly in Hawaii. *Hawaiian Planter's Record* 50: 53-55.

Tsuruta, K., White, I.M., Bandara, H.M.J., Rajapakse, H., Sundaraperuma, S.A.H., Kahawatta, S.B.M.U.C. and Rajapakse, G.B.J.P. (1997). A preliminary notes on the host-plants of fruit flies of the tribe Dacini (Diptera, Tephritidae) in Sri Lanka. *Esakia* 37: 149-160.

Waterhouse, D.F. (1993). *The Major Arthropod Pests and Weeds of Agriculture in Southeast Asia*. ACIAR Monograph No. 21. Canberra, Australia: Australian Centre for International Agricultural Research (ACIAR), 141 pp.

Wharton, R.H. (1989). Classical biological control of fruit-infesting Tephritidae. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 303-313.

White, I.M. and Elson-Harris, M.M. (1994). *Fruit Flies of Economic Significance: Their Identification and Bionomics*. Reprint with addendum. Wallingford, UK: CAB International, 601 pp.

3.3 ***Bactrocera papayae* (Drew & Hancock) [Diptera: Tephritidae]**

Synonyms and changes in combination: *Bactrocera conformis* Doleschall; *Bactrocera* sp. "Malaysian B".

Common name(s): Papaya fruit fly; Asian papaya fruit fly.

Host(s): In Malaysia, this species is a pest of papaya and it also caused heavy attack on mango and ripe (not green) banana (R.A.I. Drew, unpublished data, 1990, as reported by White and Elson-Harris, 1994). This species is present in Thailand (Drew and Romig, 1996), but has not been reported to infest mangosteen in Thailand, although mangosteen has been reported to be a host by CAB International (2002).

Other recorded commercial hosts are: *Anacardium occidentale* (cashew), *Annona glabra* (pond apple), *Annona muricata* (soursop), *Annona reticulata* (bullock's heart), *Annona squamosa* (sugar apple), *Areca catechu* (betelnut palm), *Arenga pinnata* (sugar palm), *Artocarpus altilis* (breadfruit), *Artocarpus heterophyllus* (jackfruit), *Artocarpus integer* (chempedak), *Averrhoa bilimbi* (bilimbi), *Averrhoa carambola* (carambola), *Borassus flabellifer* (fan palm), *Calophyllum inophyllum* (Alexandrian laurel), *Capsicum annuum* (bell pepper, capsicum), *Carica papaya* (pawpaw), *Castanopsis* sp., *Chrysophyllum cainito* (star-apple), *Citrus aurantifolia* (lime), *Citrus limon* (lemon), *Citrus madurensis* (calamondin), *Citrus maxima* (pummelo), *Citrus reticulata* (mandarin), *Citrus sinensis* (navel orange), *Citrus* × *paradisi* (grapefruit), *Clausena lansium* (wampi), C*offea arabica* (arabica coffee), *Coffea canephora* (robusta coffee), *Cucumis sativus* (cucumber), *Diospyros blancoi* (velvet apple), *Eriobotrya japonica* (loquat), *Eugenia uniflora* (Brazil cherry), *Ficus benjamina* (Benjamina fig), *Ficus microcarpa* (Indian laurel tree), *Flacourtia rukam* (rukam), *Fortunella japonica* (round kumquat), *Fortunella margarita* (oval kumquat), *Garcinia mangostana* (mangosteen), *Lycopersicon esculentum* (tomato), *Malpighia glabra* (acerola), *Mangifera foetida* (bachang mango), *Mangifera indica* (mango), *Mangifera odorata*, *Manilkara zapota* (sapodilla), *Mimusops elengi* (Asian bulletwood), *Momordica charantia* (balsam apple), *Morinda citrifolia* (Indian mulberry), *Morus alba* (white mulberry), *Muntingia calabura* (Jamaica cherry), *Musa acuminata* (dwarf banana tree), *Musa balbisiana*, *Musa paradisiaca* (banana, plantain), *Nephelium lappaceum* (rambutan), *Passiflora edulis* (passionfruit), *Passiflora quadrangularis* (giant granadilla), *Passiflora suberosa* (Corky passionflower), *Persea americana* (avocado), *Phaseolus vulgaris* (bean), *Pouteria campechiana* (yellow sapote), *Prunus persica* (peach), *Psidium cattleianum* (strawberry guava), *Psidium guajava* (guava), *Punica granatum* (pomegranate), *Rhizophora* sp., *Rollinia pulchrinervis*, *Solanum incanum* (bitter apple), *Solanum melongena* (aubergine), *Solanum torvum* (devil’s fig), *Spondias cytherea* (ambarella), *Syzygium aqueum* (water apple), *Syzygium jambos* (rose apple), *Syzygium malaccense* (Malay apple), *Syzygium samarangense* (wax apple), *Terminalia catappa* (beach almond), *Theobroma cacao* (cocoa), *Thevetia peruviana* (yellow oleander), *Ziziphus jujuba* (jujube) and *Ziziphus mauritiana* (Chinese date) (Allwood *et al*., 1999; CAB International, 2002; Drew and Hancock, 1994; Hancock *et al*., 2000; Yong, 1994).

Plant part(s) affected: Fruit (CAB International, 2002).

Distribution: *Bactrocera papayae* is a very serious pest in Malaysia and the recent outbreak in north Queensland, Australia caused considerable concern (now eradicated). *B. papayae* is found in Malaysia, the southern (peninsular) area of Thailand and throughout western Indonesia. The distribution of *B. papayae* was mapped by IIE (1994). In Asia, *B. papayae* is recorded from Brunei Darussalam (CAB International, 2002), Christmas Island (Drew and Hancock, 1994); Indonesia (Drew and Hancock, 1994); Malaysia (Drew and Hancock, 1994); Papua New Guinea (CAB International, 2002); Singapore (Drew and Hancock, 1994) and Thailand (Drew and Hancock, 1994).

Biology: No specific details on the biology of *B. papayae* are available.

The eggs of *B. oleae* were described in detail by Margaritis (1985) and those of other species are probably very similar. They are 0.8 mm long, 0.2 mm wide, and white to yellow-white in colour (Margaritis, 1985). Eggs of related species are laid below the skin of the host fruit. These hatch within a day (although delayed up to 20 days in cool conditions) and the larvae feed for another 6-35 days, depending on the season. Eggs are visible to the naked eye (CAB International, 2002). Third instar larvae of *B. papayae* are medium-sized, 7-9 mm long and 1.5-1.8 mm wide (White and

Elson-Harris, 1994).

Pupariation is 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 about 60-80% length of larva. Fruits and growing media are liable to carry pupae of this fruit fly in trade/transport (CAB International, 2002). 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. Other plant parts are not known to carry the pest in trade/transport (CAB International, 2002).

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 (similar to *B. dorsalis*). The abdomen is oval or parallel sided with a mediolateral dark stripe running most of its length (similar to *B. dorsalis*) (Carrol *et al*., 2002). Adults occur throughout the year and begin mating after about 8-12 days, and may live 1-3 months depending on temperature (up to 12 months in cool conditions) (Christenson and Foote, 1960).

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).

Little information is available on the attack time for most fruits but few *Bactrocera* spp. attack prior to ripening (CAB International, 2002). 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 drop from trees can occur (CAB International, 2002).

Control: Fruits (locally grown or samples of fruit imports) should be inspected for puncture marks and any associated necrosis. Suspect fruits should be cut open and checked for larvae. Larval identification is difficult, so if time allows, mature larvae should be transferred to saw dust (or similar dry medium) to allow pupariation. Upon emergence, adult flies must be fed with sugar and water for several days to allow hardening and full colour to develop, before they can be identified (CAB International, 2002). One of the most effective control techniques against fruit flies in general is to wrap fruit, either in newspaper, a paper bag, or in the case of long/thin fruits, a polythene sleeve. This is a simple physical barrier to oviposition but it has to be applied well before the fruit is attacked.

Larvae of *Bactrocera* spp. can be attacked either by parasitoids or by vertebrates eating fruit (either on the tree or as fallen fruit). Parasitoids appear to have little effect on the populations of most fruit flies and Fletcher (1987) noted that 0-30% levels of parasitism are typical. Mortality due to vertebrate fruit consumption can be very high as can puparial mortality in the soil, either due to predation or environmental mortality (White and Elson-Harris, 1994). To date, there are no records of biological control success for any *Bactrocera* or *Dacus* spp. (Wharton, 1989). Laboratory studies have indicated that *B. papayae* can be attacked by the braconid *Diachasmimorpha longicaudata* Ashmead (Petcharat, 1997a) and some field trial of this as a possible biocontrol agent have also been carried out in Thailand (Petcharat, 1997b).

References:

Allwood, A.L., Chinajariyawong, A., Drew, R.A.I., Hamacek, E.L., Hancock, D.L., Hengsawad, C., Jipanin, J.C., Jirasurat, M., Kong Krong, C., Kritsaneepaiboon, S., Leong, C.T.S. and Vijaysegaran, S. (1999). Host plant records for fruit flies (Diptera: Tephritidae) in South East Asia. *The Raffles Bulletin of Zoology, Supplement* 7: 1-92.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Carrol, L.E., White, I.M., Friedberg, A., Norrbom, A.L., Dallwitz, M.J. and Thompson, F.C. (2002 onwards). *Pest Fruit Flies of the World: Descriptions, Illustrations, Identification, and Information Retrieval*. Version: 8th August 2002. http://www.sel.barc.usda.gov/Diptera/tephriti/pests/adults/

Christenson, L.D. and Foote, R.H. (1960). Biology of fruit flies. *Annual Review of Entomology* 5: 171-192.

Drew, R.A.I. and Hancock, D.L. (1994). The *Bactrocera dorsalis* complex of fruit flies (Diptera: Tephritidae: Dacinae) in Asia. *Bulletin of Entomological Research, Supplement* 2: 1-68.

Drew, R.A.I. and Romig, M.C. (1996). Overview – Tephritidae in the Pacific and southeast Asia. In: Allwood, A.J. and Drew, R.A.I. (eds). *Management of Fruit Flies in the Pacific*. ACIAR Proceedings No. 76. Canberra, Australia: Australian Centre for International Agricultural Research (ACIAR), pp. 46-53.

Fletcher, B.S. (1987). The biology of Dacine fruit flies. *Annual Review of Entomology* 32: 115-144.

Fletcher, B.S. (1989). Life history strategies of tephritid fruit flies. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 195-208.

Hancock, D.L., Hamacek, E.L., Lloyd, A.C. and Elson-Harris, M.M. (2000). *The Distribution and Host Plants of Fruit Flies (Diptera: Tephritidae) in Australia*. Information Series QI99067. Brisbane, Australia: Queensland Department of Primary Industries, 75 pp.

IIE (International Institute of Entomology) (1994). *Bactrocera papayae* Drew & Hancock. *Distribution Maps of Pests, Series A, Map No. 547*. Wallingford, UK: CAB International, 2 pp.

Margaritis, L.H. (1985). Comparative study of the eggshell of the fruit flies *Dacus oleae* and *Ceratitis capitata* (Diptera: Trypetidae). *Canadian Journal of Zoology* 63(9): 2194-2206.

Petcharat, J. (1997a). Biology of *Diachasmimorpha longicaudata* Ashmead (Hymenoptera: Braconidae): a larval-pupal parasitoid of the Oriental fruit fly *Bactrocera papayae* Drew &

Hancock. *Kaen Kaset-Khon Kaen Agriculture Journal* 25: 30-35.

Petcharat, J. (1997b). A small-scale field trial on the release of *Diachasmimorpha longicaudata* Ashmead (Hymenoptera: Braconidae) in an attempt to control the fruit fly *Bactrocera papayae* Drew & Hancock (Diptera: Tephritidae) population. *Kaen Kaset-Khon Kaen Agriculture Journal* 25: 62-65.

Wharton, R.H. (1989). Classical biological control of fruit-infesting Tephritidae. In: Robinson, A.S. and Hooper, G. (eds). *Fruit Flies: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 3B. Amsterdam, Netherlands: Elsevier Science Publishers, pp. 303-313.

White, I.M. and Elson-Harris, M.M. (1994). *Fruit Flies of Economic Significance: Their Identification and Bionomics*. Reprint with addendum. Wallingford, UK: CAB International, 601 pp.

Yong, H.S. (1994). Host fruit preferences in two sympatric taxa of the *Bactrocera dorsalis* complex (Insecta: Diptera: Tephritidae). In: Yong, H.S. and Khoo, S.G. (eds). *Current Research on Tropical Fruit Flies and their Management*. Kuala Lumpur, Malaysia: The Working Group on Malaysian Fruit Flies, pp. 1-8.

3.4 *Dolichoderus* sp. (Lund, 1831) [Hymenoptera: Formicidae]

Synonyms and changes in combination for genus: *Hypoclinea* sp. Mayr, 1855; *Acanthoclinea* sp. Wheeler, 1935; *Diceratoclinea* sp. Wheeler, 1935.

Common name(s): Black ant.

Host(s): *Dolichoderus* sp. is found in forested areas, from dry savannah woodlands through mallee, dry sclerophyll and wet sclerophyll, and into rainforests (Shattuck and Barnett, 2001). Host species include *Cordia alliodora* (Longino, 1996); *Garcinia mangostana* (mangosteen) (Sudhi-Aromna, 2002); Fabaceae, *Dioclea* sp., *Goupia glabra*, *Philodendron* sp., *Vochysia* sp., *Xylopia* sp. (Blüthgen *et al*., 2000b); *Guzmania lingulata*, *Tillandsia adpressiflora* (crazy pineapple), *Vriesea procera* and *Vriesea rubra* (Blüthgen *et al*., 2000a).

Plant part(s) affected: *Dolichoderus* sp. roam all over plants in search of honeydew secreted by mealybugs and extra floral nectaries from the plant itself (Delabie, 2001). They are also generalist inhabitants of dead stems and nodes (Longino, 1996).

Distribution: *Dolichoderus* sp. is distributed worldwide except for the Afrotropics and Madagascar (Lund, 1831). The 142 described species and subspecies of *Dolichoderus* occur in southern North America, northern South America, Europe east to the Black Sea, and from India east to Japan, and south to Australia (Shattuck, 1992). Within Australia, there are 22 described species and subspecies. These occur in eastern Queensland from Cape York Peninsula south through eastern New South Wales, Victoria, southern South Australia and southern Western

Australia. The only known Tasmanian population is apparently introduced (Shattuck and Barnett, 2001).

Biology: *Dolichoderus* sp. are medium sized black ants, the worker body length is 3-5 mm. They can be identified by the presence of a weak to well-developed flange (that is sometimes tooth-like) on the underside of the head near the base of the mouthparts. The body is often strongly sculptured and the plates on the underside of the body above the front legs (visible only when the front legs are removed) are expanded and overlapping along the centre-line of the body (Shattuck and Barnett, 2001).

Dolichoderus sp. are often found in small numbers foraging in columns on the ground or on low vegetation and trees. Nesting occurs either in the soil or in the trees. Sometimes plant fibres are used to form coverings over the nest area during construction. During warm weather, some species will move their larvae to the surface of the ground for warmth. Workers generally scavenge and tend Hemiptera in order to collect honeydew as nutrients (Shattuck and Barnett, 2001). Honeydew-producing 'Homoptera' can be seen as an ecological equivalent of plant extra floral nectaries, and the presence of both ants and sap-sucking insects should be understood as a mechanism beneficial to the plant, if trophobiont density remains low (Cushman and Addicott, 1991; Way, 1963; Wood, 1982).

Ants play a vital role in rainforest ecology. They have developed mutual relationships with many types of trees and other plants, some so important that without one another they would not be able to survive. By developing these relationships, both the ants and the plants create an optimal environment for each other in which they can avoid predation, provide protection, and cycle nutrients and waste products with each other. Some plants have even developed ways to provide a habitat and nutrients for ants, which live on them. In turn, the ants protect the plant from herbivores and from certain types of plant diseases (Peck, 2001). Some mobile Homoptera provide an example. The honeydew they secrete collects on the plants surface and generally promotes the formation of large spots of the fungus sooty mould (Carter, 1962; Gullan, 1997; Way, 1963). This can damage the foliage of the plant and reduce the amount of photosynthesis possible. However, the ants that are in a mutualistic relationship with the Homoptera clean up the honeydew and in addition scavenge other sap-sucking insects that could cause further damage to the plant (Paulson, 1998).

Following are examples of *Dolichoderus* species along with their interactions with plants and/or Homopterans. *D. thoracicus* is commonly used throughout Southeast Asia to help control major insect pests of cocoa (Chong, 2001), which include the mirid *Helopeltis theivora* (Khoo and Ho, 1992), the moth *Conopomorpha cramerella* (See and Khoo, 1996) and the fruit borer *Alophia* sp. (Paul *et al*., 1999). *D. thoracicus* has a mutualistic relationship with the mealybug *Cataenococcus hispidus* on the cocoa plant. The ants protect the mealybugs from predators in exchange for nutrients in the form of honeydew, which the mealybugs secrete (Ho and Khoo, 1997). Trophobiosis between *D. bidens* (L.) and the mealybug *Planococcus citri* (Risso) on a cocoa pod occurs at Bahia in Brazil (Delabie, 2001). Several species of the genus *Dolichoderus* living in the

Malaysian Peninsula are known as herdsmen ants because they spend all their life as nomads, migrating together with symbiotic Allomyrmococcini mealybugs, and occasionally tending some Coccidae or Membracidae (Hölldobler and Wilson, 1990; Maschwitz and Dill, 1998; Maschwitz and Hänel, 1985).

Many of the mealybugs tended by *Dolichoderus* sp. are economic pests of crops. For example, *Planococcus citri* is a citrus pest that is also a vector of cocoa swollen shoot virus and has been implicated with the transmission of grapevine leafroll associated virus 3 (GLRaV-3) (Cabaleiro and Segura, 1997). It has also been reported, for the first time, as a vector of banana streak virus and cucumber mosaic virus infecting banana cultivars (*Musa* spp.) in Taiwan (Su *et al*., 1997).

References:

Blüthgen, N., Verhaagh, M., Goitía, W. and Blüthgen, N. (2000a). Ant nests in tank bromeliads – an example of non-specific interaction. *Insectes Sociaux* 47: 313-316.

Blüthgen, N., Verhaagh, M., Goitía, W., Jaffe, K., Morawetz, W. and Barthlott, W. (2000b). How plants shape the ant community in the Amazonian rainforest canopy: the key role of extrafloral nectaries and homopteran honeydew. *Oecologia* 125: 229-240.

Cabaleiro, C. and Segura, A. (1997). Some characteristics of the transmission of grapevine leafroll associated virus 3 by *Planococcus citri* Risso. *European Journal of Plant Pathology* 103: 373-378.

Carter, W. (1962). *Insects in Relation to Plant Disease (2nd edition)*. New York, USA: John Wiley & Sons, 705 pp.

Chong, K. (2001). The management of major insect pests of cocoa in Southeast Asia using *Dolichoderus thoracicus* (Hymenoptera: Formicidae): Current status of research. In: *Proceedings. Incoped 3rd International Seminar 16-17 October, 2000*. Sabah, Malaysia: Kota Kinabalu, pp. 50-53.

Cushman, J.H. and Addicott, J.F. (1991). Conditional interactions in ant-plant-herbivore mutualisms. In: Huxley, C.R. and Cutler, D.F. (eds). *Ant-plant Interactions*. Oxford, UK: Oxford University Press, pp. 92-103.

Delabie, J.H.C. (2001). Trophobiosis between Formicidae and Hemiptera (Sternorrhyncha and Auchenorrhyncha): an overview. *Neotropical Entomology* 30(4): 501-516.

Gullan, P.J. (1997). Relationships with ants. In: Ben-Dov, Y. and Hodgson, C.J. (eds). *Soft Scale Insects: Their Biology, Natural Enemies and Control*. World Crop Pests. Volume 7A. Amsterdam, Netherlands: Elsevier Science, pp. 351-374.

Ho, C.T. and Khoo, K.C. (1997). Partners in biological control of cocoa pests: mutualism between *Dolichoderus thoracicus* (Hymenoptera: Formicidae) and *Cataenococcus hispidus* (Hemiptera: Pseudococcidae). *Bulletin of Entomological Research* 87: 461-470.

Hölldobler, B. and Wilson, E.O. (1990). *The Ants*. Cambridge, Massachusetts, USA: The Belknap Press of Harvard University Press, 732 pp.

Khoo, K.C. and Ho, C.T. (1992). The influence of *Dolichoderus thoracicus* (Hymenoptera: Formicidae) on losses due to *Helopeltis theivora* (Heteroptera: Miridae), black pod disease, and mammalian pests in cocoa in Malaysia. *Bulletin of Entomological Research* 82: 485-491.

Longino, J.T. (1996). Taxonomic characterization of some live-stem inhabiting Azteca (Hymenoptera: Formicidae) in Costa Rica, with special reference to the ants of *Cordia* (Boraginaceae) and *Triplaris* (Polygonaceae). *Journal of Hymenoptera Research* 5: 131-156.

Lund, M. (1831). Lettre sur les habitudes de quelques fourmis de Tay Bresil, Audouin. *Annales des Sciences Naturelles* 23: 113-138.

Maschwitz, U. and Dill, M. (1998). Migrating herdsmen of Mount Kinabalu. *Borneo* 4: 32-41.

Maschwitz, U. and Hänel, H. (1985). The migrating herdsman *Dolichoderus* (*Diabolu*s) *cuspidatu*s: an ant with a novel mode of life. *Behavioural and Ecological Sociobiology* 17: 171-184.

Paul, V.M., Nguyen, T.T.C., Hong, L.W., Sastroutomo, S.S., Caunter, I.G., Ali, J., Yeang, L.K., Vijaysegaran, S. and Sen, Y.H. (1999). Predatory ants in orchards in the Mekong delta of Vietnam. In: *Biological Control in the Tropics: Towards Efficient Biodiversity and Bioresource Management for Effective Biological Control. Proceedings of the Symposium on Biological Control in the Tropics held at MARDI Training Centre, Serdang, Malaysia from 18-19 March, 1999*. Wallingford, UK: CAB International, pp. 118-122.

Paulson, G.S. (1998). Population ecology of *Formica neoclara* (Emery) (Hymenoptera: Formicidae) and its possible role in the biological control of pear psylla, *Cacopsylla pyricola* (Foerster) (Homoptera : Psyllidae). *Recent Research in Developmental Entomology* 2: 113-124.

Peck, A. (2001). *Benefits and Roles of Ant-Plant Mutualism*, Review Article. http://www.colostate.edu/Depts/Entomology/courses/en507/papers_2001/peck.htm

See, Y.A. and Khoo, K.C. (1996). Influence of *Dolichoderus thoracicus* on cocoa pod damage by *Conopomorpha cramerella* in Malaysia. *Bulletin of Entomological Research* 86(4): 467-474.

Shattuck, S.O. (1992). Generic revision of the ant subfamily Dolichoderinae (Hymenoptera: Formicidae). *Sociobiology* 21: 1-181.

Shattuck, S.O. and Barnett, N.J. (2001). Genus *Dolichoderus*. Australian Ants Online. http://www.ento.csiro.au/science/ants/dolichoderinae/dolichoderus/dolichoderus.htm

Su, H.J., Hung, T.H., Wu, M.L., Su, H.J., Hung, T.H. and Wu, M.L. (1997). First report of banana streak virus infecting banana cultivars (*Musa* spp.) in Taiwan. *Plant Disease* 81(5): 550.

Sudhi-Aromna, S. (2002). Personal communication.

Way, M.J. (1963). Mutualism between ants and honeydew-producing Homoptera. *Annual Review of Entomology* 8: 307-344.

Wood, T.K. (1982). Selective factors associated with the evolution of membracid sociality. In: Breed, M.D., Michener, C.D. and Evans, H.E. (eds). *The Biology of Social Insects*. Colorado, USA: Westview Press, Boulder, pp. 175-178.

3.5 *Dysmicoccus neobrevipes* Beardsley, 1959 [Hemiptera: Pseudococcidae]

Synonyms and changes in combination: *Dysmicoccus brevipes* (grey form) (Ito, 1938).

Common name(s): Annona mealybug; gray pineapple mealybug; pineapple grey mealybug.

Host(s): *Acacia farnesiana* (sweet wattle) (Beardsley, 1959); *Acacia koa* (Hawaiian mahogany) (Beardsley, 1959); *Agave sisalana* (sisal agave) (Beardsley, 1959); *Aglaonema treubii* (arum) (Ben-Dov, 1994); *Alpinia purpurata* (red ginger) (Beardsley, 1959); *Ananas comosus* (pineapple) (Ben-Dov, 1994; Williams and Watson, 1988); *Annona muricata* (prickly custard apple) (Williams and Watson, 1988); *Annona reticulata* (custard apple) (Beardsley, 1965); *Arachis hypogaea* (peanut) (Ben-Dov, 1994); *Artocarpus altilis* (breadfruit) (Williams and Watson, 1988); *Barringtonia asiatica* (fish-killer tree) (Beardsley, 1965); *Basella* sp. (Anon., 1979); *Brassavola cordata* (Ben-Dov, 1994); *Cajanus cajan* (pigeon pea) (Ben-Dov, 1994); *Citrus aurantifolia* (lime) (Williams and Watson, 1988); *Citrus limon* (lemon) (Williams and Watson, 1988); *Citrus sinensis* (navel orange) (Ben-Dov, 1994); *Clerodendrum* sp. (fragrant clerodendron) (Ben-Dov, 1994); *Coccoloba* sp. (sea-grape) (Williams and Watson, 1988); *Coccoloba uvifera* (sea-grape) (Williams and Watson, 1988); *Cocos nucifera* (coconut) (Beardsley, 1965); *Codiaeum* sp. (croton) (Ben-Dov, 1994); *Coffea arabica* (arabica coffee) (Williams and Watson, 1988); *Coffea canephora* (robusta coffee) (Williams and Watson, 1988); *Cordia alliodora* (Spanish elm) (Ben-Dov, 1994); *Crescentia alata* (Beardsley, 1965); *Cucurbita maxima* (giant pumpkin) (Williams and Watson, 1988); *Ficus* sp. (fig) (Anon., 1979); *Garcinia mangostana* (mangosteen) (Beardsley, 1965); *Gossypium* sp. (cotton) (Ben-Dov, 1994); *Guettarda speciosa* (Williams and Watson, 1988); *Heliconia latispatha* (Ben-Dov, 1994); *Lycopersicon esculentum* (tomato) (Williams and Watson, 1988); *Machaerium robinifolium* (Ben-Dov, 1994); *Mangifera* sp. (Anon., 1979); *Manilkara zapota* (sapodilla) (Beardsley, 1965); *Messerschmidia argentea* (Beardsley, 1959); *Musa* × *paradisiaca* (banana) (Beardsley, 1965; Williams and Watson, 1988); *Musa* sp. (banana, plantain) (Williams and Watson, 1988); *Nothopanax* sp. (Beardsley, 1959); *Opuntia megacantha* (mission prickly-pear) (Beardsley, 1959); *Pandanus* sp. (screw palm, screwpine) (Beardsley, 1959); *Phaseolus* sp. (bean) (Williams and Watson, 1988); *Philodendron* sp. (Ben-Dov, 1994); *Pipturus argentea* (Beardsley, 1965); *Piscidia piscipula* (fish-poison-tree) (Beardsley, 1965); *Pluchea* sp.

(Anon., 1979); *Plumeria* sp. (frangipani) (Anon., 1979); *Polianthes tuberosa* (tuberose) (Beardsley, 1959); *Portulacaria* sp. (Anon., 1979); *Psidium* sp. (guava) (Anon., 1979); *Punica granatum* (pomegranate) (Ben-Dov, 1994); *Samanea saman* (French tamarind, monkeypod) (Beardsley, 1959); *Solanum melongena* (aubergine, eggplant) (Williams and Watson, 1988); *Tectona grandis* (teak) (Williams and Watson, 1988); *Theobroma cacao* (cocoa) (Williams and Watson, 1988); *Thespesia populnea* (Pacific rosewood, portia tree) (Beardsley, 1959); *Tournefortia argentea* (Williams and Watson, 1988); *Vigna unguiculata* subsp. *sesquipedalis* (asparagus bean, yard-long bean) (Williams and Watson, 1988); *Vitex* sp. (Anon., 1979); *Vitis* sp. (grape, grapevine) (Anon., 1979); *Yucca guatemalensis* (spineless yucca) (Ben-Dov, 1994); *Zea mays* (corn, maize) (Williams and Watson, 1988).

Plant part(s) affected: Developing fruit (pineapple) (Beardsley, 1993); leaf (pineapple) (Ito, 1938); aerial roots, flower, fruit, leaf, stem (Kessing and Mau, 1992).

Distribution: American Samoa (Ben-Dov, 1994; Williams and Watson, 1988); Antigua and Barbuda (Ben-Dov, 1994); Bahamas (Ben-Dov, 1994); Brazil (Ben-Dov, 1994); China (Taiwan (Rohrbach *et al*., 1988)); Colombia (Ben-Dov, 1994); Cook Islands (Williams and Watson, 1988); Costa Rica (Ben-Dov, 1994); Dominican Republic (Ben-Dov *et al*., 2001); Ecuador (Ben-Dov, 1994); El Salvador (Ben-Dov, 1994); Fiji (Beardsley, 1965); Guam (Beardsley, 1965); Guatemala (Ben-Dov, 1994); Haiti (Ben-Dov, 1994); Honduras (Ben-Dov, 1994); Italy (Sicily (Ben-Dov, 1994)); Jamaica (Beardsley, 1965); Kiribati (Williams and Watson, 1988) (Gilbert Islands (Beardsley, 1965)); Marshall Islands (Ben-Dov, 1994); Malaysia (Kessing and Mau, 1992); Mexico (Beardsley, 1965); Micronesia, Federated States of (Kessing and Mau, 1992); Northern Mariana Islands (Rota Island) (Beardsley, 1965); Panama (Ben-Dov, 1994); Peru (Ben-Dov, 1994); Philippines (Beardsley, 1965); Puerto Rico (Vieques Island (Ben-Dov, 1994)); Suriname (Ben-Dov, 1994); Trinidad and Tobago (Ben-Dov, 1994); United States (Florida (Anon., 1979), Hawaiian Islands (Beardsley, 1965)); United States Virgin Islands (Ben-Dov, 1994); Vietnam (Ben-Dov, 1994); Western Samoa (Williams and Watson, 1988).

Biology: *D. neobrevipes* reproduces sexually, and mating must occur for young to be produced (Beardsley, 1965; Ito, 1938; Rohrbach *et al*., 1988). No eggs are laid; the young emerge from the female as fully developed first instar larvae called crawlers. The crawler stage is the primary dispersal stage (Rohrbach *et al*., 1988). Crawlers move about actively for a short period of time, no more than a day, and may be dispersed onto other plants up to several hundred yards by wind (Rohrbach *et al*., 1988). Larvae only feed during the first instar and the early part of the second instar (Kessing and Mau, 1992).

Females undergo three larval stages (moults) before reaching maturity; each larval stage lasts for 11-23 days, 6-20 days and 7-28 days respectively (Kessing and Mau, 1992), or an average of 8-14 days (Ito, 1938). The total larval period varies from 26-52 days, averaging about 35 days (Kessing and Mau, 1992). When the adult female emerges, there is a period of about 25 days before it produces its first larvae (Kessing and Mau, 1992). During this period the female is mated by males. Further mating can take place at any time after the maturation of the female. The female then produces larvae for a period of about 30 days (Kessing and Mau, 1992). Females die about four days after they cease to produce young (Ito, 1938; Kessing and Mau, 1992). Each female can produce up to 350 larvae (Ito, 1938), but there are some that produce up to 1000 young (Kessing and Mau, 1992). Unmated females live for an average length of 148 days, while mated females an average of 95 days (Ito, 1938). Duration of female adult life varies from 48-72 days, averaging about 61 days (Kessing and Mau, 1992). In comparison, males are short lived and live for only 2-7 days (Kessing and Mau, 1992).

Males moult four times before reaching the winged, adult stage; each larval stage lasts for 11-19 days, 7-19 days, 2-7 days and 2-8 days respectively (Kessing and Mau, 1992), or an average of 3-13 days (Ito, 1938). The total larval period varies from 22-53 days (Kessing and Mau, 1992). Feeding is limited to the first and second stages, which together last for about 20 days. The second, third and fourth moults of the male take place inside a waxy cocoon, during a period of about 12 days. When the adult male emerges from this cocoon, it is a fragile insect about 1 mm long, with a pair of membranous wings. It has no mouthparts, and lives for only a few days (Ito, 1938). Winged adult males live for an average length of 37 days (Ito, 1938). The lifespan from first instar to adult death varies from 59-117 days, averaging 90 days (Kessing and Mau, 1992).

Adults appear predominantly grey in colour as their common name implies. In actuality their bodies are brown to greyish-orange, but take on a greyish appearance in combination with the waxy exudation that covers them (Kessing and Mau, 1992). The body is broadly oval and measures about 1/17 inch long by 1/25 inch wide. The back is heavily coated with tiny tufts of white mealy wax. Short filaments of wax extend from around the margin of the entire body. Lateral wax filaments are usually less than one fourth as long as the breadth of the body and those towards the back of the insect are one-half as long as the body.

In pineapple fields in Hawaii, mealybug populations were mostly confined to the actively growing portions of the plant, such as young leaves and developing fruit (Beardsley *et al*., 1982). They are normally found on the aerial parts of its hosts such as leaves, stems, aerial roots, and flower and fruit clusters (Kessing and Mau, 1992). However, mealybug populations declined rapidly as the fruits and foliage approached maturity (Beardsley *et al*., 1982). Following the harvest of the first fruit crop new shoot growth could again support large mealybug populations, and both mealybug and ant populations increased (Beardsley *et al*., 1982). Sustained heavy rain may also cause a decline in ant and mealybug populations, but pest populations can recover after the return of dry weather (Beardsley *et al*., 1982).

In pineapple fields in Hawaii, *D. neobrevipes* is tended by *Pheidole megacephala* (big-headed ant). This ant greatly encourages the mealybug by interfering with their natural enemies, and maintaining the health of the mealybug colony by removing excess honeydew (Beardsley *et al*., 1982). Ants move mealybugs from one plant to another, and control of mealybugs depends on control of the ants (Beardsley *et al*., 1982; Carter, 1973; McEwen *et al*., 1979). The ant that attends and encourages this mealybug, *Pheidole megacephala*, is common in eastern and northern Australia (Shattuck, 1999). However, in the absence of natural enemies and inclement weather, the ants do not move mealybugs from one plant to another and do not cause an increase in mealybug populations (Jahn and Beardsley, 1996). Attempts to use natural enemies to control mealybugs have been unsuccessful unless the ants were also controlled (Rohrbach *et al*., 1988). Infestations of mealybugs and their attendant ants originate along field margins and gradually move inwards. Mealybug wilt spreads from single infested plants to adjacent plants. Cultivation destroys ant populations, and newly-prepared fields are re-invaded slowly from adjacent infested fields. Pesticide treatment around the margins of new plantings would prevent the establishment of new ant populations, and hence prevent the establishment of mealybug populations (Beardsley *et al*., 1982).

D. neobrevipes is the principal vector of pineapple wilt disease (Beardsley, 1965; McEwen *et al*., 1979; Rohrbach *et al*., 1988), which appears to be caused by a virus (Carter, 1963). Pineapple wilt, or mealybug wilt, is the most serious type of damage and is the principal cause of crop failure in Hawaii (Kessing and Mau, 1992). It can cause complete loss of pineapple crops if not controlled (Beardsley, 1993). There are two types of wilt, "quick wilt" and "slow wilt". Both types cause the collapse of roots by the invasion of saprophytic organisms or by drying up (Kessing and Mau, 1992). "Quick wilt" is produced by a short period of feeding by a large colony of mealybugs and is characterized by discolouration of leaves to yellows or reds and the loss of rigidity in leaves (Kessing and Mau, 1992). "Slow wilt" occurs after the development of a large colony of mealybugs and shows fewer colour changes (Kessing and Mau, 1992). Leaves will be covered with mealybug feeding sites, leaf tips are browned, outer leaves droop, and the leaf will be flaccid to the touch (Kessing and Mau, 1992). Pineapple wilt has also been called "edge wilt" because the margins of the field would be affected first and the infection would move inward as the mealybug infestation dispersed. Fortunately, this disease has been controlled for the last three decades by routine ant control (Kessing and Mau, 1992). However, it may once again become prevalent if mealybugs are not continually suppressed by limiting ant populations (Kessing and Mau, 1992).

D. neobrevipes is also implicated as a vector of green spot disease on pineapple leaves (Beardsley, 1993; Carter, 1933; Kessing and Mau, 1992). Green spotting is characterised by the production of welt-like simulations of galls. The galls are produced by a secretion of this mealybug that reacts with the plant tissues (Kessing and Mau, 1992).

References:

Anon. (1979). A mealybug (*Dysmicoccus neobrevipes* Beardsley) - Florida - new continental United States record. *Cooperative Plant Pest Report* 4(5-6): 59-68.

Beardsley, J.W. (1959). On the taxonomy of pineapple mealybugs in Hawaii, with a description of a previously unnamed species (Homoptera: Pseudococcidae) *Proceedings of the Hawaiian Entomological Society* 17: 29-37.

Beardsley, J.W. (1965). Notes on the pineapple mealybug complex, with descriptions of two new species (Homoptera: Pseudococcidae). *Proceedings of the Hawaiian Entomological Society* 19: 55-68.

Beardsley, J.W. (1993). The pineapple mealybug complex; taxonomy, distribution and host relationships. *Acta Horticulturae* 334: 383-386.

Beardsley, J.W. Jr, Su, T.H., McEwen, F.L. and Gerling, D. (1982). Field investigations on the interrelationships of the big-headed ant, the gray pineapple mealybug, and pineapple wilt disease in Hawaii. *Proceedings of the Hawaiian Entomological Society* 24: 51-67.

Ben-Dov, Y. (1994). *A Systematic Catalogue of the Mealybugs of the World (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with Data on Geographical Distribution, Host Plants, Biology and Economic Importance*. Andover, UK: Intercept Limited, 686 pp.

Ben-Dov, Y., Miller, D.R. and Gibson, G.A.P. (2001). ScaleNet. http://www.sel.barc.usda.gov/scalenet/scalenet.htm

Carter, W. (1933). The spotting of pineapple leaves caused by *Pseudococcus brevipes*, the pineapple mealy bug. *Phytopathology* 23: 243-259.

Carter, W. (1963). Mealybug wilt of pineapple; a reappraisal. *Annals of the New York Academy of Sciences* 105: 741-764.

Carter, W. (1973). *Insects in Relation to Plant Disease (2nd edition)*. New York, USA: John Wiley and Sons, pp. 274-308.

Ito, K. (1938). Studies on the life history of the pineapple mealybug, *Pseudococcus brevipes* (Ckll.). *Journal of Economic Entomology* 31: 291-298.

Jahn, G.C. and Beardsley, J.W. (1996). Effects of *Pheidole megacephala* (Hymenoptera: Formicidae) on survival and dispersal of *Dysmicoccus neobrevipes* (Homoptera: Pseudococcidae). *Journal of Economic Entomology* 89: 1124-1129.

Kessing, J.L.M. and Mau, R.F.L. (1992). Crop Knowledge Master. *Dysmicoccus neobrevipes* (Beardsley). http://www.extento.hawaii.edu/kbase/crop/Type/d_neobre.htm

McEwen, F.L., Beardsley, J.W. Jr, Hapai, M. and Su, T.H. (1979). Laboratory tests with candidate insecticides for control of the big-headed ant, *Pheidole megacephala* (Fabricius). *Proceedings of the Hawaiian Entomological Society* 13: 119-123.

Rohrbach, K.G., Beardsley, J.W., German, T.L., Reimer, N.J. and Sanford, W.G. (1988). Mealybug wilt, mealybugs, and ants on pineapple. *Plant Disease* 72: 558-565.

Shattuck, S.O. (1999). Australian Ants: Their Biology and Identification. *Monographs on Invertebrate Taxonomy. Volume 3*. Collingwood, Australia: CSIRO Publishing, 226 pp.

Williams, D.J. and Watson, G.W. (1988). *The Scale Insects of the Tropical South Pacific Region. Part 2. The Mealybugs (Pseudococcidae)*. Wallingford, UK: CAB International, 260 pp.

3.6 *Pseudococcus cryptus* (Hempel, 1918) [Hemiptera: Pseudococcidae]

Synonyms and changes in combination: *Dysmicoccus cryptus* Hempel, 1918; *Pseudococcus citriculus* Green, 1922.

Common name(s): Cryptic mealybug; citriculus mealybug.

Host(s): *Artocarpus altilis* (breadfruit) (Ben-Dov, 1994); *Artocarpus incisa* (breadfruit) (Ben-Dov, 1994); *Artocarpus odoratissimus* (tarap) (Lit, 1997); *Calophyllum inophyllum* (Alexandrian laurel) (Ben-Dov, 1994); *Citrus aurantifolia* (lime) (Ben-Dov, 1994); *Citrus aurantium* (bitter orange) (Ben-Dov, 1994); *Citrus maxima* (pummelo) (Ben-Dov, 1994); *Citrus limon* (lemon) (Ben-Dov, 1994); *Citrus* × *paradisi* (grapefruit) (Ben-Dov, 1994); *Citrus reticulata* (mandarin) (CAB International, 2002); *Citrus reticulata* (mandarin) (Ben-Dov, 1994); *Citrus sinensis* (sweet orange) (Ben-Dov, 1994); *Citrus unshiu* (Satsuma) (CAB International, 2002); *Citrus* sp. (Lit, 1997); *Cocos nucifera* (coconut) (Ben-Dov, 1994); *Coffea arabica* (Arabian coffee) (Ben-Dov, 1994); *Coffea liberica* (Liberian coffee) (Williams and Watson, 1988); *Crinum asiaticum* (Asiatic poison lily) (Ben-Dov, 1994); *Dahlia* sp. (Williams and Granara de Willink, 1992); *Dillenia indica* (elephant-apple) (Ben-Dov, 1994); *Elaeis guineensis* (African oil palm) (Williams and Watson, 1988); *Erythrina* sp. (coral tree) (Ben-Dov, 1994); *Garcinia mangostana* (mangosteen) (Anon., 2000); *Gardenia* sp. (Ben-Dov, 1994); *Heliconia* sp. (Lit, 1997); *Hevea brasiliensis* (rubbertree) (Williams and Watson, 1988); *Ixora* sp. (Lit, 1997); *Mangifera indica* (mango) (Ben-Dov, 1994); *Ocotea pedalifolia* (Stout, 1979); *Osbornia ocdonta* (Lit, 1997); *Pandanus* sp. (screwpine) (Ben-Dov, 1994); *Pandanus upoluensis* (palm) (Ben-Dov, 1994); *Passiflora foetida* (wild passionfruit) (Williams and Watson, 1988); *Persea americana* (avocado) (Ben-Dov, 1994); *Piper methysticum* (kava) (Ben-Dov, 1994); *Plumeria* sp. (frangipani) (Ben-Dov, 1994); *Psidium guajava* (guava) (Williams and Watson, 1988); *Selaginella* sp. (spike moss) (Ben-Dov, 1994).

Plant part(s) affected: Roots of coffee (Santa Cecilia *et al*., 2002). Most mealybug species feed on foliage, flowers, fruits and stems, but some species e.g. *Rhizoecus* feed on roots (Drees and Jackman, 1999).

Distribution: *Pseudococcus cryptus* is widely distributed in South East Asia, tropical Africa, mideastern Mediterranean and South America. However, it is particularly a pest of citrus in Israel, into which it was inadvertently introduced in 1937 (Blumberg *et al*., 1999). Following importation of the encyrtid *Clausenia purpurea* Ishii, the pest was successfully controlled.

Afghanistan (Ben-Dov, 1994); American Samoa (Ben-Dov, 1994); Argentina (Williams and Granara de Willink, 1992); Bangladesh (Varshney, 1992); Brazil (Ben-Dov, 1994); British Indian Ocean Territories (Chagos Archipelago) (Ben-Dov, 1994); China (Hu *et al*., 1992); Costa Rica (Ben-Dov, 1994); El Salvador (Ben-Dov, 1994); India (West Bengal) (Nath, 1972); Iran (Kozár *et al*., 1996); Israel (Ben-Dov, 1994); Japan (Ben-Dov, 1994); Kenya (Ben-Dov, 1994); Mauritius (Ben-Dov, 1994); Micronesia, Federated States of (Ponape Island) (Ben-Dov, 1994); Paraguay (Williams and Granara de Willink, 1992); Philippines (Lit, 1997); Palau (Beardsley, 1966); Sri Lanka (Ben-Dov, 1994); Taiwan (Ben-Dov, 1994); United States (Hawaii) (Ben-Dov, 1994);

United States Virgin Islands (Ben-Dov, 1994); Vietnam (Ben-Dov, 1994); Western Samoa (Williams and Watson, 1988); Zanzibar (Ben-Dov, 1994).

Biology: 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 *Planococcus 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 ¼ 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. About 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). From late summer, they also settle in the navel of oranges. Mealybugs produce honeydew, resulting in heavy growths of sooty mould (Smith *et al*., 1997).

Control: 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* (Moore, 1988); *Cryptanusia luzonica*; *Paraplatycerus citriculus* and *Promuscidea unfasciativentris*; and following predators: *Amblyseius swirskii*; *Brumoides suturalis*; *Chilocorus nigrita*; *Diadiplosis hirticornis*; and *Pseudoscymnus dwipakalpa* (CAB International, 2002).

References:

Anon. (2000). *Research report to increase yield and fruit quality of mangosteen. 1.3 Integrated control of mangosteen pests*. Bangkok, Thailand: Department of Agriculture. (In Thai).

Beardsley, J.W. (1966). Insects of Micronesia. Homoptera: Coccoidea. *Insects of Micronesia* 6: 377-562.

Ben-Dov, Y. (1994). *A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance*. Andover, UK: Intercept Limited, 686 pp.

Blumberg, D., Ben-Dov, Y., Mendel, Z., Hodgson, C. and Porcelli, F. (1999). The citriculus mealybug, *Pseudococcus cryptus* Hempel, and its natural enemies in Israel: history and present situation. Proceedings of the VIII International Symposium on Scale Insect Studies ISSIS-VIII held at Wye (UK) August 31st - September 6th 1998. *Entomologica* 33: 233-242.

CAB International (2002). *Crop Protection Compendium (2002 edition)*. Wallingford, UK: CAB International.

Drees, B.M. and Jackman, J. (1999). *Field Guide to Texas Insects*. Houston, Texas: Gulf Publishing Company. http://insects.tamu.edu/images/insects/fieldguide/bimg118.html

Hu, X., He, J. and Wang, X. (1992). Homoptera: Coccoidea. In: Peng, J., Liu, Y., Zhao, J. *et al*. (eds). *Iconography of Forest Insects in Hunan China*. Hunan Forestry Institute, pp. 176-203.

Kozár, F., Fowjhan, M.A. and Zarrabi, M. (1996). Check-list of Coccoidea and Aleyrodoidea (Homoptera) of Afghanistan and Iran, with additional data to the scale insects of fruit trees in Iran. *Acta Phytopathologica et Entomologica Hungarica* 31: 61-74.

Lit, I.L., Jr. (1997). New records and additional notes on Philippine mealybugs (Pseudococcidae, Coccoidea, Hemiptera). *Philippine Entomologist* 11(1): 33-48.

Moore, D. (1988). Agents used for biological control of mealybugs (Pseudococcidae). *Biocontrol News & Information* 9(4): 209-225.

Nath, K. (1972). Studies on the citrus inhabiting coccids (Coccoidea: Hemiptera) of Darjeeling District, West Bengal. *Bulletin of Entomology* 13: 1-10.

Santa Cecilia, L.V.C., Reis, P.R. and Souza, J.C. (2002). About the nomenclature of coffee mealybug species in Minas Gerais and Espirito Santo States, Brazil. *Neotropical Entomology* 31(2): 333-334.

Smith, D., Beattie, G.A.C. and Broadley, R. (1997). *Citrus Pests and their Natural Enemies: Integrated Pest Management in Australia*. Information Series QI97030. Brisbane, Australia: Queensland Department of Primary Industries and Horticultural Research and Development Corporation, 263 pp.

Stout, J. (1979). An association of an ant, a mealy bug, and an understorey tree from a Costa Rican rain forest. *Biotropica* 11(4): 309-311.

Varshney, R.K. (1992). A checklist of the scale insects and mealy bugs of South Asia. Part 1. *Records of the Zoological Survey of India, Occasional Paper* 139: 1-152.

Williams, D.J. and Granara de Willink, M.C. (1992). *Mealybugs of Central and South America*. Wallingford, UK: CAB International, 635 pp.

Williams, D.J. and Watson, G.W. (1988). *The Scale Insects of the Tropical South Pacific Region. Part 2. The Mealybugs (Pseudococcidae)*. Wallingford, UK: CAB International, 260 pp.

3.7 *Technomyrmex butteli* (Forel, 1913) [Hymenoptera: Formicidae]

Note: There is very little information regarding the hosts, effect, global distribution, biology and control of the species *Technomyrmex butteli*. Only one reference to this species was found in the literature apart from the work that described *T. butteli*. Wenseleers *et al*. (1998) surveyed many ant species, including *T. butteli*, for infection by the bacterium *Wolbachia*, which may represent a widespread and previously unrecognised party active in the conflicts of interest within social insect colonies.

Synonyms and changes in combination: Not known.

Common name(s): Black ant.

Host(s): *Garcinia mangostana* (mangosteen) (Sudhi-Aromna, 2002).

Workers of *Technomyrmex* sp. commonly forage in houses in search of food and water. They enter through small cracks and, on finding a suitable food source, form distinct trails with many workers travelling between their nest sites and the food source. In general they nest outdoors but will sometimes establish small nests in a suitable location indoors near a well-maintained food supply (Shattuck and Barnett, 2001).

Plant part(s) affected: Damage by ants to agricultural commodities is usually indirect. Mealybugs, aphids, soft scales and whiteflies secrete honeydew, which attracts ants. Ants feed on honeydew, driving away the natural enemies of aphids and scale insects. The pests multiply and inflict damage on the plants (Nechols and Seibert, 1985).

Distribution: *Technomyrmex butteli* was described by Forel from specimens collected in West Malaysia. It has also been found in West Java (Wenseleers *et al*., 1998).

The 89 known species and subspecies of *Technomyrmex* occur from Africa east through southern Asia to Australia, with a single species (with one subspecies) known from Panama. Within Australia, there are seven species and subspecies. These occur along the east coast from Torres Strait south through eastern Queensland, New South Wales, Victoria and Tasmania to Kangaroo Island, South Australia, as well as southern Western Australia and the upper Northern Territory. They are most common in moist, forested habitats (Shattuck and Barnett, 2001).

Biology: *Technomyrmex* workers are general scavengers, foraging on the ground, low vegetation and trees. They nest in the soil with or without a covering, in twigs or branches, under loose bark, and in nests constructed of plant fibres which are attached under leaves or to tree trunks. Some species are known to have worker-like males and queens (Terron, 1972).

Generally eggs of *Technomyrmex* are laid, usually by a queen, in the nest they are protected by workers. They may be fertilized or unfertilised. Eggs are approximately 0.5 mm, white or yellowish ovals (Wheeler, 1910). Young larvae are soft, legless, pale grubs shaped like crook-necked squash (fat and bulbous at the bottom and narrow and curled at the head). Adult ants lick the larvae, and the saliva makes them sticky and easily transported in groups when the colony is disturbed (Wheeler, 1910). Most ant species have four larval stages. The larvae are attended by adults, usually of the worker caste (Hölldobler and Wilson, 1990). Adults are polymorphic i.e. having different body types. Adults of one body type form a social unit called a caste, which is also defined by the role in the community. Queens are usually comparatively large and winged early in life. They are reproductives, laying fertile and unfertile eggs throughout their lives. Males are usually short-lived and function only in reproduction (Victoria and Arnold, 1992). *Technomyrmex* is known to have multiple queen colonies (Shattuck, 2003, pers. comm.). Mating flights are the primary means of colony propagation for *Technomyrmex*, secondarily, satellite nests (or budding) can occur in which a portion of a colony becomes an autonomous unit (Shattuck, 2003, pers. comm.).

Males of *T. albipes* lack wings and are very similar in appearance to workers, a condition in ants referred to as ergatomorphic (Wheeler, 1910). Adult workers are wingless, medium-sized, dull black ants 2-4 mm long (less than ¼-inch) (Huddleston and Fluker, 1968). Adults recently emerged from the pupal stage are paler (Wheeler, 1910). Workers are females, which tend all stages of juvenile ants, construct and maintain nests, and forage for food. Commonly, only individuals of the worker caste are encountered because they are the most numerous and the most likely to be found outside the nest (Victoria and Arnold, 1992).

In a study conducted in Guam, survival of mealybugs was significantly higher when *T. albipes* was present due to decreased parasitisation of the mealybugs by encyrtid wasps and decreased predation by other arthropods. Ants were observed chasing away parasitic wasps and attacking predatory coccinellids by grabbing the beetles's legs (Nechols and Seibert, 1985).

Control: Many external and internal insect and mite parasites of ants live in ant nests. These usually stunt development in the ant. Some wasps and flies lay eggs in worker ants (Wheeler, 1910). The major predators of ant species are often other ant species (Hölldobler and Wilson, 1990). Interspecific competition occurs for ants sharing the same habitat (McGregor and Moxon, 1985). Birds, reptiles, amphibians, arthropods, and mammals, including humans, consume ants (Wheeler, 1910).

References:

Hölldobler, B. and Wilson, E.O. (1990). *The Ants*. Cambridge, Massachusetts, USA: The Belknap Press of Harvard University Press, 732 pp.

Huddleston, E.W. and Fluker, S.S. (1968). Distribution of ant species of Hawaii. *Proceedings of the Hawaiian Entomological Society* 20: 45-69.

McGregor, A.J. and Moxon, J.E. (1985). Potential for biological control of tent building species of ants associated with *Phytophthora palmivora* pod rot of cocoa in Papua New Guinea. *Annals of Applied Biology* 107(2): 271-277.

Nechols, J.R. and Seibert, T.F. (1985). Biological control of the spherical mealybug, *Nipaecoccus vastator* (Homoptera: Pseudococcidae): assessment by ant exclusion. *Environmental*

Entomology 14(1): 45-47.

Shattuck, S.O. (2003). Personal communication.

Shattuck, S.O. and Barnett, N.J. (2001). Genus *Dolichoderus*. In: Australian Ants Online. http://www.ento.csiro.au/science/ants/dolichoderinae/dolichoderus/dolichoderus.htm

Sudhi-Aromna, S. (2002). Personal communication.

Terron, G. (1972). Observations sur les mâles ergatoïdes et les mâles ailés chez une fourmie du genre *Technomyrmex* Mayr (Hym., Formicidae, Dolichoderinae). *Ann. Fac. Sci. Cameroun* 10: 107-120. (In French).

Victoria, L.T. and Arnold, H.H. (1992). Crop Knowledge Master. *Technomyrmex albipes* (Fr. Smith). http://www.extento.hawaii.edu/kbase/crop/Type/technomy.htm

Wenseleers, T., Ito, F., Van Borm, S., Huybrechts, R., Volckaert, F. and Billen, J. (1998). Widespread occurrence of the micro-organism *Wolbachia* in ants. *Proceedings of the Royal Society of London, Series B* 265: 1447-1452.

Wheeler, W.M. (1910). *Ants*. New York, USA: Columbia University Press, 663 pp.