Australian Government

Biosecurity Australia

Final

Review of policy: importation of hop (*Humulus* species) propagative material into Australia

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Cover image: Hop rhizome

www.youcanbrew.com/Garden/Hops/hops_garden.htm; flickr.com/photos/14376476@N00/143097971/

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Acronyms and abbreviations

Term or abbreviation	Definition
ALOP	Appropriate level of protection
APPD	Australian Plant Pest Database (Plant Health Australia)
AQIS	Australian Quarantine and Inspection Service
CABI	CAB International
CMI	Commonwealth Mycological Institute
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
ELISA	Enzyme-linked immunosorbent assay
FAO	Food and Agriculture Organization of the United Nations
IPC	International Phytosanitary Certificate
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IRA	Import Risk Analysis
ISPM	International Standard for Phytosanitary Measures
NPPO	National Plant Protection Organization
NSW	New South Wales
NT	Northern Territory
PCR	Polymerase chain reaction
PEQ	Post-entry quarantine
PRA	Pest risk analysis
Qld.	Queensland
SA	South Australia
SPS	Sanitary and phytosanitary
Tas.	Tasmania
Vic.	Victoria
WA	Western Australia
WTO	World Trade Organisation

Abbreviations of units

Term or abbreviation	Definition
°C	Degree Celsius
°F	Degree Fahrenheit
RH	Relative humidity (expressed as a percentage)
km	Kilometre
LT_{50}s	Time taken for 50% mortality of a population
m	Metre
mm	Millimetre

Summary

Australia initiated a qualitative pathway-initiated pest risk assessment following a request from industry to develop import conditions for propagative material of *Humulus* species and their cultivars, so that new germplasm can be introduced into Australia.

Australia's established policy for the importation of hop was suspended due to disease concerns in 2004 pending the outcome of a pest risk analysis. All consignments of hop propagative material (dormant rhizomes only) imported prior to 2004 were subjected to mandatory on-arrival inspection, fumigation and growth in closed government post entry quarantine (PEQ) facility with pathogen screening.

This review has identified insect pests and pathogens of quarantine concern associated with hop propagative material (soil free dormant rhizomes, foliage free dormant cuttings, tissue cultures and seed for sowing) and recommended quarantine measures to manage the risks. The recommended risk management measures are based on tiered safeguards. This process ensures that if one mitigating measure fails, other safeguards exist to ensure that the risk is progressively reduced and managed.

Biosecurity Australia considers that the risk management measures recommended in this final PRA report will achieve Australia's appropriate level of protection (ALOP) against identified pests. Specifically, the recommended risk management measures for the different propagative materials are:

Soil free dormant rhizomes and foliage free dormant cuttings

- On-arrival inspection and fumigation, hot water treatment (50 °C for 30 minutes), surface sterilisation (1% NaOCl for 10 minutes), growth in closed government PEQ facilities of new mother plants at 15–25 °C for a minimum period of six months for visual observation; and
- Molecular testing techniques including polymerase chain reaction (PCR) test for fungal pathogens, herbaceous indexing and enzyme-linked immunosorbent assay (ELISA) and/or PCR test for viruses and viroids and generic nested primer PCR test for the phytoplasma.

Seed for sowing

- Hot water treatment (50 °C for 30 minutes), surface sterilisation (1% NaOCl for 10 minutes); fungicidal treatment and growth in closed government PEQ facilities at 15–25 °C for a minimum period of six months; and
- Molecular testing techniques including PCR test for fungal pathogens, herbaceous indexing and ELISA and/or PCR test for viruses.

Tissue culture

- Growth in closed government PEQ facilities at 15–25 °C for a minimum period of six months for visual observation; and
- Herbaceous indexing, laboratory assay and molecular testing techniques including ELISA and/or PCR test for fungi, viruses and viroids and generic nested primer PCR for the phytoplasma.

Biosecurity Australia has made several changes following consideration of stakeholder comments on the Draft review of policy: importation of hop (*Humulus* species) propagative material into Australia. These changes include:

- The correction of the taxonomy for '*Candidatus* Liberibacter asteris'. The draft policy referred to the species as '*Candidatus* Liberibacter asteris' which is incorrect; the text has now been updated to correctly reflect its current accepted name which is '*Candidatus* Phytoplasma asteris'.
- Clarification that pathogen screening for imported seed is only required for those pathogens which have been indentified to be seed-borne.
- Inclusion of additional laboratory assay for *Podosphaera macularis* and *Pseudoperonospora humuli* in tissue culture imports due to the inability of these species to be detected in artificial media through visual inspection.

1 Introduction

1.1 Australia's biosecurity policy framework

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

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

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

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

More information about Australia's biosecurity framework is provided in the *Import Risk Analysis Handbook 2007* (update 2009) located on the Biosecurity Australia website www.daff.gov.au/ba.

1.2 This review of existing policy

Propagative material represents one of the highest plant quarantine risks, as it can harbour various forms of pathogens and arthropod pests. Many pests have been introduced to new locations on propagative material. The introduction of plant pathogens, especially pathogens with latent infection, is of particular concern in propagative material. A range of exotic arthropod pests and pathogens can be introduced and established via propagative material when imported in a viable state for ongoing propagation purposes.

1.2.1 Background

Australia had an established policy for the importation of *Humulus* propagative material which allowed the importation of hop propagative material through the State Government

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

PEQ facility in Tasmania. The phytosanitary conditions included on-arrival inspection, on-arrival methyl bromide fumigation and growth in post-entry quarantine (PEQ) at a government station for a minimum period of nine months for fungal disease and virus screening. Due to disease concerns, the import conditions were suspended by AQIS in 2004 pending the outcome of a pest risk assessment. Subsequently, industry requested Biosecurity Australia to review the import conditions for propagative material of *Humulus* cultivars, so that new germplasm can be introduced into Australia.

1.2.2 Scope

Humulus propagative material could be imported as dormant rhizomes, dormant cuttings, tissue culture or seed for sowing. Whole plants of *Humulus* were previously not allowed entry into Australia due to the significantly higher risk in comparison to other types of nursery stock commodities so whole plants are not considered in this review. The scope of this review is limited to the biosecurity risks associated with the importation of the following propagative material from all sources:

- Dormant rhizome free from soil and foliage;
- Dormant cuttings free from foliage;
- Tissue culture and
- Seed

By limiting the scope of the pest risk analysis (PRA) to propagative material free from soil and foliage, the risk of arthropod pests, nematodes and pathogens associated with soil and leaves is minimised.

The PRA proposes phytosanitary measures for the quarantine pests that have an unrestricted risk above Australia's appropriate level of protection (ALOP).

1.2.3 Import policy for *Humulus* propagative material

Currently, there are no import conditions for *Humulus* species propagative material on the AQIS Import Conditions (ICON) Database. Prior to the suspension of the import policy for hop, importation of hop propagative material generally only occurred through the state government PEQ facility in Tasmania.

All consignments of hop nursery stock imported prior to 2004 were subjected to quarantine/biosecurity measures set out in the import conditions for *Humulus* nursery stock and Condition C7300 'General Import requirements, nursery stock for all species'.

The general requirements include:

- an AQIS import permit
- freedom from regulated articles including soil, disease symptoms and other extraneous contamination of quarantine concern
- on-arrival inspection
- mandatory methyl bromide fumigation
- growth under closed quarantine, at a Government post-entry quarantine facility with pathogen screening.

2 Method for pest risk analysis

Biosecurity Australia has conducted this pest risk analysis (PRA) in accordance with the International Standards for Phytosanitary Measures (ISPMs), including ISPM 2: *Framework for pest risk analysis* (FAO 2007) and ISPM 11: *Pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms* (FAO 2004). The standards provide a broad rationale for the analysis of the scientific evidence to be taken into consideration when identifying and assessing the risk posed by quarantine pests.

Following ISPM 11, this pest risk analysis process comprises three discrete stages:

- Stage 1: Initiation
- Stage 2: Pest Risk Assessment
- Stage 3: Pest Risk Management

Phytosanitary terms used in this PRA are defined in ISPM 5 (FAO 2009).

2.1 Stage 1: Initiation

The *initiation* of risk analysis involves the identification of the pest(s) and pathway(s) that are of quarantine concern and should be considered for risk analysis in relation to the identified PRA area.

The initiation point for this pest risk analysis was a request from Australian industry to import new *Humulus* genetic material from all sources for propagation into Australia.

For this PRA, the 'PRA area' is defined as Australia for pests that are absent from Australia or of limited distribution and under official control in Australia.

In the context of this PRA, *Humulus* propagative material (dormant rhizomes, dormant cuttings, seed for sowing and tissue culture) is a potential import 'pathway' by which a pest can enter Australia.

- **Dormant rhizomes** free from foliage and soil will minimize the risk of introduction of foliage feeders and stem associated pests, and also minimise the risk of introduction of fungal pathogens associated with foliage. However, dormant rhizome provides an import pathway for some arthropod pests, nematodes and pathogens.
- **Dormant cuttings** free form foliage will minimize the risk of introduction of foliage feeders, fungal pathogens associated with foliage and nematodes. However, cuttings provide an import pathway for stem associated pests and pathogens.
- **Tissue cultures** represent an inherently lower risk than most other forms of nursery stock (e.g. rhizome and cuttings). However, many pathogens are capable of surviving the tissue culturing process and therefore tissue cultures provide an import pathway for phytoplasma, viruses and viroids.
- **Seed** provides an import pathway for seed-associated pathogens.
  - Seed pathogens have evolved many different types of associations with their hosts. These associations span a continuum of relationships ranging from passive hitchhiking on seed coats to infecting embryonic tissue (Elmer 2001).

Therefore, a list of pests associated with *Humulus* species was developed. This information is set out in Appendix A and forms the basis of the pest categorisation (see section 2.2.1).

2.2 Stage 2: Pest Risk Assessment

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

This is a qualitative, commodity-initiated pest risk analysis and expresses risk in terms such as high, moderate or low. In a qualitative assessment, risk is estimated through a standard set of factors that contribute to introduction, establishment success, spread or economic impact potential. Risk assessment evaluates the unrestricted pest risk to determine if the risk is sufficient to warrant mitigation (management). The purpose is to determine what biological or economic consequences might occur, and what the likelihood is of their occurrence.

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

2.2.1 Pest categorisation

Pest categorisation is a process to examine, for each pest identified in Stage 1 (*Initiation of the PRA process*), whether the criteria for a quarantine pest are satisfied. The process of pest categorisation is summarised by ISPM 11 (FAO 2004) as a screening procedure based on the following criteria:

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

The objective of pest categorisation is, therefore, to screen a large list of potential quarantine pests, before the more in-depth examinations within the risk assessment is undertaken. Appendix A lists the pests associated with *Humulus* species. This list identifies the pathway association and a comparison of the pests recorded on *Humulus* species and their status in Australia (present or absent, or present but with a limited distribution and under official control), their potential to establish or spread, and their potential for economic consequences. The results of the pest categorisation are set out in Appendix A. The quarantine pests identified during the pest categorisation were carried forward for pest risk assessment and are listed in Table 3.1.

2.2.2 Assessment of the probability of entry, establishment and spread

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

In the case of propagative material imports, the concepts of entry, establishment and spread have to be considered differently. Propagative material intended for ongoing propagation purposes is deliberately introduced, distributed and aided to establish and spread. This material will enter and then be maintained in an intended habitat, potentially in substantial numbers and for an indeterminate period. Significant resources are utilised to ensure the continued welfare of imported propagative material. Therefore, the introduction and establishment of plants from imported propagative material in essence establishes the pests and pathogens associated with the propagative material. Pathogens, in particular, may not

need to leave the host to complete their life cycles, further enabling them to establish in the PRA area. Furthermore, propagative material is expected to be shipped at moderate temperatures and humidity which is unlikely to adversely affect any pest that is present during shipment.

For the purposes of this PRA, *Humulus* propagative material is assumed to come from areas where these pests specifically occur and no phytosanitary measures have been applied. Therefore, these pests will enter into the PRA area. Plants for planting imported into the PRA area will be very widely distributed to production nurseries. Movement of pests associated with imported propagative material in the nursery trade is considered the primary means for long-distance dispersal of these pests. These pests could cause loss or damage to hosts plants in the PRA area.

In its qualitative PRAs, Biosecurity Australia uses the term 'likelihood' for the descriptors it uses for its estimates of probability of entry, establishment and spread. Qualitative likelihoods are assigned to the probability of entry (comprising an importation step and a distribution step), the probability of establishment and the probability of spread. Six descriptors are used: high; moderate; low; very low; extremely low; and negligible. Descriptive definitions for these descriptors and their indicative probability ranges are given in Table 2.1.

Table 2.1: Nomenclature for qualitative likelihoods

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

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

Table 2.2: Matrix of rules for combining descriptive likelihoods

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

2.2.3 Assessment of potential consequences

The objective of the consequence assessment is to provide a structured and transparent analysis of the likely consequences if the pests were to enter, establish and spread in Australia. The assessment considers direct and indirect pest effects and their economic and environmental consequences. Considered together, these assessments and evaluations constitute a 'risk assessment' for each relevant quarantine pest.

The basic requirements for the assessment of consequences are described in the SPS Agreement, in particular Article 5.3 and Annex A. Further detail on assessing consequences is given in the "potential economic consequences" section of ISPM 11 (FAO 2004). This ISPM separates the consequences into "direct" and "indirect" and provides examples of factors to consider within each. In this PRA, the term "consequence" is used to reflect the "relevant economic factors"/"associated potential biological and economic consequences" and "potential economic consequences" terms as used in the SPS Agreement and ISPM 11 (FAO 2004), respectively.

The direct and indirect consequences were estimated over four geographic levels, defined as:

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

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

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

The estimates of the magnitude of the potential consequences over the four geographic levels were translated into a qualitative impact score (A–G)[2] using Table 2.3[3]. For example, a

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

consequence with a magnitude of 'significant' at the 'district' level will have a consequence impact score of D.

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

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

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

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

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

2.2.4 Estimation of the unrestricted risk

The unrestricted risk estimate for each pest is determined by combining the likelihood estimates of entry, of establishment and of spread with the overall potential consequences. This is done using the risk estimation matrix shown in Table 2.5. The cells of this matrix describe the product of likelihood of entry, establishment or spread and consequences of entry, establishment or spread.

[3] The decision rules for determining the consequence impact score are presented in a simpler form in Table 2.3 from earlier IRAs, to make the table easier to use. The outcome of the decision rules is the same as the previous table and makes no difference to the final impact score.

Table 2.5: Risk estimation matrix

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

Consequences of pest entry, establishment and spread

2.2.5 Australia's appropriate level of protection (ALOP)

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

Australia expresses its ALOP in qualitative terms. Australia's ALOP, which reflects community expectations through government policy, is currently expressed as providing a high level of sanitary or phytosanitary protection aimed at reducing risk to a very low level, but not to zero. The band of cells in Table 2.5 marked 'very low risk' represents Australia's ALOP.

2.3 Stage 3: Pest Risk Management

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

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

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

Examples given of measures commonly applied to traded commodities include:

- options for consignments – e.g., inspection or testing for freedom from pests, prohibition of parts of the host, a pre-entry or post-entry quarantine system, specified conditions on

preparation of the consignment, specified treatment of the consignment, restrictions on end-use, distribution and periods of entry of the commodity

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

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

3 Pest risk assessment for quarantine pests

Pest risk assessments are presented in this section for the pests associated with hop propagative material that were found to be quarantine pests for Australia in the categorisation process (Appendix A). Pest risk assessment was done to determine whether the risk posed by a pest exceeds Australia's ALOP and thus whether phytosanitary measures are required to manage the risk.

The quarantine pests for hop propagative material identified during pest categorisation are listed in Table 3.1. Full details of pest categorisation are given in Appendix A.

Table 3.1 Quarantine pests for *Humulus* propagative material

Pest Type	Common name
ARTHROPODS	
COLEOPTERA	
Prionus californicus (Motschulsky)	California prionus
LEPIDOPTERA	
Grapholita delineana Walker	Hemp borer
Hydraecia micacea Esper	Rosy rustic moth
Hydraecia immanis Guenée	Hop vine borer
Ostrinia nubilalis (Hübner)	European corn borer
PATHOGENS	
FUNGI	
Podosphaera macularis (Wallr.) U. Braun & S. Takam.	Hop powdery mildew
Pseudoperonospora humuli (Miyabe & Takah.) G.W. Wilson	Hop downy mildew
Verticillium albo-atrum Reinke & Berthold (hop strain)	Hop wilt
Verticillium dahliae Kleb. (hop strain)	
PHYTOPLASMAS	
'Candidatus Phytoplasma asteris'	Hop shoot proliferation disease
VIROIDS	
Apple fruit crinkle apscaviroid (AFCVd) (hop strain)	Apple fruit crinkle disease
Hop stunt hostuviroid (HpSVd) (hop strain)	Hop stunt disease
VIRUSES	
Alfalfa mosaic virus (AMV) (hop strain)	Alfalfa mosaic
American hop latent virus (AHLV)	Hop latent disease
Arabis mosaic virus (ArMV) (hop strain)	Hop bare-bine
Cherry leaf roll virus (CLRV)	Cherry leaf roll virus
Humulus japonicus latent virus (HJLV)	Humulus japonicus latent disease
Petunia asteroid mosaic virus (PetAMV)	Petunia steroid mosaic disease
Strawberry latent ringspot virus (SLRSV)	Strawberry latent ringspot virus
Tobacco necrosis virus (hop isolate)	Tobacco necrosis disease
NEMATODES	
Ditylenchus destructor Thorne	Potato tuber nematode
Heterodera humuli Filipjev	Hop cyst nematode

3.1 Prionus californicus

Prionus californicus is widely distributed in western North America (Alston *et al*. 2007). The adult *Prionus californicus* is a very large beetle, ranging in size from 45–60 mm long (Steffan

and Alston 2005). The larvae can be as long as 108 mm with a diameter of approximately 18 mm at the widest point of the larval body (Steffan and Alston 2005). A single female can lay 150–200 eggs on, or in, the soil near the base of plants in her 2–3 week lifetime (Gent *et al*. 2009). Larvae upon hatching move to plant roots, where they feed internally for 3–5 years (Mahaffee *et al*. 2009). Mature larvae pupate during the early spring in cells constructed from soil and lined with root material (Gent *et al*. 2009).

3.1.1 Probability of entry

Probability of importation

The likelihood that *P. californicus* will arrive in Australia with the trade in propagative material from countries where the pest is present is: **HIGH**.

- *Prionus californicus* larvae are root borers and young larvae (many less than 10 mm in length) feed within the root and tunnel upwards (Bishop *et al*. 1984; Steffan and Alston 2007). Older larvae may also be found in rhizome as they are found in the crown of host plants (Steffan and Alston 2005). Therefore, dormant rhizomes can provide a pathway for the importation of *P. californicus* into Australia.
- The primary conditions for survival of *P. californicus* are fulfilled by the presence of the live propagative material and the associated environmental conditions. Therefore, association with dormant rhizome can provide long term survival for this pest.

Probability of distribution

The likelihood that *P. californicus* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Prionus californicus* arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the pest is already within a suitable host.
- Dormant rhizome would be distributed to multiple destinations throughout Australia for propagation. The distribution of infested dormant rhizome commercially will facilitate the distribution of *P. californicus*.

Overall probability of entry (importation x distribution)

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

The likelihood that *P. californicus* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.1.2 Probability of establishment

The likelihood that *P. californicus* will establish, based on a comparison of factors in the source and destination areas that affect survival and reproduction is: **LOW**.

- *Prionus californicus* is already associated with hop rhizome and will have a distinct developmental advantage. Association of this pest with rhizome allows it to complete larval development without leaving the host. As dormant rhizomes will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment. However, *P. californicus* has a long generation time (Gent *et al*. 2009).
- The life cycle requires three to five years to complete, therefore, most of its life is spent in the larval stage (Alston *et al*. 2007). Adults live for only 2–3 weeks, during which time they have to mate and lay eggs (Barbour *et al.* 2007). Adult females lay 150–200 eggs in

the soil near the base of plants (Gent *et al*. 2009). Therefore, there will be a single generation in 3–5 years. The variable development time of larvae, which results in a staggered adult emergence, would limit the chances of successful mating occurring from small localised introductions.

- Hosts of *P. californicus* include at least 21 genera of woody perennials in 12 plant families (Barbour *et al.* 2007). It has been recorded on deciduous trees, conifers and eucalypts including a number of perennial agricultural crops such as grapes, hop, fruit trees, and caneberries (Alston *et al.* 2007; Cervantes *et al.* 2006). These susceptible hosts are widely distributed in the PRA area in both managed and unmanaged environments.

3.1.3 Probability of spread

The likelihood that *P. californicus* will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Prionus californicus* is a beetle native to North America and is widely distributed along the pacific coast from Mexico to Alaska and extending inland to the Rocky Mountains (Alston *et al*. 2007; ITIS 2009). There are similarities in the natural and urban environments of these areas with those in Australia which suggests that *P. californicus* could spread in Australia.
- Long distance dissemination could occur in nursery stock as larvae could be found in roots and rhizomes (Mahaffee *et al*. 2009; Gent *et al*. 2009). Dormant rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this pest to spread. Once a field is infested, it is difficult to prevent increase and spread of the beetle to nearby plants (Alston *et al*. 2007).
- Natural spread is facilitated by active flying; however, females are sedentary and rarely fly (Barbour *et al*. 2007). A distance of 6 km between hosts is sufficient to prevent the spread of this species (Bishop *et al*. 1984).
- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of *P. californicus*. In the absence of statutory control it is likely that *P. californicus* will be spread quickly in the PRA area by trade in host propagative material.

3.1.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that *P. californicus* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **LOW**.

3.1.5 Consequences

The consequences of the entry, establishment and spread of *P. californicus* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level *Prionus californicus* has a wide host range including 21 genera of woody perennials in 12 plant families (Barbour *et al*. 2007). It has been recorded on fruit trees, deciduous trees, conifers and eucalypts (Alston *et al*. 2007; Cervantes *et al*. 2006). The feeding damage to roots tended to be spiralling furrows which would effectively girdle and kill the roots (Steffan and Alston 2005). Severe infestations can completely destroy crowns and kill plants (Gent *et al*. 2009). • *Prionus californicus* is a serious pest of hop in the Pacific North West. It reduces hop longevity by one half (Mahaffee *et al*. 2009; Bishop *et al*. 1984). Larval feeding on the roots causes serious economic losses by damaging plant roots, resulting in decreased nutrient uptake, water stress, and reduced plant growth (Mahaffee *et al*. 2009; Steffan and Alston 2005). • Severe infestation can completely destroy plant crown, resulting in plant death. Less severe infestations can result in wilting, yellowing and death of one or more bines of infested plant (Mahaffee *et al*. 2009; Bishop *et al*. 1984; Alston *et al*. 2007).
Other aspects of the environment	**Impact score: C** – significant at the local level • *Prionus californicus* feeds on a variety of plants including fruit trees, deciduous trees, conifers and eucalypts (Alston *et al*. 2007; Cervantes *et al*. 2006). Its presence in Australia may have significant impact on eucalypt forest and urban environments at the local level.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *P. californicus* was introduced in Australia, variable costs of host plant production would increase due to the need for changes in management strategies. • Management options of *P. californicus* in orchards are limited. Avoidance and prevention are the best strategies (Alston *et al*. 2007). Control measures will be expensive as infestations can only be eliminated by fumigating the soil or leaving the fields fallow for 2–3 years (Cervantes *et al*. 2006). • Early studies have suggested that applications of insecticide at the base of host plants may provide control (Bishop *et al*. 1984). However, this treatment is likely to be labour intensive, will not be possible for wild hosts or volunteer plants and is likely to provide only short term control. Application of insecticides is unlikely to affect larvae already within the roots of a plant (Steffan and Alston 2005). • Some pesticides have been shown to suppress the local population if used annually over several years (Steffan and Alston 2005). Management through mating disruption or adult trapping techniques may be possible (Mahaffee *et al*. 2009).
Domestic trade	**Impact score: D** – significant at the district level • The presence of *P. californicus* in parts of the PRA area may result in interstate nursery stock trade restrictions. Restrictions may lead to a loss of markets and result in the need for industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of *P. californicus* in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pest is absent.
Environmental and non-commercial	**Impact score: C** – significant at the local level Removal of infested host plants would have significant effects on the environment. Additionally, infestation by *P. californicus* can facilitate infection by secondary pathogens which cause further decay and damage to host plants (Alston *et al.* 2007). • Broad-scale chemical treatments are effective against younger larvae (Steffan and Alston 2005) but may have some impacts on native insects. Direct application of pesticides may have some impact on water, soil and non-target organisms.

3.1.6 Unrestricted risk estimate

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

The unrestricted risk for *P. californicus* has been assessed as 'low' which exceeds Australia's ALOP. Therefore, specific risk management measures are required for *P. californicus*.

3.2 Grapholita delineana

Grapholita delineana (hemp borer) is a lepidopteron pest species with a host range restricted to *Cannabis sativa, Humulus japonicus* and *H. lupulus* (Meijerman and Ulenberg 2000). There are two known strains of *G. delineana* with different host preferences. One is a hop-feeding strain that originated in Europe and the other is a strain originating from Asia that prefers to feed on *Cannabis sativa* (McPartland 2002). *Grapholita delineana* was originally described from China in 1863 (Tsao 1963) and spread to the hemp-growing areas of North America in 1943 (Miller 1982) and south-eastern Europe in 1960s (Nagy 1967). Prior to the sudden outbreak of *G. delineana* as a hemp pest in south-eastern Europe, it was known in that region as a minor pest of hop (Nagy 1967).

3.2.1 Probability of entry

Probability of importation

The likelihood that *G. delineana* will arrive in Australia with the trade in propagative material from countries where the pest is present is: **LOW**.

- *Grapholita delineana* could be imported into Australia on infested cuttings, as the larvae tunnels into the stalks and pupation can take place in the stalk of host plants (Meijerman and Ulenberg 2000). Larvae can reach 9–10 mm in length at maturity (McPartland 2002).
- Young damaged host plants droop and wither and the plants that survive develop galls of 1–2 cm at the entry and exit holes caused by larvae (AgroAtlas 2009a). Cuttings are a potential phytosanitary risk because larvae survive in harvested stalks (McPartland 2002). However, infested cuttings would be likely to be detected before shipment or on-arrival in Australia.
- The primary conditions for survival of *G. delineana* species are fulfilled by the presence of the live propagative material and the associated environmental conditions. Therefore, association with cuttings can provide long term survival for this pest.

Probability of distribution

The likelihood that *G. delineana* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Grapholita delineana* arriving in Australia within infested propagative material would not need to move from the import pathway to a suitable host as the pest is already within a host suitable for larval development.
- Propagative material would be distributed to multiple destinations throughout Australia for growth. The distribution of infested propagative material commercially will facilitate the distribution of *Grapholita delineana*.

Overall probability of entry (importation x distribution)

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

The likelihood that *G. delineana* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **LOW**.

3.2.2 Probability of establishment

The likelihood that *G. delineana* will establish, based on a comparison of factors in the source and destination areas that affect pest survival and reproduction is: **MODERATE**.

- *Grapholita delineana* is already associated with hop cuttings and will have a distinctive developmental advantage. Association of this pest with cuttings allows it to complete larval development without leaving the host. As cuttings will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment.
- *Grapholita delineana* produce 2–3 generations annually (Meijerman and Ulenberg 2000) and overlapping generations result in the presence of adults throughout the season. Adult females lay 350–500 eggs over the course of their lifetime but eggs are susceptible to low humidity; for example, humidity of 40% causes death of 80% of eggs (AgroAtlas 2009a). Survival rates of larvae to first instar are also very low which may hamper its ability to establish (McPartland 2002).
- Hosts of *G. delineana* are widely distributed, and often co-located, in the parts of the PRA area and will help establish this pest in new areas. However, the two host crops, hemp and hop (Meijerman and Ulenberg 2000), are only grown on a large scale in southern Australia which may hinder the established of *G. delineana* in other regions of Australia.

3.2.3 Probability of spread

The likelihood that *G. delineana* will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Grapholita delineana* was described from China (Tsao 1963) and spread to North America in 1943 (Miller 1982) and south-eastern Europe in 1960s (Nagy 1967). There are similarities in the natural and urban environments of these areas with those in Australia which suggests that *G. delineana* could spread in Australia.
- Long distance dissemination could occur in cuttings as the larvae tunnels into the stalks and pupation can take place in the stalk of host plants (Meijerman and Ulenberg 2000; McPartland 2002). Cuttings will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this pest to spread.
- Natural spread is facilitated by active flying and adult moths are known to disperse up to 20 kms (McPartland 2002). However, the scarcity of hosts present throughout the northern PRA area may hinder the spread of *G. delineana* in Australia as hop and hemp are only grown on a large scale in the southern areas of Australia (Tasmania and Victoria). Natural physical barriers between suitable hosts may prevent unassisted spread.
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of *G. delineana*. In the absence of statutory control it is likely that *G. delineana* will be spread quickly in the PRA area by trade in host propagative material.

3.2.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that *G. delineana* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **LOW**.

3.2.5 Consequences

The consequences of the entry, establishment and spread of *G. delineana* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** — significant at the regional level • *Grapholita delineana* is not considered an important pest of hemp and hop in its known range because the area under cultivation has decreased; however, if the area under cultivation increases it may become an important pest of hemp and hop (AgroAtlas 2009a). • *Grapholita delineana* lays eggs on leaves, stalks and inflorescences and, after hatching, young larvae skeletonize leaves for several days before they bore into petioles, branches and stalks. Feeding galleries within branches and stalks cause fusiform-shaped galls and splitting. Larvae feed on leaves for several days before boring into stems. Early-season larvae pupate within stems. The damage done by the borers is visible as trails on the stalk and the galls (AgroAtlas 2009a). • Branches and stalks may break at galls (Miller 1982). Boring near the terminal shoot may kill the shoot and cause branching at that point. In warmer regions where two or more generations occur per year, late-season larvae that hatch in the autumn will feed on leaves, flowers and seeds. Late-season larvae pupate in curled leaves within buds, bound together by strands of silk. • *Grapholita delineana* is responsible for causing 30–40% loss of hemp seed and 100% damage to the stalks of *Cannabis sativa* plants in the Ukraine (Meijerman and Ulenberg 2000) and Romania (McPartland 2002). Young damaged host plants droop and wither and the stalks of plants that survive develop galls of 1–2 cm at the larvae's entry and exit holes (AgroAtlas 2009a). Destruction of growing-point results underdevelopment, deformation of stalk and formation of lateral shoots (AgroAtlas 2009a).
Other aspects of the environment	**Impact score: A** — indiscernible at the local level • There are no known direct consequences of this pest on any other aspects of the environment. Its narrow host range may limit its impact upon other species and/or ecosystems.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** — significant at the district level If *G. delineana* was introduced to hop production areas of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Management options for *G. delineana* in orchards are limited as the larvae occur internally in the plant. Methods of control for this pest include selecting plants for resistance, the use of insect parasitoids and chemical controls (McPartland 2002). • Cultural methods such as destruction of crop debris and deep ploughing will provide good control as ploughing buries overwintering larvae and pupae too deep for the pest to emerge from the soil. Similarly early harvest may decrease the overwintering population of *G. delineana* because this practice destroys a high percentage of larval population (Nagy 1979). Destruction of wild hemp and hop would eliminate sanctuary for overwintering populations. • Biological measures such as use of pheromone traps for monitoring of populations and to attract and trap male moths, preventing reproduction would help controlling the pest (AgroAtlas 2009a). Chemical measures including insecticide treatments during leafing-out against 1st generation caterpillars, and later against 2nd generation caterpillars would also help controlling the pest (AgroAtlas 2009a).
Domestic trade	**Impact score: D** — significant at the district level • The presence of *G. delineana* in Australia is likely to cause nursery stock trade restrictions within the Australian states. Restrictions may lead to a loss of markets and result in the need for industry adjustment.
International trade	**Impact score: D** — significant at the district level • The presence of *G. delineana* in Australia is likely to cause limitations to overseas markets where this pest is absent. For example, *G. delineana* has not been reported from hemp-growing regions in the southern hemisphere (South America, Africa) and from hemp-cultivation centres in Western Europe, such as Italy, Germany, France, Netherlands and UK.
Environmental and non-commercial	**Impact score: A** — indiscernible at the local level • There are no known direct consequences of this pathogen on any other aspects of the environment. It is unlikely to affect other species due to its narrow host range.

3.2.6 Unrestricted risk estimate

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

The unrestricted risk for *Grapholita delineana* is has been assessed as 'low' which is above Australia's ALOP. Therefore, specific risk management measures are required for *Grapholita delineana*.

3.3 Hydraecia species

Hydraecia micacea and *H. immanis* are boring moths which have a single generation per year (Šedivỳ *et al*. 2005; Levine 1986). A single female of *H. micacea* can lay 189–1529 eggs over its life time (Deedat *et al*. 1983). Eggs are laid on weeds and young larvae initially feed on these species before moving to cultivated plants such as hop (French *et al.* 1973; Ŝedivỳ *et al.* 2005). The larvae then feed on the base of the bine or tunnel into the crown or roots of the plant. In some cases larvae do not tunnel into the bines but feed immediately on the crown and roots (French *et al.* 1973; Ŝedivỳ *et al.* 2005). Waterlogged areas close to infested hop gardens may serve as reservoirs for *Hydraecia micacea,* especially in years with unfavourable weather

conditions. Presence of, and damage caused by, *Hydraecia micacea* is obvious only in hop gardens infested by quackgrass, as females deposit their eggs on this species (Ŝedivỳ *et al.* 2005).

Hydraecia micacea and *H. immanis* have been grouped together because of similar biology (Rings and Metzler 1982). The discussion below largely concentrates on *Hydraecia micacea* as an example of these lepidopterans of concern due to significant published literature being available on this species. However, the conclusions reached are expected to be valid for both species being considered in this risk assessment.

3.3.1 Probability of entry

Probability of importation

The likelihood that *Hydraecia* species will arrive in Australia with the trade in propagative material from countries where the pest is present is: **HIGH**.

- *Hydraecia micacea* larvae bore into the stems and later invade rhizomes (Ŝedivỳ *et al.* 2005). The number of larvae which may infest a single rhizome varies from 6–63 (Ŝedivỳ *et al.* 2005). Therefore, rhizomes can provide a pathway for the importation of *Hydraecia* species into Australia.
- The primary conditions for survival of *Hydraecia* species are fulfilled by the presence of the live propagative material and the associated environmental conditions. Therefore, association with dormant rhizome can provide long term survival for this pest.

Probability of distribution

The likelihood that *Hydraecia* species will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Hydraecia micacea* and *H. immanis* arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the pest is already within a suitable host.
- Dormant rhizome would be distributed to multiple destinations throughout Australia for propagation. The distribution of infested dormant rhizome commercially will facilitate the distribution of *Hydraecia* species.

Overall probability of entry (importation x distribution)

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

The likelihood that *Hydraecia* species will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.3.2 Probability of establishment

The likelihood that *Hydraecia* species will establish based on a comparison of factors in the source and destination areas that affect pest survival and reproduction is: **LOW**.

- *Hydraecia micacea* is already associated with hop rhizome and will have a distinctive developmental advantage. Association of this pest with rhizome allows it to complete larval development without leaving the host. As rhizomes will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment. However, *Hydraecia micacea* has a long generation time (Ŝedivỳ *et al.* 2005).

- The life cycle requires one year to complete with the eggs being the overwintering stage which lasts 7–9 months; thus, most of the lifecycle is spent in the egg stage (Giebink *et al*. 1992). The adult females live for about 1–2 weeks, and lay 200–1500 eggs in masses of 30–300 (Giebink *et al*. 1992).
- *Hydraecia* species are polyphagous, recorded on 50 species of plants from 20 families (Giebink *et al*. 1992). They have been recorded on hop, potatoes, cereals and grasses (Ŝedivỳ *et al.* 2005; French *et al.* 1973). These susceptible hosts are widely distributed in the PRA area in both managed and unmanaged environments.

3.3.3 Probability of spread

The likelihood that *Hydraecia* species will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Hydraecia micacea* is native to Europe, Japan and Siberia and was introduced into the maritime provinces of Canada in the early 1900's and spread to the north-eastern United States as a result of natural dispersal of moths flying southward (Giebink *et al.* 1984). There are similarities in the natural and urban environments of these areas with those in Australia which suggests that *H. micacea* could spread in Australia.
- *Hydraecia micacea* can spread both independently and in association with infested planting material. Independent spread is facilitated by active flying (Giebink *et al*. 1984); however, adults are short lived (Giebink *et al*. 1992). Long distance dissemination could occur in nursery stock as larvae can be found in rhizomes (Ŝedivỳ *et al.* 2005). Imported rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this pest to spread.
- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of *Hydraecia* species. In the absence of statutory control it is likely that *Hydraecia* species will be spread quickly in the PRA area by trade in host propagative material.

3.3.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that *Hydraecia* species will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **LOW**.

3.3.5 Consequences

The consequences of the entry, establishment and spread of *Hydraecia* species in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level • *Hydraecia micacea* has a wide host range including 50 species in 20 plant families (Scherney 1970; Giebink *et al.* 1992). It has been recorded on hop, potatoes, cereals and grasses (French *et al.* 1973; Ŝedivỳ *et al.* 2005). • *Hydraecia micacea* is a serious pest of hop in Europe (French *et al*. 1973; Ŝedivỳ *et al*. 2005). *Hydraecia immanis* is recorded to have destroyed 25–50% of the Wisconsin hop crop before disappearing for approximately 100 years (1875–1975) as the hop industry moved to the west coast states of California, Idaho, Oregon and Washington (Scriber and Hainze 1988). *Hydraecia immanis* survived at very low densities during these 100 years (Godfrey 1981) and then suddenly arose to prominence as a new corn pest which was spreading (causing noticeable damage) from central Wisconsin rapidly into adjacent states (Scriber 1980; Giebink *et al*. 1984). • The larvae feed on the leaves, making a tiny entry hole to tunnel into the stem and then move through the plant to the roots (French *et al*. 1973). In hop, feeding by *H. micacea* has been reported to cause some leaf yellowing but no wilting or obvious reduction in host vigour. Damage to newly planted hop is more serious and can lead to the death of the plant (French *et al*. 1973). • Feeding injury results in bine die-back and reduced cone production. Bine injured by stem-boring larvae also has a greater incidence of *Fusarium* canker than undamaged bines (Mahaffee *et al*. 2009). • In North America *Hydraecia micacea* has been of primary economic significance as a pest of corn. However, cultivated hop may be at risk should the pest be introduced into hop-growing regions of the western United States (Mahaffee *et al*. 2009).
Other aspects of the environment	**Impact score: C** – significant at the local level • *Hydraecia micacea* feeds on a variety of plants including cereals, grasses, sugar beet, onion, rhubarb, tomatoes and strawberry (Scherney 1970; Ŝedivỳ *et al*. 2005). Its presence in Australia may have significant impact on grassland environments at the local level.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *Hydraecia* species were introduced to hop production areas of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Management options of *Hydraecia* species are limited. Chemical control is difficult as the larvae are stem borers as well as external feeders of crown and roots below the soil surface. Control measures will be expensive as the eggs are laid on weed species, weed management is a major factor in controlling this pest. In-field chemical controls have also been proven to be effective (French *et al*. 1973). • In the past *Hydraecia* species on hop were controlled, and economic losses significantly reduced, with the use of DDT (French *et al*. 1973). In 1972, banning of DDT and similar pesticides combined with reduced tillage practices in Wisconsin and adjacent states (Minnesota, Illinois and Iowa) caused the rapid spread (from 1976 to 1985) of the native *Hydraecia* species into cropping areas causing significant damage (Giebink *et al*. 1984; Scriber and Hainze 1988).
Domestic trade	**Impact score: D** – significant at the district level • The presence of *Hydraecia* species in parts of the PRA area may result in interstate nursery stock trade restrictions. Restrictions may lead to a loss of markets and result in the need for industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of *Hydraecia* species in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pest is absent.

Criterion	Estimate and rationale
Environmental and non-commercial	**Impact score: C** – significant at the local level Infestation by *Hydraecia* species can facilitate infection by secondary pathogens which cause further decay and damage to host plants (Mahaffee *et al*. 2009). • Broad-scale chemical treatments are effective against stem boring stages (Mahaffee *et al*. 2009) but may also have some impacts on native insects. Direct application of pesticides may have some impact on water, soil and non-target organisms.

3.3.6 Unrestricted risk estimate

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

The unrestricted risk for *Hydraecia* species has been assessed as 'low' which exceeds Australia's ALOP. Therefore, specific risk management measures are required for *Hydraecia* species.

3.4 Ostrinia nubilalis

Ostrinia nubilalis (European corn borer) is an economically important lepidopteron pest in corn growing regions of the world (Hudon and LeRoux 1986). *Ostrina nubilalis* attacks nearly all robust herbaceous plants with a stem large enough for the larvae to enter (Capinera 2000) including hop (Bourguet *et al.* 2000) and several weed species (Capinera 2000). The European corn borer (ECB) originating from Europe is thought to have been introduced multiple times to North America in shipments of millet from Italy and Hungary (Krumm *et al*. 2008). The ECB exhibits considerable genetic diversity. For example, voltinism differences between populations in North America were recognized shortly after the insect was discovered. Voltinism associated with diapause is when an inherited characteristic is modified by environmental factors. The wide geographic distribution exposes *O. nubilalis* to ecological conditions that differ in photoperiod, temperature, host plant availability, and growing season length (Calvin *et al*. 1991) resulting in populations that can be univoltine, bivoltine or multivoltine (Krumm *et al*. 2008). Voltinism displayed a response to short photoperiods whereby *O. nubilalis* could adapt quickly to local conditions (Krumm *et al*. 2008). As a result, historically bivoltine populations can become univoltine by a simple drop in temperature during critical days of diapause giving the species the flexibility to take advantage of the full growing season depending on altitude and latitude (Krumm *et al*. 2008).

3.4.1 Probability of entry

Probability of importation

The likelihood that *O. nubilalis* will arrive in Australia with the trade in propagative material from countries where the pest is present is: **LOW**.

- *Ostrinia nubilalis* larvae are stem borers (Malausa *et al.* 2007); therefore, cuttings can provide a pathway for the importation of *O. nubilalis* into Australia. However, larvae can reach 1.6–19.9 mm in length at maturity (Capinera 2000) and produce clearly discernable entry or exit holes. Therefore, infested cuttings would be likely to be detected before shipment or on-arrival in Australia.
- The primary conditions for survival of *O. nubilalis* species are fulfilled by the presence of the live propagative material and the associated environmental conditions. Therefore, association with cuttings can provide long term survival for this pest.

Probability of distribution

The likelihood that *O. nubilalis* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Ostrinia nubilalis* arriving in Australia with infected propagative material would not need to move from the import pathway to a suitable host as the pest is already within a host suitable for larval development.
- Propagative material would be distributed to multiple destinations throughout Australia for growth. The distribution of infested propagative material commercially will facilitate the distribution of *O. nubilalis*.

Overall probability of entry (importation x distribution)

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

The likelihood that *O. nubilalis* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **LOW**.

3.4.2 Probability of establishment

The likelihood that *O. nubilalis* will establish, based on a comparison of factors in the source and destination areas that affect survival and reproduction is: **HIGH**.

- *Ostrinia nubilalis* is already associated with hop cuttings and will have a distinctive developmental advantage. Association of this pest with cuttings allows it to complete larval development without leaving the host. As cuttings will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment.
- *Ostrinia nubilalis* can produce one to four generations a year depending on climate (Capinera 2000); overlapping generations result in the presence of adults throughout the season. Adults are capable of flying across tens of kilometers in search of places suitable for oviposition. For oviposition to begin, adults need water. Lack of water also prevents hibernated larvae from starting their pupation. Therefore, insect establishment depends on precipitation during the spring and summer periods. Hibernating larvae survive easily after long periods of very low winter temperatures (AgroAtlas 2009b).
- The wide geographic distribution exposes *O. nubilalis* to ecological conditions that differ in photoperiod, temperature, host plant availability, and growing season length (Calvin *et al*. 1991). Due to voltinism in the species, it has demonstrated an ability to respond to short photoperiods by adapting quickly to local conditions (Krumm *et al*. 2008). As a result, *O. nubilalis* is likely to establish in any new location after introduction.
- *Ostrinia nubilalis* has a wide host range including 223 plant species (both monocotyledon and dicotyledon) on which the borers can develop (Lewis 1975), including hop (Bourguet *et al.* 2000). However, research has suggested that those *O. nubilalis* which feed on hop are genetically differentiated from those that feed on other host plants (Malausa *et al.* 2007; Bontemps *et al.* 2004). Susceptible hosts, which include economically important species and weeds, are widely distributed throughout the PRA area.

3.4.3 Probability of spread

The likelihood that *O. nubilalis* will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Ostrinia nubilalis* has established in a variety of environments throughout Europe, northern Africa, North America and Russia (AgroAtlas 2009b). There are similarities in the natural and managed environments of these areas with those in the PRA area. The environmental conditions in the PRA area are likely to support the spread of *O. nubilalis.*
- *Ostrinia nubilalis* can spread both independently and in association with infested planting material. Independent spread is facilitated by active flying (Showers *et al.* 2001). The adults of *O. nubilalis* are strong fliers and both males and females have been known to disperse up to 14 kms in a few minutes and up to 49 kms over a few nights (Showers *et al.* 2001). Long distance dissemination could occur in nursery stock as larvae can be found in cuttings (Malausa *et al.* 2007). Imported cuttings will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this pest to spread.
- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of *O. nubilalis*. In the absence of statutory control it is likely that *O. nubilalis* will be spread quickly in the PRA area by trade in host propagative material.

3.4.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that *O. nubilalis* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **LOW**.

3.4.5 Consequences

The consequences of the entry, establishment and spread of *O. nubilalis* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level • *Ostrinia nubilalis* is considered a major biotic constraint for maize development and production (Krumm *et al*. 2008). In North America, losses from reduced yield and control programs resulting from *O. nubilalis* exceed $1 billion per year (Showers *et al.* 2001). • The pest is known to be polyphagous, attacking many herbaceous plants with stems large enough for the larvae to enter (Capinera 2000), including hop (Bourguet *et al*. 2000) and several weed species (Capinera 2000). *Ostrinia nubilalis* individuals which feed on hop are genetically differentiated from those that feed on other host plants (Malausa *et al.* 2007; Bontemps *et al*. 2004). On hop, symptoms from *O. nubilalis* feeding include yellow and chewed tendrils and cones which are smaller and ripen early (Benedek *et al.* 1966). • Fecundity of females is usually 200–700 eggs; however, some females have been recorded as producing up to 1250 eggs (AgroAtlas 2009b). Females lay eggs on leaves after hatching and young larvae burrow into the stem to establish a feeding site and also to overwinter in tunnels within the stem of a suitable host plant (Capinera 2000). Damage occurs in the form of bore holes created by the caterpillars as they bore through the stalk, but no gall is formed. Since the European corn borers are larger insects and consume more than the hemp borers, they devour larger pieces of wood, causing the stems to break in the wind.
Other aspects of the environment	**Impact score: C** – significant at the local level • *Ostrinia nubilalis* feeds on a variety of plants including maize as well as millet, hemp and hop; it is capable of injuring peppers, sorghum, soy-bean, and cotton. It infests thickly-stemmed wild-growing plants and weeds, such as *Ambrosia artemisifolia*, *Artemisia* spp., *Bidens* spp., *Echinochloa crus-galli*, *Xanthium* spp. and others (AgroAtlas 2009b). Its presence in Australia may have significant impact on grassland environments at the local level.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *O. nubilalis* was introduced to hop production areas of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Management of this pest involves monitoring with pheromone and blacklight traps, in-field insecticide applications and cultural practices such as destruction of overwintering larvae sites through deep ploughing (Capinera 2000). • Cultural methods such as destruction of crop debris and deep ploughing will provide good control as ploughing buries overwintering larvae and pupae too deep for the pest to emerge from the soil. • Biological control of *O. nubilalis* using augmentative and inundative releases of *Trichogramma* spp. is now used (Kanour and Burbutis 1984). Microbial control using formulations of *Bacillus thuringiensis* subsp. *kurstaki* generally gives good results, particularly when the treatments are correctly applied and target first stage larvae (Curto 1996).
Domestic trade	**Impact score: D** – significance at the district level • The presence of *O. nubilalis* in Australia is likely to cause nursery stock trade restrictions within the Australian states. Restrictions may lead to a loss of markets and result in the need for industry adjustment.
International trade	**Impact score: D** – significance at the district level • The presence of *O. nubilalis* in Australia is likely to cause limitations to overseas markets where this pest is absent. For example *O. nubilalis* has not been reported from Asia and Australasia.

Criterion	Estimate and rationale
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pest on any other aspects of the environment.

3.4.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for *O. nubilalis*.

3.5 Podosphaera macularis

Podosphaera macularis is an obligate parasite specific to *Humulus* species which causes powdery mildew, and is an economically important fungal pathogen of hop worldwide (Mahaffee *et al*. 2003a, b). The fungus survives in infected material as mycelium or, where sexual reproduction occurs, as chasmothecia that are formed readily on infected leaves and cones and within rhizome buds (Liyanage and Royle 1976). *Podosphaera macularis* exists as two mating types (Gent *et al*. 2008) and is polycyclic with the potential for more than 20 generations in a growing season if conditions are optimal (Peetz *et al*. 2009). However, temperature impacts on conidial availability, germination and risk of infection (Peetz 2007). *Podosphaera macularis* has long been a major problem in European hop production and was partially responsible for pushing the hop industry out of the eastern United States and California and into the Pacific Northwest (Turechek and Mahaffee 2004).

3.5.1 Probability of entry

Probability of importation

The likelihood that *P. macularis* will arrive in Australia with the trade in propagative material from countries where the pest is present is: **HIGH**.

- *Podosphaera macularis* overwinters in infected rhizome buds as mycelium (Liyanage and Royle 1976; Peetz 2007). Therefore, propagative material can provide a pathway for the importation of *P. macularis* into Australia.
- The primary conditions for survival of *P. macularis* are fulfilled by the presence of the live propagative material and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for this fungus.

Probability of distribution

The likelihood that *P. macularis* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Podosphaera macularis* arriving in Australia with propagative material will not need to move from the import pathway to a suitable host as the fungus is already within a suitable host.
- Dormant rhizome would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected dormant rhizome commercially will facilitate the distribution of *P. macularis.*

Overall probability of entry (importation x distribution)

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

The likelihood that *P. macularis* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.5.2 Probability of establishment

The likelihood that *P. macularis* will establish, based on a comparison of factors in the source and destination areas that affect survival and reproduction is: **HIGH**.

- Association of *P. macularis* with infected rhizome provides a distinct epidemiological advantage to the fungus as infected rhizome will result in heavily infected shoots (Gent *et al*. 2008). This will result in the establishment of this fungus in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- Climate matching results illustrate that conditions in hop gardens in Australia are closely aligned to those of the UK and the USA (Pethybridge *et al*. 2003). *Podosphaera macularis* is present in these countries, suggesting that the pathogen would probably establish if introduced into the hop production areas of Australia.
- The optimum temperature for foliar infection and disease development of *P. macularis* is between 12 °C and 27 °C (Mahaffee *et al*. 2003b). The optimal temperature for infection, growth, and sporulation of *P. macularis* is 18 °C. The risk of infection decreases substantially once temperature exceeds 30 °C (Mahaffee *et al*. 2003b, Peetz *et al*. 2009). For instance, exposure to 30 °C for only two hours can reduce the risk of infection for *P. macularis* by 50% (Mahaffee *et al*. 2003b). These conditions are prevalent during the hop growing season in the PRA area.

3.5.3 Probability of spread

The likelihood that *P. macularis* will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Podosphaera macularis* can spread both independently and in association with infected planting material. Independent spread is facilitated by airborne conidia and ascospores (Glawe 2008). The majority of conidia are disseminated by wind less than 2 m from host plants (Glawe 2008) whereas ascospores can be disseminated over much longer distances by wind (Peetz 2007). *Podosphaera macularis* can also spread in association with infected planting material (Gent *et al*. 2009) and as such, long distance spread is facilitated by the commercial distribution of infested planting material.
- Infected rhizomes are unlikely to be grown in isolation, providing greater opportunity for spread of *P. macularis* to other plants. *Podosphaera macularis* is polycyclic, is able to complete its life cycle within five days under ideal conditions (Peetz *et al*. 2009) and produces abundant conidia which are readily wind disseminated throughout the growing season (Peetz 2007). The cycle of conidial production and infection of susceptible hosts continues and can cause rapid spread of the pathogen (Peetz *et al*. 2009).
- Temperature has a significant impact on sporulation and may thus have important implications for inoculum availability in the field. Exposure to constant low and high temperatures decreases sporulation, indicating inoculum may not always be available

once the epidemic has started. Sporulation is also decreased during brief exposures to temperatures above 30 °C. These data indicate that inoculum availability is reduced when temperatures exceeds 30 °C in the field (Peetz 2007, Peetz *et al*. 2009). These conditions may impact the spread of this fungus within hop yards.

3.5.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that *P. macularis* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **HIGH**.

3.5.5 Consequences

The consequences of the entry, establishment and spread of *P. macularis* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level • *Podosphaera macularis* can cause significant crop damage under favourable environmental conditions (Gent *et al*. 2007; Peetz *et al*. 2009), in some cases resulting in complete loss of marketable yield due to lost production and reduced cone quality (Gent *et al*. 2009). The introduction of hop powdery mildew into Washington has eliminated production of at least one very susceptible cultivar and significantly increased the production costs of others (Pethybridge *et al*. 2003). • The disease occurs on leaves and petioles, but economic losses are associated primarily with infection of inflorescences (burrs) and developing cones. Although infections of leaves are rarely economically damaging, they provide inoculum to initiate infections of burrs and cones (Gent *et al*. 2006). Economic losses are generally associated with reduction in crop quality and control costs but can also be due to yield reductions (Peetz 2007). • Losses associated with the disease include reduced yield, decreased plant vigour, diminished cone quality and increased fungicide usage (Mahaffee *et al*. 2003b). In the Pacific Northwest, losses due to these factors approached $30 million in 1999 and 2000, or about 15% of the total crop revenue (Mahaffee *et al*. 2003b). • Infection by *P. macularis* is known to cause early cone maturity which can lead to reductions in cone quality (Mahaffee *et al.* 2009). Observations in Oregon and Washington hop yards indicate that a delay in harvesting of 2–5 days can result in an unacceptable quality of aroma in hop and subsequent rejection by brewers (Gent *et al*. 2007).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *Podosphaera macularis* was introduced to hop production areas in Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Programs to minimise the impact of *P. macularis* on host plants are likely to be costly and include cultural control, chemical control and early warning systems (CABI 2010). • Cultural practices such as chemical or mechanical pruning, removal of excessive basal foliage, and sanitation of infested crop debris can reduce disease but, alone, are insufficient to control the disease (Mahaffee *et al*. 2003a, Turechek *et al*. 2001). Cultivars vary widely in their resistance or tolerance to powdery mildew (Gent *et al*. 2006), but complete resistance is not found among commercial cultivars sought by most brewers (Gent *et al*. 2006). • Currently, well-timed fungicide applications are the only effective means of controlling powdery mildew on susceptible cultivars, and growers typically spend from $300 to $600 per hectare on fungicide applications to manage the disease (Turechek and Mahaffee 2004). Fungicides are applied to hop throughout the entire season to protect newly emerged leaves, although the risk of disease varies with temperature and rainfall (Mahaffee *et al*. 2003b). • An eradication campaign for *P. macularis*, should it be detected early, is likely to be expensive as it would require eradication of susceptible hosts. It is likely that *P. macularis* will be managed by application of fungicides. Long-term management would be based on selection of genotypes that are immune or highly resistant; however, long-term breeding and testing programs will be expensive.
Domestic trade	**Impact score: D** – significant at the district level • The presence of *P. macularis* in production areas (Tasmania and Victoria) is likely to result in some domestic movement restriction for host plants. Interstate restrictions on propagative material may lead to a loss of markets, which in turn may require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of *P. macularis* in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent, such as New Zealand and South Africa (Mahaffee *et al*. 2009).
Environmental and non-commercial	**Impact score: B** – minor significance at the local level. • Additional fungicide application or other control activities may be required to contain and/or eradicate this pathogen. However, this is not considered to have significant consequences for the environment.

3.5.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'moderate' exceeds Australia's ALOP. Therefore, specific risk management measures are required for *P. macularis*.

3.6 Pseudoperonospora humuli

Pseudoperonospora humuli is an economically important fungal pathogen in many hop-growing areas of the world which causes downy mildew (Johnson *et al*. 1983; Chee *et al*. 2006; Mahaffee *et al*. 2009). The pathogen was first reported on cultivated and wild hop in

Japan in 1905 and later in Wisconsin, USA in 1909. The fungus was found in the United Kingdom in 1920 and seven years later it had spread throughout the hop-growing areas of Europe (Mahaffee *et al*. 2009). The fungus survives as mycelium in systemically infected rhizome (Briggs *et al*. 1982; Johnson and Skotland 1985; Chee *et al.* 2006) or as oospores in infected shoots and infected cones, but their role in the disease cycle has not been clearly established (Chee *et al.* 2006). *Pseudoperonospora humuli* thrives in environments with moderate temperatures, high humidity, and frequent rains. Consequently, the hop production in North America has shifted from moist areas to more arid areas (Johnson *et al*. 1983; Nelson *et al.* 2004).

3.6.1 Probability of entry

Probability of importation

The likelihood that *P. humuli* will arrive in Australia with the trade in propagative material from countries where the pest is present is: **HIGH**.

- *Pseudoperonospora humuli* overwinters in infected rhizome buds as mycelium (Chee *et al*. 2006; Mahaffee *et al*. 2009). Additionally, rhizomes can become infected at any time in the growing season by zoospores washing through the soil (Royle and Thomas 1971) as the fungus is systemic in plant parts (Nelson *et al.* 2004). Therefore, propagative material can provide a pathway for the importation of *P. humuli* into Australia.
- The primary conditions for survival of *P. humuli* are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for this fungus.

Probability of distribution

The likelihood that *P. humuli* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pest is present is: **HIGH**.

- *Pseudoperonospora humuli* arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the fungus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of *P. humuli*.

Overall probability of entry (importation x distribution)

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

The likelihood that *P. humuli* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.6.2 Probability of establishment

The likelihood that *P. humuli* will establish, based on a comparison of factors in the source and destination areas that affect fungal survival and reproduction is: **HIGH**.

- Association of *P. humuli* with infected rhizome provides a distinctive epidemiological advantage to the fungus as infected rhizome will result in heavily systemically infected shoots (Nelson *et al*. 2004; Gent *et al*. 2009). This will result in the establishment of this fungus in new areas. Additionally, rhizomes will be planted directly into regions suitable

for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.

- Climate modelling indicates that conditions in hop gardens in Australia are closely aligned to those of the UK and the USA (Pethybridge *et al*. 2003). *Pseudoperonospora humuli* is present in these countries, suggesting that the pathogen would probably establish if introduced into the hop production areas of Australia.
- The optimum temperature for disease development of *P. humuli* is between 19 °C and 23 °C. At 19–23 °C the duration of leaf wetness required for infection establishment is three hours. At temperatures of 8–10 °C, six hours of wetness is required (Johnson and Skotland 1985). These conditions are prevalent during the early part of the hop growing season in the PRA area.

3.6.3 Probability of spread

The likelihood that *P. humuli* will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **HIGH**.

- *Pseudoperonospora humuli* can spread both independently and in association with infected planting material. Independent spread is facilitated by the release of conidia, especially during rainy weather (Johnson *et al.* 1988; Mahaffee *et al*. 2009), that remain within the crop canopy. Some conidia are carried upwards by convection currents and disseminated over long distances by wind. The concentration of conidia decreases quickly with increasing distance from the source of release (Kremheller and Diercks 1983). *Pseudoperonospora humuli* can also spread in association with infected planting material (Chee *et al*. 2006; Gent *et al*. 2009; Mahaffee *et al*. 2009) and as such, long distance spread is facilitated by the commercial distribution of infected planting material.
- Infected rhizomes are unlikely to be grown in isolation, providing greater opportunity for spread of *P. humuli* to other plants. Systemically infected shoots emerge from the infected rhizome (Chee *et al*. 2006) and conidia from these infected shoots serve as the primary inocula from which the pathogen spreads to healthy leaves and shoots under appropriate environmental conditions (Chee *et al*. 2006). *Pseudoperonospora humuli* is polycyclic (Johnson *et al*. 1988) and is able to produces abundant conidia under ideal conditions which can cause rapid spread of the pathogen (Johnson and Skotland 1985; Johnson *et al*. 1988).
- Abundant moisture and mild temperatures favour sporulation, spread of conidia and secondary infection (Coley-Smith 1962; Skotland 1961). Temperature influences disease development, possibly through its effect on sporulation (Skotland 1962) and infection (Royle 1973). Low temperatures frequently restrict sporulation and infection (Johnson *et al*. 1983). For example, temperatures less than 5 °C inhibit sporangial formation on systemically infected shoots. Disease development and severity is favoured by extended periods of wetness, high humidity, and temperatures ranging from 5–23 °C (Johnson and Skotland 1985; Johnson *et al*. 1983; Royle 1973). These conditions may impact the spread of this fungus within hop yards.

3.6.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that *P. humuli* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **HIGH**.

3.6.5 Consequences

The consequences of the entry, establishment and spread of *P. humuli* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level • *Pseudoperonospora humuli* is among the most important pathogens of hop and continues to threaten the economic viability of the hop industry because of widespread fungicide resistance in the pathogen population and lack of host resistance to the pathogen in commercially acceptable cultivars (Gent and Ocamb 2009). • *Pseudoperonospora humuli* can cause significant crop damage under favourable environmental conditions (Chee *et al*. 2006). The systemic form of the pathogen results in stunted shoots, discolouration, necrotic spotting of the root vascular tissue and plant death (Pethybridge *et al*. 2003). The pathogen has been associated with losses of up to 28% of plants of susceptible commercial cultivars (Pethybridge *et al*. 2003). • Yield and quality losses from downy mildew vary depending on susceptibility of the variety and timing of infection, and may range from nondetectable to 100% crop loss if significant cone infection or plant death from crown rot occurs (Gent *et al*. 2009; Mahaffee *et al*. 2009). • The most serious yield losses typically result from infection of developing cones, which can cause complete crop loss due to cone abortion, reductions in α-acid content, and poor cone quality. In certain cultivars, the disease also may cause a crown rot and subsequent plant death (Johnson and Anliker 1985).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *Pseudoperonospora humuli* was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Programs to minimise the impact of *P. humuli* on hop are likely to be costly and include regular application of fungicides supplemented by sanitation practices such as spring crown pruning (Gent *et al*. 2010). • Cultural practices for managing *P. humuli* include using resistant cultivars and adhering to sanitation practices (removing the source of primary infection) (Skotland and Johnson 1983). A number of preventative sprays previously used to control this fungus (such as the systemic fungicide metalaxyl and fosetyl-Al) are now ineffective as the pathogen has progressively developed resistance (Hunger and Horner 1982; Hellwig *et al*. 1991; Klein 1994; Nelson *et al*. 2004). • An eradication campaign for *P. humuli*, should it be detected early, is likely to be expensive as it would require eradication of susceptible hosts. It is likely that *P. humuli* will be managed in the short term by application of fungicides. Long-term management would be based on selection of genotypes that are immune or highly resistant; however, long-term breeding and testings program will be expensive.
Domestic trade	**Impact score: D** – significant at the district level • The presence of *P. humuli* in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of *P. humuli* in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent, such as New Zealand and South Africa (Mahaffee *et al*. 2009).
Environmental and non-commercial	**Impact score: B** – minor significance at the local level. • Additional fungicide application or other control activities may be required to contain and/or eradicate this pathogen and control it. However, this is not considered to have significant consequences for the environment.

3.6.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'moderate' exceeds Australia's ALOP. Therefore, specific risk management measures are required for *P. humuli*.

3.7 Verticillium species (hop strains)

Hop-infecting *Verticillium* strains (*V. albo-atrum* and *V. dahliae*) are relatively host specific and important fungal pathogens of hop (Jamnik *et al.* 2006, Radišek *et al.* 2003). Verticillium wilt caused by *V. albo-atrum* was first recorded in 1924 in the UK and a virulent strain emerged in 1939 threatening hop crops in south-east England (Talboys 1987). Selection of resistant cultivars and cultural measures enabled sustained production. However, emergence of a super virulent strain in 1968 presented a new threat to hop production (Talboys 1987). The possibility of natural hybridisation between *V. albo-atrum* and *V. dahliae* may result in more virulent strains. Currently, Verticillium wilt on hop appears in mild or lethal forms

(Radišek *et al.* 2003). The mild form of Verticillium wilt has been reported from Belgium, England, France, Germany, New Zealand, Poland, Slovenia and the USA (Radišek *et al.* 2003, OEPP/EPPO 2007). The lethal form of hop wilt has been detected only in England and Slovenia (Radišek *et al.* 2003). The two forms differ in severity with the lethal form causing premature plant death; plants infected with the mild form continue to grow despite reduced vigour (Radišek *et al.* 2003).

3.7.1 Probability of entry

Probability of importation

The likelihood that hop-infecting *Verticillium* strains will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Hop-infecting *Verticillium* strains are soil-borne and enter the hop by root invasion and then colonise the hop vascular system (Radišek *et al.* 2003). These strains can overwinter in infected rhizomes as dormant mycelium or as microsclerotia (Agrios 2005). Once the rootstock has been infected, the mycelia may persist for many years, even if no further infection occurs (Agrios 2005). Therefore, dormant rhizomes can provide a pathway for the importation of hop infecting *Verticillium* strains into Australia.
- The primary conditions for survival of hop-infecting *Verticillium* strains are fulfilled by the presence of the live host plant and associated environmental conditions. Therefore, association with dormant rhizome can provide long term survival for this fungus.

Probability of distribution

The likelihood that hop-infecting *Verticillium* strains will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- Hop-infecting *Verticillium* strains arriving in Australia with imported dormant rhizome will not need to move from the import pathway to a suitable host as the fungus is already within a suitable host.
- Dormant rhizome would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected dormant rhizome commercially will facilitate the distribution of hop-infecting *Verticillium* strains.

Overall probability of entry (importation x distribution)

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

The likelihood that hop-infecting *Verticillium* strains will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.7.2 Probability of establishment

The likelihood that hop-infecting *Verticillium* strains will establish, based on a comparison of factors in the source and destination areas that affect fungal survival and reproduction is: **HIGH**.

- Association of hop-infecting *Verticillium* strains with rhizome provides a distinct epidemiological advantage to the fungus, as infected rhizome will result in infected plants (Gent *et al*. 2009). This will result in the establishment of this fungus in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production

within Australia; environmental conditions are likely to be conducive to disease development and establishment.

- Climate matching results illustrate that conditions in hop gardens in Australia are more closely aligned to those of the UK and the USA (Pethybridge *et al*. 2003). Hop-infecting *Verticillium* strains are present in these countries, suggesting that the pathogens would most likely establish if introduced into the hop production areas of Australia.

3.7.3 Probability of spread

The likelihood that hop-infecting *Verticillium* strains will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen: **HIGH**.

- Hop-infecting *Verticillium* strains can spread both independently and in association with infected planting material. The fungus also spreads systemically in the plant and invades leaves (Gent *et al*. 2009). Independent spread is facilitated by the production of conidia on infected tissues (Agrios 2005) which become air-borne and could spread through air currents (Fradin and Thomma 2006). Therefore, spread would be limited to the local area. Hop-infecting *Verticillium* strains can also spread in association with infected planting material (Gent *et al*. 2009; Mahaffee *et al*. 2009) and as such, long distance spread is facilitated by the commercial distribution of infected planting material.
- Infected rhizomes are unlikely to be grown in isolation, providing greater opportunity for the spread of hop-infecting *Verticillium* strains to other plants. Production of conidia on infected tissues (Agrios 2005) serve as the primary inocula, and the pathogen spreads to healthy leaves and shoots under appropriate environmental conditions (Fradin and Thomma 2006).
- *Verticillium dahliae* causes monocyclic disease where there is only one cycle of disease and inoculum production during a growing season (Fradin and Thomma 2006); whereas, *V. albo-atrum* causes polycyclic disease (Fradin and Thomma 2006). These pathogens are able to produce abundant conidia under ideal conditions and can cause the rapid spread of these pathogens (Fradin and Thomma 2006).
- The pathogens produce long-lived survival structures that can persist in soil and in the absence of a host, *V. albo-atrum* can survive three to four years in soil and *V. dahliae* can survive for 15 years or longer (Gent *et al*. 2009).

3.7.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that hop-infecting *Verticillium* strains will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **HIGH**.

3.7.5 Consequences

The consequences of the entry, establishment and spread of hop-infecting *Verticillium* strains in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: E** – significant at the regional level • Hop-infecting *Verticillium* strains, cause one of the most important fungal diseases of hop, Verticillium wilt (Radišek *et al*. 2003) and can cause significant crop damage under favourable environmental conditions (Jamnik *et al*. 2006, Radišek *et al*. 2003). • Disease severity is strongly influenced by the susceptibility of hop cultivars and environmental conditions, such as low soil temperatures and nitrogen fertilizer applications (Sewell and Wilson 1984). • Verticillium wilt on hop appears in mild or lethal forms (Radišek *et al*. 2003). The lethal form causes withering of hop, rapid death of leaves, side arms and plant death (Gent *et al*. 2009); whereas, with the mild form, plants continue to grow (Radišek *et al*. 2003). The lethal form of hop wilt is one of the most important diseases in hop, and in Europe has caused considerable economic damage in hop fields (Jamnik *et al.* 2006, Radišek *et al.* 2003). • Leaves on infected bines become yellow and die from the base up. Dying leaves usually show a tiger-stripe effect because bands of dark necrotic tissue alternate with yellow. Bines cut near the base of the hill usually show a light brown discoloration of woody tissue under the bark. Heavily infected plants die on the string, usually just before or at harvest. Fields infected with the mild form decline over a number of years while the virulent form will kill a plant in a couple of years or less (Ocamb and Gent 2010).
Other aspects of the environment	**Impact score: B** – minor significance at the local level • There are no known direct consequences of hop-infecting *Verticillium* strains on the natural or built environment. Based on restriction fragment length polymorphism (RFLP), sequencing of the internal transcribed spacer (ITS) of nuclear rDNA, and random amplified polymorphic DNA (RAPD), *Verticillium albo-atrum* isolates have been divided into two clear host-adapted groups, L (lucerne) and NL (all other hosts). Hop isolates causing mild or lethal wilt have also been placed in the NL group without differentiation with regard to their pathogenicity (Radišek *et al.* 2003).
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If hop-infecting *Verticillium* strains were introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Programs to minimise the impact of hop-infecting *Verticillium* strains are likely to be costly and include using resistant cultivars and changes in agronomic practices for sustainable production. Agronomic practices which may reduce the impact of the pathogen include using resistant cultivars, certified planting stock, low nitrogen regime and non-cultivation (Talboys 1987). These measures combined with statuary control measures and crop rotation of at least four years of non-host species (e.g. small grains, corn) can help to reduce levels of *V. albo-atrum* in the soil (Gent *et al*. 2009). • An eradication campaign for hop-infecting *Verticillium* strains, should they be detected early, is likely to be expensive as it would require eradication of susceptible hosts. Long-term management will probably be based on selection of genotypes that are immune or highly resistant; however, a long-term breeding and testing program will be expensive.
Domestic trade	**Impact score: D** – significant at district level • The presence of hop-infecting *Verticillium* strains in hop production areas (Tasmania and Victoria) is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.

Criterion	Estimate and rationale
International trade	**Impact score: D** – significant at the district level • The presence of hop-infecting *Verticillium* strains in Australian hop growing areas (Tasmania and Victoria) is likely to have a significant effect, due to limitations on access to overseas markets where hop-infecting *Verticillium* strains are absent.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level • Additional fungicide application or other control activities may be required to control and/or eradicate this pathogen. However, this is not considered to have significant consequences for the environment.

3.7.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'moderate' exceeds Australia's ALOP. Therefore, specific risk management measures are required for hop-infecting *Verticillium* strains.

3.8 'Candidatus Phytoplasma asteris'

Hop shoot proliferation disease has been reported in commercial hop crops in Poland causing severe proliferation of shoots (Solarska *et al*. 2004). This report was the first evidence that hop shoot proliferation disease is associated with natural infection by phytoplasma (Solarska *et al*. 2004). Subsequently, work on the disease's etiology has determined the causal agent to be aster yellows phytoplasma group 16SrI-B, or '*Candidatus* Phytoplasma asteris' (Mahaffee *et al*. 2009). The detection of the causal agent in asymptomatic hop highlights the need to fully elucidate the etiological role of this pathogen in the development of the disease (Solarska *et al*. 2004). Crops that are propagated vegetatively, such as hop, are particularly prone to damage by phytoplasmas as infection tends to build up in successive cycles of propagation.

3.81 Probability of entry

Probability of importation

The likelihood that '*Ca.* P. asteris' will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- '*Candidatus* Phytoplasma asteris' is a phloem-limited pathogen that inhabits phloem sieve elements in infected plants (Mahaffee *et al*. 2009). It has been detected in symptomatic as well as asymptomatic plants (Solarska *et al*. 2004), which may lead to the propagation and distribution of infected planting material, suggesting '*Ca.* L. asteris' could be introduced into Australia in infected rhizome.
- Phytoplasmas are known to be disseminated in cuttings and rhizomes taken from infected plants (Mahaffee *et al*. 2009).
- The primary conditions for survival of '*Ca.* P. asteris' are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for this phytoplasma.

Probability of distribution

The likelihood that '*Ca.* P. asteris' will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- '*Candidatus* Phytoplasma asteris' arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the pathogen is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of '*Ca.* P. asteris'.

Overall probability of entry (importation x distribution)

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

The likelihood that '*Ca.* P. asteris' will enter Australia as a result of imported propagative material from countries where the pathogen is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.8.2 Probability of establishment

The likelihood that '*Ca.* P. asteris' will establish, based on a comparison of factors in the source and destination areas that affect pathogen survival and reproduction is: **HIGH**.

- Association of '*Ca.* P. asteris' with infected rhizome provides a distinct epidemiological advantage to the phytoplasma as infected rhizome will result in numerous weak shoots (Mahaffee *et al*. 2009). This will result in the establishment of this phytoplasma in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- '*Candidatus* Phytoplasma asteris' has successfully established in the hop growing regions of Poland (Solarska *et al*. 2004). The current reported distribution of '*Ca.* P. asteris' suggests that there are similar environments in parts of Australia that would be suitable for its establishment.

3.8.3 Probability of spread

The likelihood that '*Ca.* P. asteris' will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of '*Ca.* P. asteris' relies on the movement of infective propagative material or phloem-feeding insect vectors (Mahaffee *et al*. 2009). Phytoplasmas are known to be disseminated in cuttings and rhizomes taken from infected plants (Mahaffee *et al*. 2009).
- Phytoplasmas are disseminated by certain species of leafhoppers (family Cicadellidae) and planthoppers (super family Fulgoroidea). Numerous polyphagous leafhoppers are able to transmit phytoplasmas (Mahaffee *et al*. 2009) and some of these potential vectors are widespread in Australia and will help spread '*Ca.* P. asteris' from infected plants to healthy ones. Some phytoplasmas have been recorded travelling hundreds of kilometres in vectors (Mahaffee *et al*. 2009).
- Dormant rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of '*Ca.* P. asteris'. Resultant plants are unlikely to be grown in isolation; infected shoots emerging from the infected rhizome will serve as the primary inocula; however, phloem feeders would be required to spread this pathogen (Mahaffee *et al*. 2009).

3.8.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that '*Ca.* P. asteris' will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE**.

3.8.5 Consequences

The consequences of the entry, establishment and spread of '*Ca.* P. asteris' in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • The severity of symptoms varies among plants, and some of the affected plants may remain symptomless. '*Candidatus* Phytoplasma asteris' produces symptoms on rhizome buds and shoots (Solarska *et al*. 2004). • Affected plants produce numerous weak shoots (Solarska *et al*. 2004; Mahaffee *et al*. 2009) and leaves are small, distorted and chlorotic. The most severely affected plants are stunted and do not produce flowers or produce only malformed flowers which cannot be used commercially. Later in the season, shoot proliferation, leaf necrosis and malformation, and premature death of plants may occur (Mahaffee *et al*. 2009).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level. If '*Ca.* P. asteris' was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Programs to minimise the impact of '*Ca.* P. asteris' on host plants are likely to be costly. An eradication campaign for '*Ca.* P. asteris', should it be detected early, is likely to be expensive as it would require eradication of infected plants. Removal of only symptomatic plants may allow nearby asymptomatic infected plants to remain in the hop yard. Therefore, plants adjacent to symptomatic plants would also need to be removed. • The presence of '*Ca.* P. asteris' in Australia would require testing for freedom in the production of nursery stock and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of '*Ca.* P. asteris' in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.

Criterion	Estimate and rationale
International trade	**Impact score: D** – significant at the district level • The presence of '*Ca.* P. asteris' in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent, such as New Zealand.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of '*Ca.* P. asteris'.

3.8.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for '*Ca.* P. asteris'.

3.9 Apple fruit crinkle viroid hop strain (AFCVd-hop)

Apple fruit crinkle viroid (AFCVd) has been detected in apples and hop in Japan (Sano *et al*. 2004). Apple fruit crinkle viroid hop strain (AFCVd-hop) produces symptoms similar to hop stunt viroid (Eastwell and Nelson 2007; Gent *et al*. 2009). Phylogenetic analysis of AFCVd from hop and AFCVd from apples together with the other members of the genus *Apscaviroid* revealed that isolates of AFCVd from hop (AFCVd-hop) formed a cluster that is distinct from AFCVd-apple (Sano *et al*. 2004). AFCVd-hop also shares high (ca. 85%) sequence homology with Australian grapevine viroid (Sano *et al*. 2004). The evidence strongly suggests that the three viroids, although isolated from (and specific to) different hosts, share a common ancestor (Sano *et al*. 2004). Apple fruit crinkle viroid (AFCVd) is not known to occur in Australia in either its hop (Pethybridge and Madden 2003) or fruit tree hosts (Constable *et al*. 2007). The distribution of AFCVd in hop grown outside of Japan is not known at this time. It is yet unclear whether AFCVd-hop originated in Japan or was introduced through contaminated scion stocks (Sano *et al*. 2004).

3.9.1 Probability of entry

Probability of importation

The likelihood that AFCVd-hop will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Viroids infect plants systemically (Hadidi *et al*. 2003) and have a long latent period before the appearance of discernible symptoms (Pethybridge *et al*. 2008). This frequently leads to the propagation and distribution of infected rhizomes (Sano *et al*. 2004; Pethybridge *et al*. 2008); suggesting AFCVd-hop could be introduced into Australia.
- The primary conditions for survival of AFCVd-hop are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the viroid.

Probability of distribution

The likelihood that AFCVd-hop will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- AFCVd-hop arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the viroid is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for further propagation. The distribution of infected propagative material commercially will facilitate the distribution of AFCVd-hop.

Overall probability of entry (importation x distribution)

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

The likelihood that AFCVd-hop will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.9.2 Probability of establishment

The likelihood that AFCVd-hop will establish, based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of AFCVd-hop with infected rhizome provides a distinct epidemiological advantage to the viroid as infected rhizome will result in infected shoots (Sano *et al*. 2004; Gent *et al*. 2009). This will result in the establishment of this viroid in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- The long latent period of infection before visible symptoms appear will result in non detection of the viroid (Sano *et al*. 2004). Therefore, AFCVd-hop will have ample time to establish into new areas.

3.9.3 Probability of spread

The likelihood that AFCVd-hop will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of AFCVd-hop depends on the movement of infective propagative material or mechanical transmission or pruning with contaminated tools or equipment (Sano *et al*. 2004). The long latent period of infection before visible symptoms appear may contribute to the inadvertent propagation and distribution of infected material that will help spread AFCVd-hop within the PRA area.
- Dormant rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of AFCVd-hop. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this viroid to spread to host plants by mechanical transmission (Sano *et al*. 2004). For example, the introduction of AFCVd-hop infected mother stock, propagated vegetatively in the nursery, and via the distribution of infected scion stocks resulted in the spread of AFCVd-hop in Japan (Sano *et al*. 2004).
- Modern agricultural practices, characterised by extensive plantation of genetically uniform species and intensive movement of germplasm globally, could facilitate the rapid spreading of viroids (Matousek *et al.* 2003).
- Once the viroid is established in a hop garden, mechanical transmission will help spread the viroid (Sano *et al*. 2004). The managed environment in Australian nurseries, garden

centres and private gardens are all favourable for the natural spread of AFCVd-hop. In the absence of statutory control AFCVd-hop can spread quickly in the PRA area by trade of host propagative material.

- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of AFCVd-hop. In the absence of statutory control AFCVd-hop can spread quickly in the PRA area by trade of host propagative material.

3.9.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that AFCVd-hop will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.9.5 Consequences

The consequences of the entry, establishment and spread of AFCVd-hop in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • Economic effects of viroid diseases depend on the local and global economic importance of the crop. Viruses and viroids pose significant constraints to the production of high yields of hop cultivars worldwide (Sano *et al*. 2004; Pethybridge *et al*. 2008). AFCVd-hop has been recorded occurring together with Hop latent viroid (HLVd) and Hop stunt viroid (HSVd). AFCVd-hop causes stunting and severe leaf curling in upper bines and cones from affected plants have considerably lower alpha acid making them less marketable for brewing (Sano *et al*. 2004). • Plants affected with Hop stunt viroid produce fewer and smaller cones with yields 50% lower than healthy plants (Pethybridge *et al*. 2008). It is expected that AFCVd-hop could cause similar crop loses which may rise significantly when the viroid is found in association with other virus species.
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level. If AFCVd-hop was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Knowledge of the viroid profile within a hop growing region is critical for developing management practices to ensure industry sustainability. The management of viroids requires quick identification and removal of infected plants to prevent further spread. Therefore programs to minimise the impact of AFCVd-hop on host plants are likely to be costly. • An eradication campaign for AFCVd-hop, should it be detected early, is likely to be expensive as it would require eradication of infected plants. As a result of the latency period, removal of only symptomatic plants may allow nearby infected plants to remain in the hop yard. Therefore, plants adjacent to symptomatic plants would also need to be removed. • The presence of AFCVd-hop in Australia would require testing for freedom in the production of propagative material and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of AFCVd-hop in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of AFCVd-hop in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent; as the species is only found in Japan, it is absent from most major hop growing regions (Eastwell and Nelson 2007).
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of AFCVd-hop.

3.9.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for AFCVd-hop.

3.10 Hop stunt hostuviroid (HpSVd) – hop strain

Viroids are small pathogenic RNA replicons which are fully dependent on the metabolism of host plants (Matousek *et al*. 2003). Most of the identified viroids form populations of molecular variants that conform to a quasi-species model (Eigen 1993). These molecular variants can adapt themselves to new hosts and life cycle-conditions. Hop stunt viroid (HpSVd) was first described as the causal agent of a stunt disease of hop in 1977 in Japan (Shikata 1990); and since then has been reported from Korea (Sano 2003) and the USA (Eastwell and Nelson 2007). Recently HpSVd has been reported from China on hop (Guo *et al*. 2008). A large number of HpSVd variants have now been isolated from several woody plants including almond (Canezaris *et al*. 1999), apricot (Ismaeil *et al*. 2001; El-Dougdoug *et al*. 2010), citrus, cucumber (Mahaffee *et al*. 2009), peach (Ismaeil *et al*. 2001; Zhou *et al*.

2006, El-Dougdoug *et al*. 2010), pear (El-Dougdoug *et al*. 2010), plum (Kusano and Shimomura 1997; Yang *et al*. 2007; El-Dougdoug *et al*. 2010) and pomegranate (Onelge 2000). HpSVd is latent in grapevine, apricot and pear (Ragozzino *et al.* 2004, El-Dougdoug *et al*. 2010) these hosts could represent a natural reservoir from which the viroid can potentially be transmitted to other susceptible host crops (El-Dougdoug *et al*. 2010).

3.10.1 Probability of entry

Probability of importation

The likelihood that HpSVd-hop will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Infected rhizome is the main pathway for the introduction of HpSVd-hop into new areas (Sano 2003). This mode of introduction is greatly enhanced because of long latency periods before conspicuous symptoms develop (Sano 2003; Mahaffee *et al*. 2009). Long latency periods can lead to the propagation and distribution of infected propagative material (Gent *et al*. 2009). Importation of infected rhizome from Japan introduced HpSVd-hop into Korea (Sano 2003). Therefore, infected rhizome can provide a pathway for the importation of HpSVd-hop into Australia.
- The primary conditions for survival of HpSVd-hop are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the viroid.

Probability of distribution

The likelihood that HpSVd-hop will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- HpSVd-hop arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the viroid is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of HpSVd-hop.

Overall probability of entry (importation x distribution)

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

The likelihood that HpSVd-hop will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.10.2 Probability of establishment

The likelihood that HpSVd-hop will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of HpSVd-hop with infected rhizome provides a distinct epidemiological advantage to the viroid as infected rhizome will result in infected shoots (Mahaffee *et al*. 2009; Gent *et al*. 2009). This will result in the establishment of this viroid in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- The long latent period of infection (3–5 growing seasons) before visible symptoms appear is likely to result in non detection of the HpSVd (Sano 2003; Mahaffee *et al*. 2009; Gent

et al. 2009). Therefore, HpSVd-hop will have ample time to establish into new areas undetected.

3.10.3 Probability of spread

The likelihood that HpSVd-hop will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of HpSVd-hop depends on the movement of infective propagative material or mechanical transmission or pruning with contaminated tools or equipment (Gent *et al*. 2009). The long latent period of infection (3–5 growing seasons) before visible symptoms appears (Sano 2003) may contribute to the inadvertent propagation and distribution of infected material that will help spread HpSVd-hop within the PRA area. For example, the distribution of HpSVd-hop infected mother stock, propagated vegetatively in the nursery, resulted in the spread of HpSVd-hop in Japan (Sano 2003).
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of HpSVd-hop. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this viroid to spread to host plants by mechanical transmission. Mechanical transmission of HpSVd-hop has been reported (Pethybridge *et al*. 2008).
- Modern agricultural practices characterised by extensive plantation of genetically uniform species and intensive movement of germplasm globally, could facilitate the rapid spread of viroids through mechanical transmission (Matousek *et al.* 2003). Once the viroid is established in a hop garden, mechanical transmission by workers, cutting tools, and equipment during cultural activities such as pruning, thinning, and mechanical leaf stripping (Gent *et al*. 2009) will help spread the viroid. Within hop yards, HpSVd spreads along rows, reflecting the role of cultural operations in transmission (Pethybridge *et al*. 2008).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of HpSVd-hop. In the absence of statutory control HpSVd-hop can spread quickly in the PRA area by trade of host propagative material.

3.10.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that HpSVd-hop will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.10.5 Consequences

The consequences of the entry, establishment and spread of HpSVd-hop in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • HpSVd-hop is considered an important viroid of hop and is recognized as a serious impediment to hop production in Japan (Sano 2003). This species is a newly recognized pathogen in North America that poses a serious threat to hop production (Eastwell and Nelson 2007). • The severity of symptoms is dependent on the hop variety and the weather. Hop stunt disease is recognised through the deterioration in growth of infected hop bines (Sano 2003). Typical symptoms include stunting, leaf curling, and small cones. In general, stunting is more severe in warmer climates (Eastwell and Nelson 2007). Stunting appears 3–5 years after established plants become infected, thereby facilitating the unwitting propagation of infected plants (Eastwell and Nelson 2007). • Stunting results from the shortening of internodes of the main bine and of the lateral branches. The degree of stunting is temperature dependent, and more severe stunting occurs in warmer regions. Inhibition of the development of hooks and barbs on bine impedes the ability of infected plants to climb, enhancing the appearance of stunting (Pethybridge *et al*. 2008). Infected leaves droop severely from the basal part of the petioles and the edges of the leaves curl downward (Pethybridge *et al*. 2008). • Yield of affected plants can be reduced. Infected plants produce fewer and smaller cones with yields 50% lower than healthy plants (Pethybridge *et al*. 2008).
Other aspects of the environment	**Impact score: B** – minor significance at the local level There may be some impact on insect or animal species that feed on host plants due to the reduced availability or vigour of these host plants. • In general, newly established species may affect the environment in a number of ways. Introduced species may reduce biodiversity, disrupt ecosystem function, jeopardize endangered or threatened plants, degrade critical habitat or stimulate use of chemicals or biological controls. There may be some impact on insect or animal species that feed on host plants due to the reduced availability or vigour of these host plants. • HpSVd-hop is unlikely to affect the environment in these ways, as the viroid infects only in hop.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If HpSVd-hop was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Knowledge of the viroid profile within a hop growing region is critical for developing management practices to ensure industry sustainability. The management of viroids requires quick identification and removal of infected plants to prevent further spread. Therefore, programs to minimise the impact of HpSVd-hop on host plants are likely to be costly. • An eradication campaign for HpSVd-hop, should it be detected early, is likely to be expensive as it would require eradication of infected plants. As a result of the long latency period, removal of only symptomatic plants may allow nearby infected plants to remain in the hop yard. Therefore, plants adjacent to symptomatic plants would also need to be removed. • The presence of HpSVd-hop in Australia would require testing for freedom in the production of seed and nursery stock, and planting resistant cultivars. This would add significant costs to hop production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of HpSVd-hop in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.

Criterion	Estimate and rationale
International trade	**Impact score: D** – significant at the district level • Economic effects of viroids diseases depend on the local and global economic importance of the crop. HpSVd-hop is considered a serious pathogen in Japan (Sano 2003) and North America (Eastwell and Nelson 2007). The presence of HpSVd-hop in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent; for example, Europe, New Zealand and South America (Eastwell and Nelson 2007).
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of HpSVd-hop.

3.10.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for HpSVd-hop.

3.11 Alfalfa mosaic virus (AMV)-hop strain

Alfalfa mosaic virus (AMV) was first reported on hop in the former Czechoslovakia (Novák and Lanzová 1976). An AMV-like virus has also been reported from China on the hop cultivar 'Golding' causing chlorosis. This cultivar was introduced to China from the former Yugoslavia in 1981 (Yu and Liu 1987). Virus particles isolated from cultivar 'Golding' are similar to Alfalfa mosaic virus in morphology but differs from it in host range, symptoms and serology (Yu and Liu 1987). Alfalfa mosaic virus occurs frequently in field crops grown in North America, but confirmed reports of infection of hop plants are absent (Gent *et al*. 2009). The taxonomy of AMV has been questioned as AMV (the sole member of the genus *alfamovirus*) shares the biological trait of genome activation with *ilarviruses* (Shiel and Berger 2000). It has been suggested that present taxonomy should be revised and that AMV should be considered an aphid-transmissible *ilarvirus* (Shiel and Berger 2000). The *ilarviruses* considered important in hop yards include Apple mosaic virus (Bock 1966, 1967; Crowle *et al*. 2003) and Humulus japonicus latent virus (Brunt *et al*. 1996).

3.11.1 Probability of entry

Probability of importation

The likelihood that AMV-hop will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- The pathogen infects plant systemically (Yu and Liu 1987) therefore rhizome sourced from infected plants can provide a pathway for the importation of AMV-hop into Australia.
- The primary conditions for survival of AMV-hop are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for virus.

Probability of distribution

The likelihood that AMV-hop will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- AMV-hop arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of AMV-hop.

Overall probability of entry (importation x distribution)

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

The likelihood that AMV-hop will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.11.2 Probability of establishment

The likelihood that AMV-hop will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of AMV-hop with rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected shoots. This will result in the establishment of this virus in new areas. Rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- AMV-hop is a systemic pathogen (Yu and Liu 1987); following local infection viruses can move into adjacent cells and infect the phloem. Long distance movement to the meristems occurs followed by invasion of neighbouring parenchyma cells. Virus infection leads to the production of systemic symptoms which appear first in leaves growing near the apical meristem (Bos 1999).
- Symptoms depend greatly on virus strain, host variety and stage of growth, and environmental conditions. Infection may be latent or masked and recovery often occurs (Jasper and Bos 1980). Symptoms of AMV-hop have only been produced on the cultivars ‘Golding’ and ‘Styrian’ (Yu and Liu 1987). On other hop cultivars the virus may be symptomless and may result in non-detection of the virus. Therefore, AMV-hop will have ample time to establish into new areas.

3.11.3 Probability of spread

The likelihood that AMV-hop will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of AMV-hop depends on the movement of infective propagative material, mechanical transmission or vectoring by aphids (Jasper and Bos 1980). AMV-hop produces visually obvious symptoms on the cultivars ‘Golding’ and ‘Styrian’ (Yu and Liu 1987); and may be symptomless in other cultivars. This may contribute to the inadvertent propagation and distribution of infected material that will help spread AMV-hop within the PRA area.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of AMV-hop. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of AMV-hop has been reported (Yu and Liu 1987).

- Alfalfa mosaic virus (AMV) is vector-transmitted (Jasper and Bos 1980) by several aphid species (Mahaffee *et al.* 2009). *Macrosiphon euphorbiae* and *Myzus persicae* are both known to transmit hop viruses in Australia (Crowle *et al.* 2006) and may also be capable of transmitting AMV-hop in Australian hop yards.
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of AMV-hop. In the absence of statutory control AMV-hop can spread quickly in the PRA area by trade of host propagative material.

3.11.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that AMV-hop will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.11.5 Consequences

The consequences of the entry, establishment and spread of AMV-hop in Australia have been estimated according to the methods described in Tables.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C –** significant at the local level Losses by viruses result from a reduction in growth, which leads to reduced plant size or even stunting and finally to yield loss or crop failure (Bos 1999). • AMV-hop cause chlorosis and distortion of the leaves, stunt growth, tip die-back and necrosis on the hop cultivar 'Styrian' (Yu and Liu 1989) and is expected to have similar effects on other hop cultivars, depending on susceptibility. • AMV-hop shares the biological trait of genome activation with *ilarviruses* and is closely related to Apple mosaic virus (Shiel and Berger 2000). No information is available on AMV-hop causing damage in its natural host. However, AMV-hop is expected to behave in a similar way to the related species (Apple mosaic *ilarvirus*) which is known to cause significant reductions in hop (Pethybridge *et al*. 2008). Infection by Apple mosaic virus is reported to reduce yield by 16% (Pethybridge *et al*. 2008).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If AMV-hop was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Virus control measures in the field are limited and any eradication attempt may not be commenced until an outbreak is detected at an early stage. An eradication campaign for AMV-hop is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected hop plants would need to be removed and replaced. • The presence of AMV-hop in Australia would require testing for freedom in the production of seed and nursery stock and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score**: **D** – significant at district level • The presence of AMV-hop in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of AMV-hop in Australia is likely to have a significant effect at district level, due to limitations on access to overseas markets where this pathogen is absent. Currently this virus is reported only from the former Czechoslovakia (Novák and Lanzová 1976) and China (Yu and Liu 1987); it is not present in most major hop producing regions.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of AMV-hop.

3.11.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for AMV–hop.

3.12 American hop latent virus (AHLV)

American hop latent virus (AHLV) was first described 1976 and has a limited distribution along with other viruses (Gent *et al.* 2009). AHLV along with two other viruses (Hop mosaic virus and Hop latent virus) poses significant constraints to the production of high yields of hop cultivars worldwide (Gent *et al*. 2009). AHLV is common in the United States in commercial hop yards (Pethybridge *et al*. 2008) but generally occurs at a lower frequency than Hop mosaic virus (HpMV) and Hop latent virus (HpLV) (Probasco and Skotland 1976). AHLV occurs in mixed infections with Hop mosaic virus and Hop latent virus and the viruses can be distinguished by serological means (Pethybridge *et al*. 2009). AHLV, HpMV and HpLV are principally spread between hop plants by aphid vectors and by mechanical means (Adams and Barbara 1982; Legg 1965).

3.12.1 Probability of entry

Probability of importation

The likelihood that AHLV will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Infected rhizome is the main pathway for the introduction of AHLV into new areas (Mahaffee *et al*. 2009). This mode of introduction is greatly enhanced because AHLV does not cause visually obvious symptoms on any commercial hop varieties (Gent *et al*. 2009). This is likely to lead to the propagation and distribution of infected propagative material. American hop latent *virus* (AHLV) has been intercepted in post entry quarantine of hop breeding material in Australia, Germany and the United Kingdom (Pethybridge *et al*. 2008). Therefore, infected rhizome can provide a pathway for the importation of AHLV into Australia.
- The primary conditions for survival of AHLV are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the virus.

Probability of distribution

The likelihood that AHLV will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- AHLV arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of AHLV.

Overall probability of entry (importation x distribution)

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

The likelihood that AHLV will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.12.2 Probability of establishment

The likelihood that AHLV will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of AHLV with infected rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected shoots (Mahaffee *et al*. 2009; Gent *et al*. 2009). This will result in the establishment of this virus in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- AHLV does not produce visually obvious symptoms on any commercial hop varieties (Gent *et al*. 2009) and will result in non detection of the AHLV (Mahaffee *et al*. 2009; Gent *et al*. 2009). Therefore, AHLV will have ample time to establish into new areas undetected.

3.12.3 Probability of spread

The likelihood that AHLV will spread, based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of AHLV depends on the movement of infective propagative material or mechanical transmission or by aphids (Gent *et al*. 2009). AHLV does not produce visually obvious symptoms on any commercial hop varieties (Gent *et al*. 2009) and this may contribute to the inadvertent propagation and distribution of infected material that will help spread AHLV within the PRA area. For example, the interception of AHLV in post entry quarantine of hop breeding material in Australia, Germany and the United Kingdom (Pethybridge *et al*. 2008), suggests the virus has the ability to overcome natural physical barriers through trade in infected propagative material.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of AHLV. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of AHLV has been reported (Gent *et al*. 2009) and AHLV has been transmitted by plant contact (Pethybridge *et al*. 1999). Analyses of closely related hop mosaic virus and hop latent virus epidemics in Australia strongly suggest the role of mechanical transmission through agronomic activities such as mowing of basal growth (Pethybridge *et al*. 1999).
- American hop latent virus is not seed-borne (Pethybridge *et al*. 2008) but is vector-transmitted (Gent *et al*. 2009). However, the natural aphid vector, *Phorodon humuli* is not present in Australia (Pethybridge *et al*. 2008). As most viruses transmitted non-persistently by aphids have multiple vectors, it is possible that a much wider range of aphids and perhaps transient visitors also play a role in hop carlavirus transmission (Pethybridge and Madden 2003; Pethybridge *et al*. 2004).
- *Macrosiphum euphorbiae* and *Myzus persicae* both vector closely related Hop mosaic virus and Hop latent virus (Adam and Barbara 1980; 1982; Crowle *et al*. 2006) and are present in Australia. These vector species are likely to be important in spreading AHLV in Australian hop yards where *Phorodon humuli* is not known to occur (Hay *et al*. 1992; Pethybridge *et al*. 2004).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of AHLV. In the absence of statutory control AHLV can spread quickly in the PRA area by trade of host propagative material.

3.12.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that AHLV will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.12.5 Consequences

The consequences of the entry, establishment and spread of AHLV in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • There are limited data on the influence of individual viruses (AHLV, HpMV, HpLV) on hop growth, yield, and product quality due to the high natural incidence of co-infections with multiple viruses and viroids (Pethybridge *et al*. 2008). • AHLV is considered an important virus of hop (Pethybridge *et al*. 2008) and along with the closely related Hop mosaic virus and Hop latent virus poses significant constraints to the production of high yields of hop cultivars worldwide (Pethybridge *et al*. 2008; Gent *et al.* 2009). • AHLV does not produce visually obvious symptoms on any commercial hop varieties (Gent *et al*. 2009) and occurs in mixed infections with Hop mosaic virus and Hop latent virus. The viruses can be distinguished by serological means (Pethybridge *et al*. 2009). Significant reductions in yield from mixed infections have also been reported in commercial yards (Pethybridge *et al*. 2008).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If AHLV was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Virus control measures in the field are limited and any eradication attempt may not be commenced until an outbreak is detected at an early stage. An eradication campaign for AHLV is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected hop plants would need to be removed and replaced. • The presence of AHLV in Australia would require testing for freedom in the production of nursery stock and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of AHLV in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of AHLV in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent; for example, Europe, Japan and South America (Pethybridge *et al*. 2008).
Environmental and non-commercial	**Impact score: B** – minor significance at the local level • Additional insecticide application or other control activities may be required to control aphids which can vector the virus. However, this is not considered to have significant consequences for the environment.

3.12.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for AHLV.

3.13 Arabis mosaic virus-hop strain (ArMV–H)

Hop strain of Arabis mosaic virus (ArMV-H) has been reported in commercial hop yards in many countries including Belgium, the former Czechoslovakia, France, Germany, New Zealand, Poland, Russia, South Africa and the United Kingdom (Pethybridge *et al*. 2008). In Australia and the United States, there are historical, but no recent reports of ArMV-H or disease symptoms attributed to this virus, suggesting it has been eradicated (Pethybridge *et al*. 2008). The absence of the nematode vector and the adoption of new varieties bred in the United States have contributed to the apparent elimination of ArMV from current US production areas (Gent *et al*. 2009). In Australia, eradication has been attributed to a widespread shift from imported English varieties to the locally bred cultivar Pride of Ringwood and the absence of the nematode vector (Munro 1987). Arabis mosaic virus-hop is also transmitted by dodder and is seed-borne in hop (Murant 1970; Pethybridge *et al*. 2008). Plants infected with ArMV-H can display a diversity of symptoms including barebine or spidery hop, split leaf blotch, nettlehead, and hop chlorotic disease (Thresh and Pitcher 1978). However, in Germany (McNamara and Eppler 1989) and New Zealand (Hay *et al*. 1992), infection by ArMV-H was latent. This suggests differences in cultivar susceptibility and variation in the pathogenicity of isolates (Pethybridge *et al*. 2008).

3.13.1 Probability of entry

Probability of importation

The likelihood that ArMV-H will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Infected rhizome is the main pathway for the introduction of ArMV-H into new areas (Mahaffee *et al*. 2009; Pethybridge *et al*. 2008). This mode of introduction is greatly enhanced because ArMV-H may be latent (McNamara and Eppler 1989; Hay *et al*. 1992) and may lead to the propagation and distribution of infected propagative material. ArMV-H was introduced to Australia through hop breeding from the United Kingdom and was subsequently eradicated (Wade 1962; Pethybridge *et al*. 2008). Therefore, infected rhizome can provide a pathway for the importation of ArMV-H into Australia.
- The primary conditions for survival of ArMV-H are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for virus.

Probability of distribution

The likelihood that ArMV-H will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- ArMV-H arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.

- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of ArMV-H.

Overall probability of entry (importation x distribution)

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

The likelihood that ArMV-H will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.13.2 Probability of establishment

The likelihood that ArMV-H will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of ArMV-H with infected rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected shoots (Mahaffee *et al*. 2009; Gent *et al*. 2009). This will result in the establishment of this virus in new areas. Additionally, rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- ArMV-H may be latent (McNamara and Eppler 1989; Hay *et al*. 1992) which will result in the non-detection of ArMV-H. Therefore, ArMV-H will have ample time to establish in new areas undetected. ArMV-H was once accidentally introduced and established in Australia (Pethybridge *et al*. 2008), suggesting favourable climatic conditions for establishment of ArMV-H.

3.1.3.3 Probability of spread

The likelihood that ArMV-H will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **MODERATE**.

- The natural spread of ArMV-H depends on the movement of infective propagative material or by the nematode vector or by dodder (Pethybridge *et al*. 2008; Gent *et al*. 2009). ArMV-H may be latent (McNamara and Eppler 1989; Hay *et al*. 1992) and this may contribute to the inadvertent propagation and distribution of infected material that will help spread ArMV-H within the PRA area. For example, the introduction of ArMV-H through hop breeding from the United Kingdom into Australia (Wade 1962; Pethybridge *et al*. 2008), suggests the virus has the ability to overcome natural physical barriers through trade in infected propagative material.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of ArMV-H. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. However, there are conflicting reports as to whether ArMV-H is mechanically transmissible in hop (Davies and Clark 1983; Pethybridge *et al*. 1999). There is some evidence of pollen transmission for ArMV-H but further work is required to substantiate this finding (Pethybridge *et al*. 1999).
- Arabis mosaic virus-hop (ArMV-H) is also transmitted by dodder and is seed-borne in hop (Murant 1970; Pethybridge *et al*. 2008). The species is also vector-transmitted (Pethybridge *et al*. 2008; Gent *et al*. 2009). The natural nematode vector, *Xiphinema*

diversicaudatum (Valdez *et al.* 1974), is not present in Australia (EPPO 2006; CABI 2010). Other nematode species have been implicated in the spread of ArMV-H; however, confirmation of their role in vectoring the virus is yet to be provided (Trudgill *et al*. 1983).

- In the absence of vectors, spread of ArMV-H in the PRA area would rely on mechanical transmission (Davies and Clark 1983; Pethybridge *et al*. 1999) or the movement of infected propagative material (Mahaffee *et al*. 2009; Pethybridge *et al*. 2008; Murant 1970).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of ArMV-H. In the absence of statutory control ArMV-H can spread quickly in the PRA area by trade of host propagative material.

3.13.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that ArMV-H will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.13.5 Consequences

The consequences of the entry, establishment and spread of ArMV-H in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • ArMV-H is considered an important virus in hop growing regions where its nematode vector is present (Pethybridge *et al*. 2008). For example, in the United Kingdom, where the nematode vector is indigenous, infection by ArMV-H is reported to reduce yield by 23% to 26% (Pethybridge *et al*. 2008). • Plants infected with ArMV-H can display a range of symptoms including barebine or spidery hop, split leaf blotch, nettlehead, and hop chlorotic disease (Thresh and Pitcher 1978). • Plants with barebine or spidery hop recovered following the removal of weak shoots during training, but often develop split leaf blotch or nettlehead later in the season. Severe blotch has been demonstrated to reduce cone yield by up to 50% (Thresh and Pitcher 1978). Development and maturation of cones is significantly delayed on affected bines (Gent *et al*. 2009).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If ArMV-H was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • The absence of the vector for ArMV-H (*Xiphinema diversicaudatum*) in Australia, suggests adequate control can be achieved by the use of virus-free plants for propagation. • Virus control measures in the field are limited and eradication may not occur until after an outbreak is detected at an early stage. An eradication campaign for ArMV-H is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected hop plants would need to be removed and replaced. • The presence of ArMV-H in Australia would require testing for freedom in the production of seed and nursery stock and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of ArMV-H in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of ArMV-H in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent; for example, Japan, Romania and the USA. This virus is a quarantine pest in North America and China (Pethybridge *et al*. 2008).
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of ArMV-H.

3.1.3.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for ArMV-H.

3.14 Cherry leaf roll virus (CLRV)

Cherry leaf roll virus (CLRV) has a wide host range including a range of herbaceous and woody plants (Bandte and Büttner 2001; Rebenstorf *et al*. 2006; Buchhop *et al*. 2009). CLRV isolates from different hosts may differ in their serological and molecular traits (Jones 1985; Jones *et al*. 1990; Rebenstorf *et al*. 2006) as well as in their host specificity and ability to induce symptoms (Jones 1973; Rowhani and Mircetich 1988). A strong relationship between the original host, serology and sequence based phylogeny has been demonstrated (Rebenstorf *et al*. 2006). CLRV isolates segregate into six major groups based on primary host; birch and cherry (group A), rhubarb, ash and ground elder (group B), raspberry, sorrel and chive (group C), walnut (groups D1 and D2) and elderberry (group E) (Rebenstorf *et al*. 2006). However, CLRV isolates are not arranged exclusively within phylogenetic clusters according to originating host plant species, corroborating the observations, that CLRV isolates are capable

of infecting not only one host, but could be transmitted between different plant species (Jones 1973).

Cherry leaf roll virus was described from hop in the UK after mechanical transmission on indicator plants (Clark 1975). This isolate is related to, but serologically distinct from, those obtained from cherry, blackberry and elderberry (Clark 1975). In Australia CLRV has only been reported from rhubarb and this isolate was identified using sequencing; the Australian isolate is substantially different from other important strains (Parmenter *et al*. 2009). Although strains of CLRV could be host specific (Rebenstorf *et al*. 2006; Buchhop *et al*. 2009), CRLV isolates can be transmitted between different plant species (Jones 1973).

3.14.1 Probability of entry

Probability of importation

The likelihood that CLRV will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation (Bos 1999) are infected. Therefore, rhizome sourced from infected plants can provide a pathway for the importation of CLRV into Australia. This mode of introduction is greatly enhanced because CLRV does not produce symptoms on hop (Clark 1975) and may lead to the propagation and distribution of infected propagative material unintentionally.
- The primary conditions for survival of CLRV are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the virus.

Probability of distribution

The likelihood that CLRV will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- CLRV arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of CLRV.

Overall probability of entry (importation x distribution)

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

The likelihood that CLRV will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.14.2 Probability of establishment

The likelihood that CLRV will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of CLRV with the rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected plants. This will result in the establishment of this virus in new areas. Rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.

- CLRV is widely distributed and naturally infects a wide range of herbaceous and woody hosts (Buchhop *et al*. 2009). CLRV infecting hop has only been reported from the UK (Clark 1975). The current reported distribution of CLRV suggests that there are similar environments in parts of Australia that would be suitable for its establishment.
- The virus infects a variety of deciduous trees and shrubs in temperate regions and has a wide host range within several different plant families including common birch, black elderberry, English walnut and sweet cherry (Rebenstorf *et al*. 2006). These economically important hosts are widely distributed in the PRA area.
- CLRV is asymptomatic in hop (Clark 1975) which will result in the non-detection of CLRV; therefore the pathogen will have ample time to establish into new areas.

3.14.3 Probability of spread

The likelihood that CLRV will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of CLRV depends on the movement of infective propagative material, seed or pollen. CLRV is symptomless in hop (Clark 1975) and this may contribute to the inadvertent propagation and distribution of infected material that will help spread CLRV within the PRA area. Pollen transmission is a possible pathway for distribution locally (Cooper *et al*. 1984). Strains in walnut and birch can be pollen-transmitted to receptive host plants (Mircetich *et al*. 1980; Cooper *et al*. 1984). However, no information is available on this mode of transmission in hop or other natural hosts.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of CLRV. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of CLR has been reported (Clark 1975).
- CLRV is transmitted via pollen and seed in nature (Massalski and Cooper 1984) allowing effective intra-specific dispersal of the virus. CLRV is seed-borne in several plant species including birch (Buttner *et al*. 1996), walnut (Quacquarelli and Savino 1977; Topchiiska 1993), black cherry (Schimanski *et al*. 1976) olive (Saponari *et al*. 2002) and wild potato (Crosslin *et al*. 2010); however, there is no published information to confirm it is seed-borne in hop.
- Unlike many nepoviruses, CLRV appears not to be transmitted by soil-inhabiting nematodes (Jones *et al*. 1981); however, the rate at which the virus has recently spread in Finland indicates other significant routes of virus dispersal are likely to exist (Jalkanen *et al*. 2007).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of CLRV. In the absence of statutory control CLRV can spread quickly in the PRA area by trade of host propagative material.

3.14.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that CLRV will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.14.5 Consequences

The consequences of the entry, establishment and spread of CLRV in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C** – significant at the local level Cherry leaf roll virus (CLRV) is an economically important virus due to its extensive host range and the economic losses it can cause (Buchhop *et al*. 2009). • CLRV can lead to economic losses in walnut production by inducing walnut blackline disease, which causes necrosis at grafting unions with some English walnut and rootstock combinations (Mircetich *et al*. 1980). This may lead to subsequent dieback, a common disease symptom especially of woody plants, characterized by progressive death of twigs, branches, shoots, or roots, starting at the tips. Significant economic losses due to walnut blackline disease have been reported from California (Brooks and Bruening 1995; Mircetich *et al*. 1980). • CLRV can cause decline and dieback in sweet cherry (Kegler *et al.* 1966). In raspberry in New Zealand, CLRV infection is associated with severe stunting; fruiting canes contain small, distorted leaves, some with line-pattern symptoms, severe chlorotic mottling or ringspots (Jones and Wood 1978). • CLRV was detected recently in birch trees in Finland and has been regarded as of economic importance (Jalkanen *et al*. 2007). Symptomatic birches showing vein banding, leaf roll and chlorosis with subsequent necrosis were found from the southern coast of Finland to the conifer tree-line area in northern Finland, in the sub arctic zone of northern Norway as well as in Sweden (Jalkanen *et al*. 2007).
Other aspects of the environment	**Impact score: C** – significant at the local level • CLRV infects naturally a wide range of herbaceous and woody plants, among which are *Betula* spp., *Fagus* spp., *Fraxinus* spp., *Juglans* spp., *Ulmus* spp., *Rhamnus* spp., *Sambucus* spp., *Prunus* spp. as well as *Ligustrum vulgare*., *Ptelea trifoliata* and *Cornus florida* (Bandte and Büttner 2001; Rebenstorf *et al*. 2006; Buchhop *et al*. 2009). Its presence in Australia may have significant impact on urban managed environments at the local level.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If CLRV was introduced to hop growing regions of Australia (Tasmania and Victoria), it is unlikely to change the management or variable costs of growing hop. It is likely to impose yield reductions and increased production costs on other susceptible crops. • Virus control measures in the field are limited and eradication may not be until an outbreak is detected at an early stage. An eradication campaign for CLRV is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected plants would need to be removed and replaced. • The transmission of CLRV by pollen makes its spread in crops difficult to control except by the use of plants immune or resistant to infection. In the absence of resistant material, healthy planting material should be used in areas free from known infection with CLRV in the crop species planted. The virus can be eliminated from some plants by meristem tip culture and by maintaining seedlings for 7 days at 40 °C or 20 days at 32 °C (Cooper and Walkey 1978). • The presence of CLRV in Australia would require testing for freedom in the production of nursery stock hosts and planting resistant cultivars. This would add significant costs to nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at local level • The presence of CLRV in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the local level • The presence of CLRV in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent. For example, New Zealand and the European Union require testing for CLRV in hop propagative material (NZMAF 2009; OEPP/EPPO 2008).
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of CLRV.

3.14.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for CLRV.

3.15 Humulus japonicus latent virus (HJLV)

Humulus japonicus latent virus (HJLV) was first reported from *Humulus japonicus* from the UK in seedlings grown from seed imported from China (Adams *et al*. 1989). In China this virus has been found to be common and systemic in *H. lupulus* and *H. japonicus* (Adams *et al.* 1989) and may occur without obvious visual symptoms (Gent *et al*. 2009). Symptomless infection of commercial hop plants is of concern because production losses from this virus are unknown (Gent *et al*. 2009). The effect of the viruses on yield and quality is strongly influenced by cultivar susceptibility and therefore requires assessment for each newly adopted cultivar (Pethybridge *et al*. 2008).

3.15.1 Probability of entry

Probability of importation

The likelihood that HJLV will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- The pathogen is systemic (Adams *et al.* 1989) and symptomless in the infected plant (Gent *et al*. 2009); therefore, infected dormant rhizome can provide a pathway for the importation of HJLV into Australia. This mode of introduction is greatly enhanced because HJLV does not produce symptoms on cultivated or wild hop (Mahaffee *et al.* 2009) and may lead to the propagation and distribution of infected propagative material.
- HJLV is seed-borne and was introduced to the UK through hop seed from China and was subsequently eradicated (Adams *et al.* 1989; Pethybridge *et al*. 2008). Therefore, seed can provide a pathway for the importation of HJLV into Australia.
- The primary conditions for survival of HJLV are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for virus.

Probability of distribution

The likelihood that HJLV will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- HJLV arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of HJLV.

Overall probability of entry (importation x distribution)

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

The likelihood that HJLV will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.15.2 Probability of establishment

The likelihood that HJLV will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of HJLV with infected rhizome or seed provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected shoots; and seedlings developing from seed will result in systemically infected plants (Adams *et al*. 1989; Mahaffee *et al*. 2009; Gent *et al*. 2009). This will result in the establishment of this virus in new areas. Rhizomes or seeds will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- HJLV is systemic (Adams *et al.* 1989) and symptomless in the infected plant (Gent *et al*. 2009) which is likely to result in the non-detection of HJLV. Therefore, HJLV will have ample time to establish into new areas undetected.

3.15.3 Probability of spread

The likelihood that HJLV will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of HJLV depends on the movement of infective propagative material, mechanical transmission or vectoring by thrips (Mahaffee *et al*. 2009; Gent *et al*. 2009). HJLV does not produce visually obvious symptoms on cultivated or wild hop varieties (Adams *et al*. 1989; Gent *et al*. 2009); this may contribute to the inadvertent propagation and distribution of infected material that will help spread HJLV within the PRA area. For example, the interception of HJLV in hop breeding material in the UK from China (Pethybridge *et al*. 2008), suggests the virus has the ability to overcome natural physical barriers through trade in infected propagative material.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of HJLV. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of HJLV has been reported (Mahaffee *et al*. 2009).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of HJLV. In the absence of statutory control HJLV can spread quickly in the PRA area by trade of host propagative material.

3.15.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that HJLV will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.15.5 Consequences

The consequences of the entry, establishment and spread of HJLV in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • Viruses and viroids pose significant constraints to the production of high yields of hop cultivars worldwide and *ilarviruses* are considered an important virus group (Bock 1966, 1967; Crowle *et al*. 2003). No information is available on HJLV causing damage in its natural host. However, HJLV is expected to behave in a similar way to the related species, Apple mosaic *ilarvirus*, which is known to cause significant reductions in hop (Pethybridge *et al*. 2008). Infection by HJLV is reported to reduce yield by 16% (Pethybridge *et al*. 2008). • Symptomless infection of commercial hop plants is of concern because production losses from this virus are unknown (Gent *et al*. 2009). The effect of the viruses on yield and quality is strongly influenced by cultivar susceptibility and therefore requires assessment for each newly adopted cultivar (Pethybridge *et al*. 2008).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If HJLV was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies. • Virus control measures in the field are limited and eradication may not be feasible unless an outbreak is detected at an early stage. An eradication campaign for HJLV is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected hop plants would need to be removed and replaced. • The presence of HJLV in Australia would require testing for freedom in the production of seed and nursery stock and planting resistant cultivars. This would add significant costs to hop nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of HJLV in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of HJLV in Australia is likely to have a significant effect at district level, due to limitations on access to overseas markets where this pathogen is absent. This species has a limited distribution suggesting possible impacts on a number of export markets.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of HJLV.

3.15.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for HJLV.

3.16 Petunia asteroid mosaic virus (PetAMV)

Petunia asteroid mosaic virus (PetAMV) was first found in petunia in 1954 and since then has been reported mainly from woody hosts (cherries, plums, grapes, privet and dogwood), from hop, spinach, and from the roots of *Chenopodium album*, *Cucumis melo*, *Plantago major* and *Stellaria media* (Lovisolo 1990). The virus is soil-borne due to its high concentration in roots, natural leaching of virus particles from roots, rather long persistence in soil and mechanical transmissibility (Lovisolo 1990). This virus occurs in Asia, Europe and North America; however, on hop it is reported only from the former Czechoslovakia (Gent *et al*. 2009; Mahaffee *et al.* 2009). Petunia asteroid mosaic virus (PetAMV) occurs in field crops grown in North America, but confirmed reports of infection of hop plants are absent (Gent *et al*. 2009).

3.16.1 Probability of entry

Probability of importation

The likelihood that PetAMV will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- PetAMV is found in the root zones of host plants (Lovisolo 1990; Pfeilstetter *et al.* 1996); therefore, infected rhizome is a potential pathway for the introduction of PetAMV into new areas.
- The primary conditions for survival of PetAMV are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the virus.

Probability of distribution

The likelihood that PetAMV will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present: **HIGH**.

- PetAMV arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of PetAMV.

Overall probability of entry (importation x distribution)

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

The likelihood that PetAMV will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.16.2 Probability of establishment

The likelihood that PetAMV will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of PetAMV with rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected plants. This will result in the establishment of this virus in new areas. Rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.

- PetAMV is widely distributed and has successfully established in many countries, especially in Europe (Smith *et al.* 1988); however, on hop it is reported only from the former Czechoslovakia (Mahaffee *et al.* 2009). The current reported distribution of PetAMV suggests that there are similar environments in parts of Australia that would be suitable for its establishment.
- The virus infects plants species in 3–9 plant families (Mahaffee *et al.* 2009). Important hosts include hop, cherry, petunia, plum and spinach (BIOREBA 2009). These economically important hosts are widely distributed in the PRA area.

3.16.3 Probability of spread

The likelihood that PetAMV will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pathogen is: **MODERATE**.

- The natural spread of PetAMV depends on the movement of infective propagative material, mechanical transmission or by infected soil (Lovisolo 1990; Pfeilstetter *et al.* 1996). PetAMV is primarily found in the root zone (Lovisolo 1990; Pfeilstetter *et al.* 1996); this may contribute to the inadvertent propagative and distribution of infected material that will help spread PetAMV within the PRA area.
- Cherry hosts infected with PetAMV can produce symptomless shoots that when used as propagative material, can transmit the virus to healthy rootstock at low levels (3.3%) (Pfeilstetter *et al.* 1996). If this occurs within hop, it may contribute to the inadvertent propagation and distribution of infected material that will help spread PetAMV within the PRA area.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for spread of PetAMV. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of PetAMV has been reported (Mahaffee *et al.* 2009).
- Petunia asteroid mosaic virus is not seed-borne or vector-transmitted (Pfeilstetter *et al.* 1996). Petunia asteroid mosaic virus is spread mechanically, via grafting, from infected soils (Pfeilstetter *et al.* 1996) and other means which may transfer contaminated sap (Mahaffee *et al.* 2009).
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of PetAMV. In the absence of statutory control PetAMV can spread quickly in the PRA area by trade of host propagative material and infected soil.

3.16.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that PetAMV will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.16.5 Consequences

The consequences of the entry, establishment and spread of PetAMV in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • Symptoms associated with PetAMV infected hop include chlorosis and mottling, deformed leaves with necrotic crinkles, ring spot and line patterns, perforated leaves and leaf yellowing (Gent *et al*. 2009; Mahaffee *et al*. 2009). • Although this virus is considered a minor pest of hop, PetAMV is associated with viral necrosis of sweet cherry. Viral necrosis of sweet cherry is a serious disease in Germany where heavily damaged trees have been observed showing canker-like deformations on the shoots as well as bark splits, necrosis of leaf mid-veins and misshapen fruits with necrotic spots (Pfeilstetter *et al.* 1996). • PetAMV is known to occur in association with a number of other viruses (Mahaffee *et al.* 2009). It is likely that significant reductions in yield will result from mixed infections as reported for other virus species.
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If PetAMV was introduced to hop growing regions of Australia (Tasmania and Victoria), variable costs of hop production would increase due to the need for changes in management strategies • Virus control measures in the field are limited and any eradication attempt may not be feasible unless an outbreak is detected at an early stage. An eradication campaign for PetAMV is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected host plants would need to be removed and replaced. • Petunia asteroid mosaic virus is spread mechanically, from infected soils (Pfeilstetter *et al*. 1996) and other means which may transfer contaminated sap (Mahaffee *et al*. 2009). Management measures against this would include the use of virus free propagative material and development of resistant root stock (Pfeilstetter *et al.* 1996). • The presence of PetAMV in Australia would require testing for freedom in the production of nursery stock hosts and planting resistant cultivars. This would add significant costs to nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at the district level • The presence of PetAMV in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: C** – significant at the local level • The presence of PetAMV in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent; for example, Africa and South America.
Environmental and non-commercial	**Impact score: A** – Indiscernible at the local level • There are no known indirect and non-commercial consequences of PetAMV.

3.16.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for PetAMV.

3.17 Strawberry latent ringspot virus (SLRSV)

Strawberry latent ringspot virus (SLRSV) naturally infects many cultivated plants; including hop, strawberries, raspberries, blackberries, black currants, red currants, cherries, grapes, plums, peaches, asparagus, celery, rhubarb, roses, *Sambucus nigra*, *Gladiolus* and *Narcissus*, in addition to a number of wild plants (EPPO 2010). SLRSV was described from hop in the former Czechoslovakia after mechanical transmission on indicator plants using biological and serological tests (Pethybridge *et al.* 2008). Although SLRSV occurs frequently, it is asymptomatic in commercial hop (Pethybridge *et al.* 2008).

Strawberry latent ringspot nepovirus (SLRSV) is known to be pollen and seed-borne, vegetatively propagated, graft transmitted and spread locally by the nematode vectors *Xiphinema diversicaudatum* and *Xiphinema coxi* (Faggioli *et al.* 2002; Martin and Tzanetakis 2006; Murant 1983). SLRSV is a European virus and has spread to Israel, New Zealand, North America and Turkey (EPPO 2010; Murant 1983) in other hosts. In Australia, SLRSV has only once been reported from rhubarb in South Australia (Cooke and Dube 1989) however; as there have been no records of this virus in Australia since, and its natural vector is absent from Australia, it is considered eradicated.

3.17.1 Probability of entry

Probability of importation

The likelihood that SLRSV will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation (Bos 1999) may be infected. Therefore, rhizomes sourced from infected plants can provide a pathway for the importation of SLRSV into Australia. This mode of introduction is greatly enhanced because SLRSV does not produce symptoms on hop (Gent *et al*. 2009; Mahaffee *et al.* 2009) and may lead to the propagation and distribution of infected propagative material.
- The primary conditions for survival of SLRSV are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the virus.

Probability of distribution

The likelihood that SLSRV will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present: **HIGH**.

- SLRSV arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of SLRSV.

Overall probability of entry (importation x distribution)

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

The likelihood that SLRSV will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.17.2 Probability of establishment

The likelihood that SLRSV will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of SLRSV with the rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected plants. This will result in the establishment of this virus in new areas. Rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.
- SLRSV is widely distributed and has successfully established in many countries, especially in Europe and Israel, New Zealand, North America and Turkey (EPPO 2010); however, on hop it is reported only from the former Czechoslovakia (Pethybridge *et al.* 2008). The current reported distribution of SLRSV suggests that there are similar environments in parts of Australia that would be suitable for its establishment.
- SLRSV has a wide host range within several different plant families including strawberries, raspberries, cherries and grapes (EPPO 2010; Murant 1983). These economically important hosts are widely distributed in the PRA area.
- SLRSV is asymptomatic in hop (Pethybridge *et al.* 2008) which will result in the non-detection of SLRSV; therefore, the pathogen will have ample time to establish into new areas.

3.17.3 Probability of spread

The likelihood that SLRSV will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **MODERATE**.

- The natural spread of SLRSV depends on the movement of infective propagative material, seed or with the nematode vectors (Faggioli *et al.* 2002). SLRSV is latent (Pethybridge *et al.* 2008) and this may contribute to the inadvertent propagation and distribution of infected material that will help spread SLRSV within the PRA area. Pollen transmission is a possible pathway for distribution locally to new hosts (Martin and Tzanetakis 2006).
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for the spread of SLRSV. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of SLRSV has been reported (Murant 1974).
- SLRSV is vector-transmitted (Faggioli *et al.* 2002). The natural nematode vectors, *Xiphinema diversicaudatum* and *Xiphinema coxi*, are not present in Australia. SLRSV is seed-borne in several plant species including *Apium graveolens, Chenopodium quinoa, Lamium amplexicaule, Mentha arvensis, Rubus idaeus* and *Stellaria media* (Murant 1974); but there is no published information to confirm whether it is seed-borne in hop.

- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of SLRSV. In the absence of statutory control SLRSV can spread quickly in the PRA area by trade of host propagative material.

3.17.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that SLRSV will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.17.5 Consequences

The consequences of the entry, establishment and spread of SLRSV in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C** – significant at the local level Strawberry latent ringspot virus (SLRSV) is an economically important virus due to its extensive host range and the yield losses it can cause (Tzanetakis *et al*. 2006). • Although SLRSV is symptomless in most of the hosts (Faggioli *et al*. 2002) including hop (Mahaffee *et al*. 2009), it can still cause severe symptoms and economic loss in some crops (Smith *et al*. 1988). – Olive trees can suffer severe narrowing and twisting of leaves, bunchy growth, deformed fruits and reduced yield (Faggioli *et al*. 2002). SLRSV induces growth reduction, rosetting and dieback of peach trees (Smith *et al*. 1988). – Following infection of celery with SLRSV, the seedlings either remained symptomless or developed a faint, systemic mottle, accompanied by leaf crinkling after about four weeks. After six to seven months, as the plants reach maturity, the leaves develop typical 'strap-leaf' deformity and appear stunted. This can lead to total loss of foliage in infected plants (Walkey and Mitchell 1969). – Cherry infected with SLRSV developed 'shot-hole' leaf symptoms with chlorotic line patterns (Allen *et al*. 1970).
Other aspects of the environment	**Impact score: B** – minor significance at the local level There may be some impact on insect or animal species that feed on host plants due to the reduced availability or vigour of these host plants. • SLRSV was first identified more than 40 years ago and its host range exceeds 126 species belonging to 27 families (Tzanetakis *et al*. 2006). It is latent in most of its hosts (Smith *et al*. 1988) and these hosts could represent a natural reservoir from which the virus could potentially be transmitted to other susceptible host crops.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If SLRSV was introduced to hop growing regions of Australia (Tasmania and Victoria), it is unlikely to change the management or variable costs of growing hop. It is likely to impose yield reductions and increased production costs on other susceptible crops. • The absence of the vectors for SLRSV, *Xiphinema diversicaudatum* and *Xiphinema coxi,* in Australia suggests adequate control can be achieved by the use of virus-free plants for propagation. • Virus control measures in the field are limited and eradication may not feasible unless an outbreak is detected at an early stage. An eradication campaign for SLRSV is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected host plants would need to be removed and replaced. • The presence of SLRSV in Australia would require testing for freedom in the production of nursery stock hosts and planting resistant cultivars. This would add significant costs to nursery stock production in Australia. For example, SLRSV was considered a quarantine virus in the USA until its recent identification in both strawberry and mint (Martin *et al*. 2004; Postman *et al*. 2004).
Domestic trade	**Impact score: D** – significant at local level • The presence of SLRSV in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the local level • The presence of SLRSV in Australia is likely to have a significant effect, due to limitations on access to overseas markets where this pathogen is absent such as south-east Asia.
Environmental and non-commercial	**Impact score: A** – indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of SLRSV.

3.17.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for SLRSV.

3.18 Tobacco necrosis viruses Hop isolate (TNV-H)

Tobacco necrosis virus (TNV) naturally infects many cultivated and wild plants; including tobacco, various vegetables and ornamentals, fruit trees (almonds and pears) and hop (Smith *et al.* 1988). TNV was first described from hop in Czechoslovakia after mechanical transmission on indicator plants using biological and serological tests (Albrechtova *et al* 1979) its presence was also confirmed by electron microscopy (Chod *et al*. 1979).

The taxonomy of TNV has been revised to recognise that what was originally named TNV is actually a group of related virus species. Tobacco necrosis virus A (TNV-A) and Tobacco necrosis virus D (TNV-D) have been recognised as distinct species in the *Necrovirus* genus (Coutts *et al*. 1991; Meulewaeter *et al*. 1990) , as have Chenopodium necrosis virus (ChNV) and Olive mild mosaic virus (OMMV), which were previously considered TNV isolates

(Tomlinson *et al*. 1983). TNV isolates from Nebraska and Toyama (TNV-NE and TNV-Toyama) are likely to represent two new species in the genus, but have not yet been officially recognised (Saeki *et al*. 2001; Zhang *et al*. 1993). Molecular sequence data indicates that other necroviruses originally labelled 'Tobacco necrosis virus' are likely to be confirmed as distinct species (NCBI 2010).

Tobacco necrosis virus (TNV) occurs in field crops grown in Queensland and Victoria (Teakle 1988; Finlay and Teakle 1969), but confirmed reports of infection of hop plants are absent. TNV was thought to be ubiquitous and have a worldwide distribution (Brunt and Teakle 1996; Uyemoto 1981), but this status has not been reviewed since the taxonomic revision of the virus and the acceptance of new tobacco necrosis virus-like species.

3.18.1 Probability of entry

Probability of importation

The likelihood that TNV-H will arrive in Australia with the trade in propagative material from countries where the pathogen is present is: **HIGH**.

- TNV-H has been detected in rhizome buds and the concentration of this virus can be low (Albrechtova *et al.* 1979). The propagation and distribution of infected propagative material could provide a pathway for TNV-H introduction into non-infested areas.
- The primary conditions for survival of TNV-H are fulfilled by the presence of the live host plant and the associated environmental conditions. Therefore, association with propagative material can provide long term survival for the virus.

Probability of distribution

The likelihood that TNV-H *P. californicus* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- TNV-H arriving in Australia with imported rhizome will not need to move from the import pathway to a suitable host as the virus is already within a suitable host.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of TNV-H.

Overall probability of entry (importation x distribution)

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

The likelihood that TNV-H will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.18.2 Probability of establishment

The likelihood that TNV-H will establish based on a comparison of factors in the source and destination areas that affect viral survival and reproduction is: **HIGH**.

- Association of TNV–H with rhizome provides a distinct epidemiological advantage to the virus as infected rhizome will result in infected plants. This will result in the establishment of this virus in new areas. Rhizomes will be planted directly into regions suitable for hop production within Australia; environmental conditions are likely to be conducive to disease development and establishment.

- TNV is widely distributed and has successfully established in many countries especially in Europe (Smith *et al.* 1988); however, the hop isolate is reported only from the former Czechoslovakia, France and Romania where its incidence has been reported to be as high as 28% (Mahaffee *et al.* 2009). The current reported distribution of TNV-H suggests that there are similar environments in parts of Australia that would be suitable for its establishment.
- TNV-H occurs in mixed infections with Apple mosaic virus and Hop mosaic virus (Albrechtova *et al*. 1979) and therefore may be overlooked in gardens or may not produce symptoms which would result in non-detection of the virus. Therefore, TNV-H will have ample time to establish into new areas.

3.18.3 Probability of spread

The likelihood that TNV-H will spread based on a comparison of factors in the area of origin and in Australia that affects the expansion of the geographic distribution of the pest is: **MODERATE**.

- The natural spread of TNV-H depends on the movement of infective propagative material, mechanical transmission or by soil-borne fungal vectors (*Olpidium brassicae* and *Olpidium virulentus*) (Smith *et al.* 1988; Mahaffee *et al*. 2009). TNV-H rarely produces visually obvious symptoms (Smith *et al.* 1988); this may contribute to the inadvertent propagation and distribution of infected material that will help spread TNV-H within the PRA area.
- Rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries providing greater opportunity for spread of TNV-H. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this virus to spread to host plants by mechanical transmission. Mechanical transmission of TNV-H has been reported (Albrechtova *et al.* 1979).
- TNV-H is also vector-transmitted (Smith *et al.* 1988). The natural soil-borne vector, *Olpidium brassicae* is present in Australia (APPD 2010). The zoospores of *Olpidium brassicae* and *Olpidium virulentus* transmit the virus to the roots of susceptible plants and to leaves that come in contact with the ground (Uyemoto 1981; Bawden 1956). However, under natural conditions, dispersal by this vector can only occur locally.
- The managed environment in Australian nurseries, garden centres and private gardens are all favourable for the natural spread of TNV-hop. In the absence of statutory control TNV-hop can spread quickly in the PRA area by trade of host propagative material.

3.18.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that TNV-H will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.18.5 Consequences

The consequences of the entry, establishment and spread of TNV-H in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: C** – significant at the local level • Symptoms associated with TNV-H infected hop include deformed leaves with necrotic crinkles, ring spot and line patterns, perforated leaves and leaf yellowing (Mahaffee *et al*. 2009). • TNV-H is considered a minor pathogen of hop (Pethybridge *et al.* 2008). Other TNV isolates cause rusty root disease of carrot, Augusta disease of tulip, stipple streak disease of common bean, necrosis diseases of cabbage, cucumber, soybean and zucchini and ABC disease of potato (Zitikaite and Staniulis 2009; Asjes and Blom-Barnhoorn 2002; Xi *et al*. 2008; Smith *et al*. 1988; Uyemoto 1981). . • Naturally infected vegetable crops show a range of symptoms, including spots, flecks, streaks, necrosis and stunting. In strawberry in the Czech Republic, TNV has caused dwarfing and leaf and root necrosis (Martin and Tzanetakis 2006). Losses as high as 50% have been recorded in tulips and glasshouse grown cucumbers (CABI 2010).
Other aspects of the environment	**Impact score: A** – indiscernible at the local level • There are no known direct consequences of this pathogen on other aspects of the environment.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the local level • Virus control measures in the field are limited and eradication may not be possible unless an outbreak is detected at an early stage. An eradication campaign for TNV-H is likely to be expensive as it would require extensive surveys to determine the extent of an outbreak. Infected host plants would need to be removed and replaced. • The presence of TNV-H in Australia would require testing for freedom in the production of nursery stock hosts and planting resistant cultivars. This would add significant costs to nursery stock production in Australia.
Domestic trade	**Impact score: D** – significant at district level • The presence of TNV-H in production areas is likely to result in some domestic movement restriction for host plants. Interstate restrictions on nursery stock and rhizome may lead to a loss of markets, which in turn would be likely to require industry adjustment.
International trade	**Impact score: D** – significant at the district level • The presence of TNV-H in Australia is likely to have a significant effect at district level, due to limitations on access to overseas markets where this pathogen is absent, for example TNV-H has only been reported from the former Czechoslovakia, France and Romania (Mahaffee *et al.* 2009).
Environmental and non-commercial	**Impact score: A** – Indiscernible at the local level • There are no known indirect environmental and non-commercial consequences of TNV-H.

3.18.6 Unrestricted risk estimate

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

The unrestricted risk estimate of 'low' exceeds Australia's ALOP. Therefore, specific risk management measures are required for TMV-H.

3.19 Ditylenchus destructor

Ditylenchus destructor is a significant plant parasitic nematode pest of potato in Europe and North America (Perry and Moens 2006). It occurs in many potato producing countries, but its impact is only apparent in temperate zones (Luc *et al*. 2005). It is also known as potato root or potato tuber nematode. *Ditylenchus destructor* was regarded for a long time as a strain or race of *Ditylenchus dipsaci*, and much of the earlier literature provides confused information on the two species (EPPO 1978). *Ditylenchus destructor* was reported as present in Australia in 1958; however, these records may be a result of misidentification of the species. Regardless, no confirmatory records have been made since 1958 and the species is now considered to be absent from Australia. *Ditylenchus destructor* has been isolated from rotted roots, with severely stunted growth, from commercial hop yards in New Zealand (Mahaffee *et al*. 2009). Although no biological races of *Ditylenchus destructor* have been characterized, isolates from hop, iris and mint differed in host range, suggesting such races may occur (Mahaffee *et al*. 2009).

3.19.1 Probability of entry

Probability of importation

The likelihood that *Ditylenchus destructor* will arrive in Australia with the trade in propagative material from countries where the nematode is present is: **HIGH**.

- *Ditylenchus destructor* is a migratory endoparasitic nematode and all life stages can be found within under-ground parts of plant tissue (EPPO 1978; Perry and Moens 2006; Mahaffee *et al*. 2009) or in infested soil (Mahaffee *et al*. 2009). Soil surrounding infected plants can contain up to 520 nematodes per 100 ml of soil (Mahaffee *et al*. 2009). This suggests that rhizomes, or soil adhering to rhizomes, can provide a pathway for the importation of *D. destructor* into Australia.
- The primary conditions for survival of *D. destructor* are fulfilled by the presence of the live host plant and associated environmental conditions. Therefore, the association with propagative material can provide long term survival for the nematode.

Probability of distribution

The likelihood that *D. destructor P. californicus* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the nematode is present is: **HIGH**.

- *Ditylenchus destructor* arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the nematode is an endoparasite and is already within a suitable host. *Ditylenchus destructor* will continue to live and develop within harvested underground parts (Luc *et al*. 2005; EPPO 1978).
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infected propagative material commercially will facilitate the distribution of *D. destructor*.

Overall probability of entry (importation x distribution)

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

The likelihood that *Ditylenchus destructor* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.19.2 Probability of establishment

The likelihood that *Ditylenchus destructor* will establish based on a comparison of factors in the source and destination areas that affect nematode survival and reproduction is: **HIGH**.

- *Ditylenchus destructor* is already associated with rhizome, or soil adhering to rhizome, and will have a distinct developmental advantage. Association of this pest with rhizome allows it to complete development without leaving the host. As rhizomes will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment.
- *Ditylenchus destructor* overwinters in soil as adults, larvae or eggs and may even multiply on alternative weed hosts (Luc *et al*. 2005). Eggs hatch in spring and larvae are immediately able to parasitise hosts (EPPO 1978). It is also capable of reproducing on the mycelium of many soil fungi (EPPO 1978). Consequently, even low host availability will still ensure establishment of the nematode in the PRA area.
- *Ditylenchus destructor* will survive in soils at temperature as low as -28 °C. However, the optimum temperature for *D. destructor* development is between 15–20 °C and at relative humidity above 90% (EPPO 1978; Luc *et al*. 2005). High relative humidity is a very important factor in the establishment of *D. destructor*. The nematode cannot survive under drought or low (<40%) relative humidity (Luc *et al*. 2005). The requirement for high relative humidity means it would be unlikely to become a problem in areas with warm, dry soils; however, it will be problem in temperate regions where many of its host plants are common.

3.19.3 Probability of spread

The likelihood that *Ditylenchus destructor* will spread based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the pest is: **MODERATE**.

- *Ditylenchus destructor* can spread only in association with infected planting material or in soil adhering to planting material. *Ditylenchus destructor* cannot move very far by itself, and is primarily reliant on human activity for long distance transportation (Luc *et al.* 2005).
- The main means of dispersal is with the movement of infested plant material, including bulbs and rhizomes (Luc *et al*. 2005; EPPO 1978). Mechanisms that spread infested soil such as contaminated machinery, wind-borne dust, runoff or flood water and irrigation water can also spread the nematode to new areas (Luc *et al*. 2005; EPPO 1978).
- Long distance dissemination could occur in nursery stock as larvae could be found in rhizomes or in infested soil adhering to planting material (Luc *et al*. 2005). Imported rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this nematode to spread.
- *Ditylenchus destructor* has a wide host range. The presence of many cultivated and wild hosts throughout the PRA area would facilitate the spread of the nematode in Australia. Some weeds (e.g. *Mentha arvensis* and *Sonchus arvensis*) could act as alternate hosts and provide a source for infection of new crop plants (EPPO 1978). It is also capable of reproducing on the mycelium of many soil fungi (EPPO 1978).

- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of *D. destructor*. In the absence of statutory control there are high probabilities for *D. destructor* to be spread quickly in the PRA area by trade of host plants for planting.

3.19.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of 'rules' for combining descriptive likelihood (Table 2.2).

The likelihood that *D. destructor* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.19.5 Consequences

The consequences of the entry, establishment and spread of *Ditylenchus destructor* in Australia have been estimated according to the methods described in Tables 2.3. Based on the decision rules described in Table 2.4, that is, where the consequences of a pest with respect to one or more criteria are 'D', the overall consequences are estimated to be **LOW**.

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • The potato rot nematode, *Ditylenchus destructor*, has been reported as causing severe damage to hop (Mercer 1994). *Ditylenchus destructor* has been isolated from rotted roots exhibiting severely stunted growth in New Zealand (Mahaffee *et al*. 2009). • High potato yield losses occur in the areas where climatological conditions favour establishment of *Ditylenchus destructor* (Jatala and Bridge 1993). • *Ditylenchus destructor* suppresses peanut seed yield, increases seed blemishes and causes seeds to germinate before harvest (Venter *et al*. 1993). • In hop, *Ditylenchus destructor* was found to cause root rot and severely stunt plant growth (Foot and Wood 1982).
Other aspects of the environment	**Impact score: B** – minor significance at the local level • In general, newly established species may adversely affect the environment in a number of ways. Introduced species may reduce biodiversity, disrupt ecosystem function, jeopardise endangered or threatened plants, degrade critical habitat, or stimulate use of chemical or biological controls. *Ditylenchus destructor* is likely to affect the environment in many of these ways.

Criterion	Estimate and rationale
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *Ditylenchus destructor* was introduced to host plant production areas, variable costs of production would increase due to the need for changes in management strategies • Programs to minimise the impact of *D. destructor* on host plants are likely to be costly and include cultural control and chemical control (EPPO 1978). Cultural control by crop rotation is possible using non-host crops, and the use of resistant host varieties (Winslow 1978), but it is important to control weeds because of the polyphagous habit of the nematode. • Treatment with soil applied nematicides can provide a high level of control but can be expensive (EPPO 1978). The nematode can also be controlled by means of repeated fumigation with ethylene dibromide, combined with official restriction of movement of infected nursery stock (Darling *et al*.1983).
Domestic trade	**Impact score: D** – significant at district level • The presence of *D. destructor* in host production areas is likely to result in some domestic movement restriction for host commodities. Interstate restrictions on nursery stock of host plants may lead to a loss of markets, which in turn would require industry adjustment. For example, *D. destructor* is listed as a quarantine pest in Tasmania.
International trade	**Impact score: D** – significant at the district level • The presence of *D. destructor* in Australia is likely to have a significant effect, due to limitations on access to overseas markets where the nematode is absent. Many of Australia's significant export markets have quarantine restrictions in place to prevent the introduction of this nematode. Member countries of regional phytosanitary bodies in Asia-Pacific and South America consider this pest to be of quarantine significance (EPPO 2006).
Environmental and non-commercial	**Impact score: B** – minor significance at the local level • Nematicide application or other control activities, such as fumigation with ethylene dibromide, may be required to control and/or eradicate this pest and control it on susceptible crops. However, this is not considered to have significant consequences for the environment.

3.19.6 Unrestricted risk estimate

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

The unrestricted risk for *Ditylenchus destructor* has been assessed as 'low' which exceeds Australia's ALOP. Therefore, specific risk management measures are required for *Ditylenchus destructor*.

3.20 Heterodera humuli

Heterodera humuli is a significant plant parasitic nematode pest of hop which occurs at high population densities in hop gardens in countries where hop are grown, including Canada Europe, New Zealand and USA (Hay and Pethybridge 2003; von Mende and McNamara 1995b; Decker 1989). In Australia, *Heterodera humuli* has a limited distribution and is recorded in only two hop gardens in Tasmania where it occurs at high population densities (Hay and Pethybridge 2003). This species is under official control in Australia. The perennial nature of hop, the size of its root system, and its rapid growth rate during spring suggest that hop plants have a great capacity to tolerate nematode feeding (Gent *et al*. 2009).

The Tasmanian Department of Primary Industries, Parks, Water and Environment (TDPIPWE, personal communication) is currently reviewing the quarantine and control status of this species. Until this review is completed, and the results adopted, it will continue to be assessed as a List B (under official control) species.

3.20.1 Probability of entry

Probability of importation

The likelihood that *Heterodera humuli* will arrive in Australia with the trade in propagative material from countries where the nematode is present is: **HIGH**.

- *Heterodera humuli* is an endoparasitic nematode that feeds within the root system of its host (DeFrancesco and Murray 2008) and can be found on underground parts of plants or infested soil adhering to the rhizome. *Heterodera humuli* has been intercepted in post-entry quarantine in India from hop planting material from Australia (Raychaudhurdi *et al*. 1976) and the USA (Arjun and Mathur 1995) suggesting rhizomes, or soil adhering to rhizomes, can provide a pathway for the importation of *Heterodera humuli* into Australia.
- The primary conditions for survival of *H. humuli* are fulfilled by the presence of the live host plant and associated environmental conditions. Therefore, the association with propagative material can provide long term survival for the nematode.

Probability of distribution

The likelihood that *H. humuli* will be distributed in Australia in a viable state as a result of imported propagative material from countries where the pathogen is present is: **HIGH**.

- *Heterodera humuli* arriving in Australia with imported propagative material will not need to move from the import pathway to a suitable host as the nematode is an endoparasite and is already associated with a suitable host and can continue to live and develop within harvested underground parts.
- Propagative material would be distributed to multiple destinations throughout Australia for propagation. The distribution of infested propagative material commercially will facilitate the distribution of *H. humuli*.

Overall probability of entry (importation x distribution)

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

The likelihood that *H. humuli* will enter Australia as a result of imported propagative material from countries where the pest is known to occur and distributed in a viable state to a suitable host: **HIGH**.

3.20.2 Probability of establishment

The likelihood that *Heterodera humuli* will establish based on a comparison of factors in the source and destination areas that affect nematode survival and reproduction is: **HIGH**.

- *Heterodera humuli* is already associated with rhizome, or soil adhering to rhizome, and will have a distinct developmental advantage. Association of this nematode with rhizome allows it to complete development without leaving the host. As rhizomes will be planted directly into regions suitable for hop production within Australia, environmental conditions are likely to be conducive to pest development and establishment. Juveniles penetrate the root and form a feeding site (Mahaffee *et al.* 2009).
- *Heterodera humuli* overwinters as eggs inside the hardened cysts that often remain attached to the root surface (Hay and Pethybridge 2003). Eggs within the cyst remain

viable for several years (Mahaffee *et al.* 2009). In spring, eggs hatch to second stage juveniles and are immediately able to parasitise hosts in response to root exudates (de Grisse and Gillard 1963). The protective cyst allows the succeeding generation to survive for extended periods until a suitable host and/or weather conditions are available (Perry and Moens 2006).

- The optimal temperature for the development of *H. humuli* in the roots of hop is reported to be 20 °C, and the juveniles invade hop roots at 15 °C, but egg hatch was greatest at 20 °C (von Mende and McNamara 1995a). The hop industry in Australia is situated in the temperate climatic zone with a mild summer. These climatic conditions will favour *H. humuli* development and establishment, especially in spring. The nematode has already established in two hop gardens in Tasmania (Hay and Pethybridge 2003) suggesting that the nematode is likely to establish if introduced into other production areas of Australia.

3.20.3 Probability of spread

The likelihood that *H. humuli* will spread based on a comparison of factors in the area of origin and in Australia that affect the expansion of the geographic distribution of the nematode is: **MODERATE**.

- Natural movement of the nematode is very limited, as it has no stage for long-distance active dispersal, though movement of other cyst nematodes by wind and water has been noted (Potter and Olthof 1993). Long distance dissemination could occur with infected planting material or in soil adhering to planting material (von Mende and McNamara 1995a). Imported rhizomes will be widely distributed to retail outlets, greenhouses or production nurseries. Resultant plants are unlikely to be grown in isolation, providing greater opportunity for this nematode to spread.
- *Heterodera humuli* has been reported in the top 15 cm of soil of hop gardens (von Mende and McNamara 1995a). Mechanisms such as contaminated machinery, wind-borne dust and runoff or flood water can spread infested soil with the nematode to new areas.
- Natural physical barriers (e.g. deserts/arid areas) may prevent long-range spread of the nematode. However, the interception of *H. humuli* in post-entry quarantine of hop breeding material in India (Raychaudhurdi *et al.* 1976; Arjun and Mathur 1995), suggests the nematode has the ability to overcome natural physical barriers through trade in infected propagative material.
- The managed environment in Australian nurseries, garden centres, private gardens and public greens are all favourable for the natural spread of *H. humuli*. In the absence of statutory control there are high probabilities for *H. humuli* to be spread quickly in the PRA area by trade of host plants for planting.

3.20.4 Overall probability of entry, establishment and spread

The overall probability of entry, establishment and spread is determined by combining the probability of entry, of establishment and of spread using the matrix of ‘rules’ for combining descriptive likelihood (Table 2.2).

The likelihood that *H. humuli* will enter Australia as result of imported propagative material from countries where the pest is known to occur, be distributed in a viable state to susceptible hosts, establish in that area and subsequently spread within Australia: **MODERATE.**

3.20.5 Consequences

The consequences of the entry, establishment and spread of *Heterodera humuli* in Australia have been estimated according to the methods described in Tables 2.3.

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

The assessment of potential consequences is provided below.

Criterion	Estimate and rationale
Direct	
Plant life or health	**Impact score: D** – significant at the district level • Cyst-forming nematodes are highly specialized and economically important soil-borne parasites attacking numerous agricultural crops worldwide. Injury to crops by these nematodes is probably second in importance to damage caused by root-knot nematodes (Madani *et al*. 2004). • The presence of *H. humuli* in hop yards has been shown to increase the severity of other diseases affecting hop, such as Verticillium wilt (Mahaffee *et al.* 2009). • Although the effect of *H. humuli* on the quantity and quality of hop crops under field conditions is not well established, results of experiments indicate *H. humuli* can adversely affect hop yield (Hay and Pethybridge 2003; von Mende and McNamara 1995b; Hafez *et al*. 1988). Reductions of up to 38% of hop cone weight have been recorded experimentally (Mahaffee *et al.* 2009). • Symptoms associated with *H. humuli* feeding include reduced bine length and chlorosis of leaves (Mahaffee *et al.* 2009). Hop plants infected experimentally showed significant reduction in plant height and shoot fresh and dry weight. Mortality rate of 20% was observed 146 days after inoculation (Hafez *et al*. 1988). Observations in gardens and the glasshouse suggest that *H. humuli* can put hop under stress as several millions of juveniles can infect a single plant (von Mende and McNamara 1995b).
Other aspects of the environment	**Impact score: B** – minor significance at the local level • In general, newly established species may adversely affect the environment in a number of ways. Introduced species may reduce biodiversity, disrupt ecosystem function, jeopardise endangered or threatened plants, degrade critical habitat, or stimulate use of chemical or biological controls. *Heterodera humuli* is likely to affect the environment in many of these ways.
Indirect	
Eradication, control etc.	**Impact score: D** – significant at the district level If *Heterodera humuli* was introduced to host plant production areas, variable costs of production would increase due to the need for changes in management strategies • Control of nematodes with nematicide is unlikely to be economic or effective due to the perennial nature of the hop, rapid multiplication rate of *H. humuli* and difficulty of applying an effective dose of a nematicide to the depths that hop roots and nematodes can penetrate (Gent *et al*. 2009). • Cultural control by crop rotation is possible using non-host crops; pre-plant soil fumigation for other soil pests may help reduce nematode populations (DeFrancesco and Murray 2008).
Domestic trade	**Impact score: D** – significant at district level • The presence of *H. humuli* in host production areas is likely to result in some domestic movement restriction for host nursery stock. Interstate restrictions on nursery stock of host plants may lead to a loss of markets and industry adjustment.
International trade	**Impact score: B** – minor significant at the local level • The presence of *H. humuli* in commercial hop production areas in Australia would not have a significant effect, as this nematode is widespread in all hop growing regions.
Environmental and non-commercial	**Impact score: B** – minor significance at the local level • Nematicide application or other control activities, such as soil fumigation, may be required to control and/or eradicate this pest on susceptible crops. However, this is not considered to have significant consequences for the environment.

3.20.5 Unrestricted risk estimate

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

The unrestricted risk for *Heterodera humuli* is has been assessed as 'low' which exceeds Australia's ALOP. Therefore, specific risk management measures are required for *Heterodera humuli*.

3.21 Risk assessment conclusion

Table 3.2 summarises the detailed risk assessments and provides unrestricted risk estimates for the quarantine pests considered to be associated with dormant propagative materials. These pests are most likely to enter Australia on propagative material from areas where these pests specifically occur.

Key to table 3.2

Genus species [EP]	pests for which policy already exists. The outcomes of previous assessments and/or reassessments in this IRA are presented in table 3.2

Likelihoods for entry, establishment and spread

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

Assessment of consequences from pest entry, establishment and spread

PLH	plant life or health
OE	other aspects of the environment
EC	eradication control etc
DT	domestic trade
IT	international trade
ENC	environmental and non-commercial
A-G	consequence impact scores are detailed in Section 2
URE	unrestricted risk estimate. This is expressed on an ascending scale from negligible to extreme.

Table 3.2: Unrestricted risk summary

Pests/pathways	Entry			Establishment	Spread	P[EES]	Consequences							URE
	Importation	Distribution	Overall				Direct		Indirect				Overall	
							PLH	OE	EC	DT	IT	ENC		
Arthropods														
Prionus californicus	H	H	**H**	**L**	**H**	**L**	E	C	D	D	D	C	M	**L**
Grapholita delineana	L	H	**L**	**M**	**H**	**L**	E	A	D	D	D	A	M	**L**
Hydraecia micacea	H	H	**H**	**L**	**H**	**L**	E	C	D	D	D	C	M	**L**
Hydraecia immanis	H	H	**H**	**L**	**H**	**L**	E	C	D	D	D	C	M	**L**
Ostrinia nubilalis	L	H	**L**	**H**	**H**	**L**	E	C	D	D	D	A	M	**L**
Fungi														
Podosphaera macularis	H	H	**H**	**H**	**H**	**H**	E	A	D	D	D	B	M	**M**
Pseudoperonospora humuli	H	H	**H**	**H**	**H**	**H**	E	A	D	D	D	B	M	**M**
Verticillium albo-atrum (hop strain)	H	H	**H**	**H**	**H**	**H**	E	B	D	D	D	B	M	**M**
Verticillium dahliae (hop strain)	H	H	**H**	**H**	**H**	**H**	E	B	D	D	D	B	M	**M**
Phytoplasma														
'Candidatus Phytoplasma asteris'	H	H	**H**	**H**	**M**	**M**	D	A	D	D	D	A	L	**L**
Viroids														
Apple fruit crinkle *apscaviroid* – hop strain	H	H	**H**	**H**	**M**	**M**	D	A	D	D	D	A	L	**L**
Hop stunt *hustoviroid* –hop strain	H	H	**H**	**H**	**M**	**M**	D	B	D	D	D	A	L	**L**
Viruses														
Alfalfa mosaic virus – hop strain	H	H	**H**	**H**	**M**	**M**	C	A	D	D	D	A	L	**L**
American hop latent virus	H	H	**H**	**H**	**M**	**M**	D	A	D	D	D	B	L	**L**
Arabis mosaic virus – hop strain	H	H	**H**	**H**	**M**	**M**	D	A	D	D	D	A	L	**L**
Cherry leaf roll virus	H	H	**H**	**H**	**M**	**M**	C	C	D	D	D	A	L	**L**

Pests/pathways	**Entry**			**Establishment**	**Spread**	**P[EES]**	**Consequences**							**URE**
	Importation	Distribution	**Overall**				Direct		Indirect				**Overall**	
							PLH	OE	EC	DT	IT	ENC		
Humulus japanicus latent virus	H	H	**H**	**H**	**M**	**M**	D	A	D	D	D	A	L	**L**
Petunia asteroid mosaic virus	H	H	**H**	**H**	**M**	**M**	D	A	D	D	C	A	L	**L**
Strawberry latent ringspot virus	H	H	**H**	**H**	**M**	**M**	C	B	D	D	D	A	L	**L**
Tobacco necrosis virus – Hop isolates	H	H	**H**	**H**	**M**	**M**	C	A	D	D	D	A	L	**L**
Nematodes														
Ditylenchus destructor	H	H	**H**	**H**	**M**	**M**	D	B	D	D	D	B	L	**L**
Heterodera humuli	H	H	**H**	**H**	**M**	**M**	D	B	D	D	B	B	L	**L**

4 Pest risk management

Pest risk management evaluates and selects risk management options to reduce the risk of entry, establishment or spread of quarantine pests identified with an unrestricted risk exceeding Australia's appropriate level of protection (ALOP).

To effectively prevent the introduction of pests associated with an identified pathway a series of important safeguards, conditions or phytosanitary measures must be in place. *Humulus* propagative material represents a direct pathway for pests identified by the detailed risk assessment outlined in Section 3.2. These pathways are direct since the end-use is planting of a known host plant (hop nursery stock). The recommended pest risk management measures for pests associated with hop propagative material are summarised in Table 3.3.

Table 3.3: Recommended phytosanitary measures for *Humulus* propagative material

PEST OF CONCERN	Rhizome	Cuttings	Seed	Tissue culture
ARTHOPODS • *Prionus californicus* • *Grapholita delineana* • *Hydraecia micacea* • *Hydraecia immanis* • *Ostrinia nubilalis*	On-arrival inspection and fumigation		Not on pathway	Not on pathway
FUNGI • *Podosphaera macularis* • *Pseudoperonospora humuli* • *Verticillium albo-atrum* • *Verticillium dahliae*	Sodium hypochlorite treatment, growth in PEQ, laboratory assay, and PCR testing		Sodium hypochlorite and fungicidal seed treatment, growth in PEQ, laboratory assay and PCR testing	On-arrival inspection and laboratory assay
PHYTOPLASMAS • *'Candidatus* Phytoplasma asteris'	Hot water treatment; Growth in PEQ and PCR testing		Not on pathway	Growth in PEQ and PCR testing
VIROIDS • AFCVd– hop • HpSVd – hop	Growth in PEQ, herbaceous indexing and PCR		Not on pathway	Growth in PEQ, herbaceous indexing and PCR
VIRUSES • AMV (hop strain) • AHLV • ArMV (hop strain) • Cherry leaf roll virus • HJLV • PetAMV • SLRSV • TNV (hop isolate)	Growth in PEQ, herbaceous indexing and ELISA/PCR testing		Growth in PEQ, herbaceous indexing and ELISA/PCR (ArMV–H and HJLV only) testing	Growth in PEQ, herbaceous indexing and ELISA/PCR testing
NEMATODES • *Ditylenchus destructor* • *Heterodera humuli*	Hot water treatment	Not on pathway	Not on pathway	Not on pathway

Biosecurity Australia considers that the risk management measures recommended in this pest risk analysis will achieve Australia's ALOP. While the following measures are recommended by Biosecurity Australia, any other measure that provides an equivalent level of protection could be considered.

4.1 Existing risk management measures for propagative material

All imported nursery stock consignments are subject to the quarantine/biosecurity measures set out in Condition C7300 'General import requirements, nursery stock for all species'.

4.1.1 Existing policy to import *Humulus* propagative material

Currently, there are no import conditions for *Humulus* species propagative material on the AQIS Import Conditions (ICON) Database. However, prior to suspension Australia's policy for *Humulus* nursery stock only allowed the entry of dormant rhizomes. All consignments of hop nursery stock imported prior to 2004 were subjected to mandatory on-arrival inspection, fumigation and growth in closed government PEQ with pathogen screening.

4.2 Recommended risk management measures for *Humulus* propagative material

The recommended import conditions for *Humulus* propagative material (soil free dormant rhizome, foliage free dormant cuttings, tissue culture and seed for sowing) are based on tiered safeguards. This process ensures that if one mitigating measure fails, other safeguards exist to ensure that the risk is progressively reduced and managed.

4.2.1 Recommended policy to import soil free *Humulus* dormant rhizome and foliage free dormant cuttings

The recommended policy on *Humulus* dormant rhizome and cuttings includes:

- mandatory on-arrival inspection;
- mandatory methyl bromide fumigation;
- mandatory hot water treatment;
- mandatory sodium hypochlorite treatment by dipping; and
- mandatory growth of new mother plants in closed government PEQ facilities with pathogen screening (original rhizome/cuttings destroyed).

Mandatory on-arrival inspection

It is recommended that hop dormant rhizomes and cuttings be subjected to on-arrival AQIS inspection to verify freedom from disease symptoms, live insects, soil and other extraneous contaminants of quarantine concern. If diseased material is detected during on-arrival inspection, the material must be subjected to treatments (hot water treatment, surface sterilisation) and sections from the infected material must be plated out on agar medium for isolation and identification of the pathogens.

On-arrival visual inspection may not detect internal feeders (larvae) and latent infection caused by pathogens. Reliance on on-arrival visual inspection only to detect pests is inefficient in the case of nursery stock, including hop dormant rhizomes and cuttings. For this

reason, visual inspection is not considered an appropriate measure to mitigate the risk posed by internal feeders and pathogens associated with dormant rhizomes and cuttings. Therefore, additional risk management measures are required for these pests.

Mandatory on-arrival fumigation

It is recommended that imported dormant rhizomes and cuttings be subjected to mandatory on-arrival fumigation, to minimise the risk of accidental introduction of arthropod pests.

Methyl bromide fumigation is a treatment regarded as effective against all life stages of arthropods pests. Methyl bromide fumigation of hop dormant rhizomes and cuttings is undertaken in accordance with the relevant AQIS standards at one of the following rates:

- 48 g/m^3 for 2 hours at 10–15 °C
- 40 g/m^3 for 2 hours at 16–20 °C
- 32 g/m^3 for 2 hours at 21 °C +

Treatments of hop dormant rhizomes and cuttings, other than by methyl bromide fumigation, will be considered on a case by case basis by Biosecurity Australia if proposed by an exporting country. Prior to the acceptance of an alternative fumigant Biosecurity Australia would have to assess the efficacy of that fumigant to ensure it gives an equivalent level of treatment to methyl bromide.

Mandatory on-arrival fumigation is effective against arthropod pests. However, mandatory on-arrival fumigation may not be effective against pathogens, including fungi, phytoplasmas, viruses, viroids and nematodes. Therefore, additional risk management measures are required for these pathogens.

Mandatory hot water treatment (rhizome only)

Hot water treatment (HWT) is applied to minimise the risk of accidental introduction of nematodes and other pests including phytoplasma. It can also be effective against some pathogens.

Extensive scientific publications have demonstrated HWT can control a number of important pathogens. For example, hot water treatment at 50 °C for 30 minutes is reported to be highly effective against some phytoplasmas and fungi (Caudwell *et al*. 1997; USDA 2010).

It is recommended that imported hop dormant rhizomes and cuttings must be subjected to hot water treatment at 50 °C for 30 minutes (core temperature). However, hot water treatment alone may not be effective against all pathogens, including viruses and viroids. Therefore, additional mitigation measures are required for these pathogens.

It should be noted that the quarantine and control status of *H. humuli* is currently under review by the Tasmanian Department of Primary Industries, Parks, Water and Environment (TDPIPWE, personal communication). In the event that the species is removed from Tasmanian legislation and no longer meets the IPPC definition of a quarantine pest, this measure would not be required for the control of *H. humuli*. However, as the measure is also required to manage the risk from *D. destructor*, its application for rhizome propagative material will remain unchanged.

Mandatory sodium hypochlorite treatment

Imported hop dormant rhizomes and cuttings must be subjected to sodium hypochlorite treatment (1% NaOCl for 10 minutes) for surface sterilisation. This risk management measure will be effective against superficial contaminating fungal pathogens. Treatment with sodium hypochlorite should be undertaken after the hot water treatment outlined above; this should allow some residual effect and increase the efficacy of the treatment.

Treatment with sodium hypochlorite alone may not be effective against endophytic fungi. Therefore, additional mitigation measures are required for endophytic fungal pathogens.

Mandatory growth in PEQ facilities with pathogen screening

It is recommended that imported dormant rhizomes and cuttings must be grown in closed government PEQ facilities; and cuttings must be taken to establish new mother plants. Once new mother plants (derived from imported rhizome and cuttings) are established the original rhizome and cutting are destroyed. Newly established mother plants must be grown under conditions that are conducive to symptom expression of the pathogens for a period of observation and until the required pathogen screening/testing is complete. This increases the likelihood that pathogens will be detected.

It is recommended that newly established mother plants must be grown at 15–25 °C for a minimum period of six months for visual observation of disease symptoms and until the required pathogen screening/testing is completed. As *Humulus* species are fast growing perennials which can typically complete a full life cycle in a single growing season a six month period of active growth in PEQ is considered to be adequate for pathogen expression and detection to occur.

Pathogen screening

Although visual assessment is an important method for screening pathogens, hop plants may be infected and not produce any obvious disease symptoms due to cultivar susceptibility, environmental conditions or other plant related factors. Therefore, in addition to the observation for symptoms, Biosecurity Australia recommends active testing using PCR for identified fungal pathogens (Patzak 2003; NZMAF 2009), herbaceous indexing and ELISA and/or PCR for identified viruses and viroids and a generic nested primer PCR for identified phytoplasma (Barbara *et al*. 1978; Adams and Barbara 1980, 1982; Waterworth and Mock 1999; Hadidi *et al*. 2003).

Fungal pathogens

- *Verticillium albo-atrum* and *Verticillium dahliae*: the existing stem end test is recommended to continue, but due to the economic importance and existence of a super-virulent (lethal) strain, additional PCR tests are proposed (Carder *et al*. 1994; Patzak 2003; NZMAF 2009).
- *Podosphaera macularis* and *Pseudoperonospora humuli*: the existing growth under mist and heat (cuttings established on a mist/heat bed for mildew check) is recommended to continue, but due to the economic importance of these pathogens, additional PCR tests are proposed (Patzak 2003; NZMAF 2009).

Phytoplasma

- A generic nested primer PCR test is recommended to detect phytoplasma (Deng and Hiruki 1991; Lee *et al*. 1995; Schneider *et al*. 1995).

The nested primer PCR test is highly sensitive and is accepted by US regulatory officials as a suitable replacement for their three-year woody indexing procedure (Waterworth and Mock 1999). General tests for phytoplasmas are routinely used by some of the diagnostic laboratories in Australia. AQIS Plant Pathologists can make arrangements for the phytoplasma PCR test to be carried out at an AQIS approved diagnostic laboratory where the test is available.

Viroids

- Herbaceous indexing, and cDNA hybridization or PCR is proposed to detect Apple fruit crinkle viroid and Hop stunt viroid.
  - A RT-PCR is proposed to detect Apple fruit crinkle viroid (NZMAF 2009).
  - Herbaceous indexing (Hadidi *et al*. 2003) confirmed by cDNA hybridization or PCR is proposed to detect Hop stunt viroid (Barbra *et al*. 1990; Sano *et al*. 1988; Yaguchi and Takahashi 1984; Hadidi *et* al. 1992; Hadidi *et al*. 2003; NZMAF 2009).

Viral pathogens

- Herbaceous indexing confirmed by ELISA or PCR can be used to detect Alfalfa mosaic virus – hop isolate, American hop latent virus, Arabis mosaic virus hop strain, Cherry leafroll virus, Humulus japonicus latent virus, Petunia asteroid mosaic virus, Tobacco necrosis virus (Hop) and Strawberry latent ringspot virus (Barbara *et al*. 1978, Adams and Barbara 1980, 1982; NZMAF 2009; Pfeilstetter *et al*. 1996; Chod *et al*. 1979; Allen *et al*. 1970; Martin *et al*. 2004; Borodynko *et al*. 2007).
  - Herbaceous indexing is proposed to detect Alfalfa mosaic virus – hop isolate (Yu and Liu 1987).
  - Herbaceous indexing, confirmed by ELISA is proposed for American hop latent virus and Arabis mosaic virus – hop strain (Adam and Barbra 1982; Adam *et al*. 1987).
  - Herbaceous indexing, confirmed by ELISA or PCR is proposed for Cherry leaf roll virus and Humulus japonicus latent virus (Topchiiska 1993; Kumari 2009; Adam *et al*. 1989; NZMAF 2009).
  - Herbaceous indexing, confirmed by ELISA is proposed for Petunia asteroid mosaic virus, Tobacco necrosis virus (Hop) and Strawberry latent ringspot virus (Pfeilstetter *et al*. 1996; Chod *et al*. 1979; Allen *et al*. 1970; Martin *et al*. 2004; Borodynko *et al*. 2007).

A summary of indexing procedures is presented in Table 3.4.

Table 3.4: Recommended hop indexing procedures

Pathogen type	Bioassay[4]	Laboratory Assays	Tests need validation[5]	Reference(s)
Fungi				
Podosphaera macularis		Growth under mist and heat	PCR	Patzak 2003; NZMAF 2009
Pseudoperonospora humuli				
Verticillium albo-atrum		Stem end test (*Verticillium* specific media)	PCR	Patzak 2003; Carder *et al*. 1994; NZMAF 2009
Verticillium dahliae				
Phytoplasma				
'*Candidatus* Phytoplasma asteris'			PCR	Deng and Hiruki 1991; Lee *et al*. 1995; Schneider *et al*. 1995
Viroids				
Apple fruit crinkle viroid			RT-PCR	Hadidi *et al*. 2003
Hop stunt hostuviroid hop strain	*Cucumis sativus*	cDNA hybridization*	PCR*	Barbara *et al*. 1990; Sano *et al*. 1988; Yaguchi and Takahashi 1984; Hadidi *et* al. 1992; Hadidi *et al*. 2003; NZMAF 2009
Viruses				
Alfalfa mosaic virus hop strain	*Chenopodium amaranticola, Ch. quinoa*			Yu and Liu 1987
American hop latent virus	*Ch. quinoa*	ELISA		Adam and Barbara 1982
Arabis mosaic virus hop strain	*Ch quinoa*	ELISA		Adam *et al*. 1987
Cherry leaf roll virus	*Ch. quinoa*, *Nicotiana* sp.	ELISA*	RT-PCR*	Topchiiska 1993; Kumari 2009
Humulus japonicus latent virus	*Ch. quinoa*	ELISA*	PCR*	Adam *et al*. 1989; NZMAF 2009
Petunia asteroid mosaic virus	*Nicotiana clevelandii*	ELISA		Pfeilstetter *et al*. 1996
Strawberry latent ringspot virus	*Ch. quinoa, Cu. sativus*	ELISA		Allen *et al*. 1970; Martin *et al*. 2004; Borodynko *et al*. 2007
Tobacco necrosis virus (Hop isolate)	*Ch. quinoa, Cu.sativus*	ELISA		Chod *et al.* 1979

All measures, except those denoted by ∗, are mandatory. One of the two measures denoted by ∗ may be chosen as a secondary testing measure for identified pathogens.

[4] Bioassay should be done in early spring; young and vigorous indicator plants must be used. Where possible ELISA testing should be done to confirm negative Bioassay results.

[5] These tests are reported in the scientific literature to be able to detect the given pathogen; however, at this time only a few isolates of the pathogens have been studied. A broader range of isolates need to be detected with the described assay to ensure its usefulness in detecting a broad range of isolates of the pathogen before the test can be recommended for certification or quarantine purposes.

4.2.2 Recommended policy to import Humulus seed for sowing

Currently *Humulus* seed is prohibited entry into Australia under Schedule 6 of the *Quarantine Proclamation 1998* under "Kinds of plants that must not be imported". Hop seeds are capable of transmitting Arabis mosaic *nepovirus* (ArMV-H) and Humulus japonicus latent *ilarivirus* (HJLV) (Adams *et al*. 1989). Therefore, phytosanitary measures must be in place to effectively prevent the introduction of these pathogens associated with hop seed.

Although ArMV-H and HJLV are seed-borne in hop, the risk of spreading these viruses in hop seed is reduced because virtually all movement of hop propagative material (for both commercial purposes and research) is of vegetative material of established cultivars (Adams *et al*. 1989). Using vegetative material of established cultivars ensures daughter plants are true to type.

Other potential pathogens that may be associated with seed includes *Pseudoperonospora humuli* and *Verticillium* species. *Pseudoperonospora humuli* form oospores in infected shoots and especially infected cones (Chee *et al*. 2006; Mahaffee *et al*. 2009). Seed harvested from infected cones may become contaminated by fungal oospores. Attempts to induce consistent germination of oospores in the laboratory or under field conditions have failed, and the role of oospores in the disease cycle is considered circumstantial (Chee *et al*. 2006).

Verticillium species (*V. albo-atrum* and *V. dahliae*) are closely related, typically soil-borne or debris-borne pathogens which are usually distinguished by the resting structures produced (dark resting mycelium and micro-sclerotia, respectively) (OEPP/EPPO 2007). There is currently no published evidence that *Verticillium* species are seed-borne in hop. Seed transmission in the genus is uncommon (Sackston and Martens 1959); however, *V. albo-atrum* has been reported to be seed-borne on lucerne (Huang *et al*. 1985) which is thought to be the main means of spread to new areas in North America (OEPP/EPPO 2007). Considering the pathogenic strains, high economic risk of the pathogen and demonstrated seed transmission in other crops, seed is considered a pathway for *Verticillium* species in this assessment.

All restricted seed consignments are subject to the quarantine/biosecurity measures set out in Condition C7100 'General import requirements, seed for sowing'. Biosecurity Australia recommends C7100 be applied to *Humulus* species seed.

In addition to the general conditions (C7100), the following specific conditions are recommended to manage the risks posed by seed-borne pathogens identified in this review.

Sodium hypochlorite treatment

It is recommended that imported seed must be subjected to sodium hypochlorite treatment (1% NaOCl for 10 minutes) for surface sterilisation. This risk management measure will be effective against superficial fungal pathogens. However, treatment with sodium hypochlorite may not be effective against endophytic fungi and viruses. Therefore, additional mitigation measures are required for endophytic fungal pathogens and viruses.

Mandatory fungicidal treatment

It is recommended that imported seed must be treated with a fungicide. Seeds must be soaked in solution of fungicide (such as 0.2% aqueous suspension of dithiocarbamate fungicide), drained and stored in a plastic bag at 0–4 ºC for a minimum of six weeks (maximum of eight weeks) prior to seed being sown in the PEQ facility. Fungicidal seed treatment should be undertaken after the sodium hypochlorite treatment.

Mandatory growth in PEQ facilities with pathogen screening

It is recommended that imported hop seed must be grown out at closed government PEQ facilities. Newly established plants must be subject to conditions that are conducive to symptom expression of the pathogens during a period of observation and until the required pathogen screening/testing is complete (pathogen testing is only required for pathogens identified to be seed-borne in hops as listed in Table 3.3). This increases the likelihood that pathogens will be detected.

Plant growth rate and leaf succulence strongly influence the development of *Pseudoperonospora humuli*. Plants that are not growing vigorously may not show symptoms. Therefore, it is recommended that newly established plants must be grown at 15–25 °C for a minimum period of six months for visual observation of disease symptoms and until the required pathogen screening/testing is completed. As *Humulus* species are fast growing perennials which can typically complete a full life cycle in a single growing season a six month period of active growth in PEQ is considered to be adequate for pathogen expression and detection to occur.

Newly established plants from imported seed must be screened for fungi (*Verticillium albo-atrum* and *V. dahliae*) and viruses (Arabis mosaic virus and Humulus japonicus latent virus) as described in section 3.3.2 (Table 3.4).

4.2.3 Recommended policy to import Humulus tissue culture

The safest and preferred method for inter-country hop germplasm movement is *in vitro* cultures. *In vitro* techniques are effective in eliminating most fungal and bacterial diseases, and may currently be the only option to eliminate any diseases of unknown etiology. However, currently there are no import conditions for tissue cultures. To minimize the entry and establishment of viral diseases in Australia, effective testing (indexing) procedures are required to ensure that imported hop tissue culture is free of viral diseases of quarantine concern.

Tissues cultures represent an inherently lower risk than most other forms of nursery stock (e.g. rhizome and cuttings) and require fewer phytosanitary measures accordingly. However, tissue culture still requires some form of quarantine measures due to the fact that many pathogens are capable of surviving the tissue culturing process. The proposed policy is based on tiered safeguards, which ensures that if one mitigating measure fails, other safeguards exist to ensure that the risk is progressively reduced and managed.

The recommended policy for *Humulus* species tissue cultures includes:

- mandatory on-arrival inspection;
- mandatory growth in closed government PEQ facilities with pathogen screening.

Mandatory on-arrival inspection

It is recommended that imported tissue cultures be subject to on-arrival AQIS inspection to verify freedom from fungal and bacterial contamination. The agar culture media must be clear and not contain antibiotics. If diseased material is detected during on-arrival inspection the material must be destroyed.

On-arrival visual inspection of the tissue culture medium will not be effective in detecting the presence of the downy and powdery mildews, *Pseudoperonospora humuli* and *Podospaera*

macularis, as these species do not grow in artificial media. Therefore, additional measures for *P. humuli* and *P. macularis* are required.

Mandatory growth in PEQ facilities with pathogen screening

It is recommended that imported hop cultures must be grown for minimum of six months in a government PEQ station for pathogen screening. The tissue culture must be maintained in conditions suitable for disease development and must undergo general disease screening and virus indexing using herbaceous indicators, ELISA and/or PCR. As *Humulus* species are fast growing perennials which can typically complete a full life cycle in a single growing season a six month period of active growth in PEQ is considered to be adequate for pathogen expression and detection to occur.

It is not necessary to index for fungal pathogens (*Verticillium albo-atrum* and *Verticillium dahlia*) as these pathogens will be apparent in the culture medium. However, due to the inability to detect *Podosphaera macularis* and *Pseudoperonospora humuli* in artificial growth media: the existing growth under mist and heat (cultures established on a mist/heat bed for mildew check) is recommended to continue.

Newly established plants from imported tissue culture must be screened for phytoplasma (‘*Candidatus* Phytoplasma asteris’), viroids (Apple fruit crinkle viroid, Hop stunt viroid) and viruses (Alfalfa mosaic virus hop strain, American hop latent virus, Arabis mosaic virus hop strain, Cherry leaf roll virus, Humulus japonicus latent virus, Petunia asteroid mosaic virus, strawberry latent ringspot virus and Tobacco necrosis virus hop strain) as described in Section 3.3.2 (Table 3.4).

Appendices

Appendix A: Initiation and pest categorisation of pests associated with *Humulus* species from all countries

Initiation (columns 1 – 2) identifies the pests of *Humulus* species that have the potential to be associated with the pathway. The identified pathways are soil free dormant rhizome, foliage free dormant cuttings, tissue culture and seed.
Pest categorisation (columns 3 – 6) identifies which of the pests with the potential to be on the import pathway are quarantine pests for Australia and require pest risk assessment. Details of the method used in this PRA are given in Section 2: Method for pest risk analysis.

Note: Only valid names are used in this table. For lists of synonyms for potential pests of quarantine concern, refer to Appendix B

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
ARTHROPODS					
ACARI (mites)					
Amblyseius bellinus Womersley, 1954 [Acari: Phytoseiidae]	No: These species are predatory mites (Kim *et al.* 1999).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Amblyseius dieteri Schicha, 1979 [Acari: Phytoseiidae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Amblyseius womersleyi Schicha, 1975 [Acari: Phytoseiidae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Galendromus occidentalis Nesbitt, 1951 [Acari: Phytoseiidae]	No: This species is a predatory mite (Colfer *et al.* 2003).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Neoseiulella cottieri (Collyer, 1964) [Acari: Phytoseiidae]	No: Phytoseiid mites are predators of phytophagous mites and insects (McMurtry 1982; Helle and Sabelis 1985; Kostiainen and Hoy 1996).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Neoseiulus barkeri Hughes, 1948 [Acari: Phytoseiidae]	No: Members of the genus *Neoseiulus* are predatory mites (Croft *et al.* 1998).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Neoseiulus fallacies (Garman, 1948) [Acari: Phytoseiidae]		Yes (AICN 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Tetranychus kanzawai Kishida, 1927 [Acari: Tetranychidae]	No: These mite species feed on foliage of a wide variety of host plants (Kondo and Takafuji 1985).	Yes (AICN 2010)	Assessment not required	Assessment not required	
Tetranychus urticae Koch, 1836 [Acari: Tetranychidae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Typhlodromus doreenae Schicha, 1987 [Acari: Phytoseiidae]	No: This species is a predatory mite (James and Whitney 1993).	Yes (APPD 2010)	Assessment not required	Assessment not required	
COLEOPTERA (beetles, weevils)					
Agriotes lineatus Linnaeus, 1767 [Coleoptera: Elateridae]	No: Eggs are laid in the upper soil layers in damp areas; eggs are quite prone to desiccation and die where moisture is not sufficient (AgroAtlas 2010a). Larvae of *Agriotes* species feed on roots and develop up to 3 cm long (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Aoplocnemis rufipes Latreille, 1802 [Coleoptera: Curculionidae]	No: There is no evidence to suggest that this species is associated with hop propagative material.	Yes (APPD 2010)	Assessment not required	Assessment not required	
Chaetocnema concinna Marsham, 1802 [Coleoptera: Chrysomelidae]	No: This species is a foliage feeder (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Coccinella septempunctata Linnaeus, 1758 [Coleoptera: Coccinellidae]	No: Coccinellids are predatory beetles which feed on aphids and other insects (Legrand and Barbosa 2003).	Not known to occur	Assessment not required	Assessment not required	
Coccinella transversoguttata Faldermann ,1835 [Coleoptera: Coccinellidae]		Not known to occur	Assessment not required	Assessment not required	
Diabrotica undecimpunctata Barber, 1947 [Coleoptera: Chrysomelidae]	No: Adults of this species have been recorded feeding on the cones, leaves and flowers of hop	Yes (APPD 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
	(Mahaffee *et al*. 2009; Berry 1998).				
Hippodamia convergens Guérin-Méneville, 1842 [Coleoptera: Coccinellidae]	No: *Hippodamia* spp. are predatory beetles (Prasifka *et al.* 2004).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Hippodamia tredecimpunctata (Linnaeus, 1758) [Coleoptera: Coccinellidae]		Not known to occur	Assessment not required	Assessment not required	
Melobasis nervosa Boisduval, 1835 [Coleoptera: Buprestidae]	No: Larvae of this species are hard wood borers (Turner and Hawkeswood 1995).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Melolontha melolontha Linnaeus, 1758 [Coleoptera: Scarabaeidae]	No: Larvae of this species are polyphagous and externally feed on the roots of several crops (Graham 2008).	Not known to occur	Assessment not required	Assessment not required	
Otiorhynchus ligustici (Linnaeus, 1758) [Coleoptera: Curculionidae]	No: Eggs are deposited on the soil surface, in soil crevices and on leaves (Gent *et al*. 2009) and larvae feed on roots (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Otiorhynchus ovatus (Linnaeus, 1758) [Coleoptera: Curculionidae]					
Otiorhynchus meridionalis Gyllenhal, 1834 [Coleoptera: Curculionidae]					
Otiorhynchus singularis (Linnaeus, 1767) [Coleoptera: Curculionidae]					
Otiorhynchus rugosostriatus (Goeze, 1777) [Coleoptera: Curculionidae]		Yes (AICN 2010)	Assessment not required	Assessment not required	
Otiorhynchus sulcatus (Fabricius, 1775) [Coleoptera: Curculionidae]		Yes (AICN 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Oulema melanopus (Linnaeus, 1758) [Coleoptera: Chrysomelidae]	No: Adults and larvae of this species feed between the leaf veins and are primarily found on cereals (CFIA 2006).	Not known to occur	Assessment not required	Assessment not required	
Polyphylla crinita LeConte, 1856 [Coleoptera: Scarabaeidae]	No: Females lay eggs in the soil and larvae feed on roots. Adult beetles feed on leaves (Mahaffee *et al.* 2009)	Not known to occur	Assessment not required	Assessment not required	
Polyphylla decemlineata Say, 1823 [Scarabaeidae]		Not known to occur	Assessment not required	Assessment not required	
Prionus californicus (Motschulsky, 1845) [Coleoptera: Cerambycidae]	**Yes:** Small larvae are found deep in the root and may tunnel into the rhizome (Mahaffee *et al*. 2009). Therefore larvae may be associated with the rhizome (Mahaffee *et al*. 2009).	Not known to occur	**Yes:** Polyphagous nature of the pest (Cervantes *et al.* 2006) and suitable environmental conditions will help establish and spread this insect in the PRA area.	**Yes:** *Prionus californicus* feed on at least 21 genera of woody perennials in 12 plant families (Barbour *et al*. 2007) including grapes and fruit trees, from deciduous trees, conifers, *Eucalyptus* spp. and is a serious pest of hop (Alston *et al*. 2007; Cervantes *et al*. 2006).	**Yes**
Psylliodes attenuatus Koch, 1803 [Coleoptera: Chrysomelidae]	No: Adult beetles feed on leaves and on bracteoles of young cones (Mahaffee *et al*. 2009)	Not known to occur	Assessment not required	Assessment not required	
Psylliodes punctulatus Melsheimer, 1842 [Coleoptera: Chrysomelidae]		Not known to occur	Assessment not required	Assessment not required	
Stethorus histrio Chazeau, 1974 [Coleoptera: Coccinellidae]	No: This species is predatory species which attacks aphids (Carver and Kent 2000).	Yes (APPD 2010)	Assessment not required	Assessment not required	
DERMAPTERA (earwigs)					
Forficula auricularia Linnaeus, 1758 [Dermaptera: Forficulidae]	No: This species is a foliage feeder. It can feed on vine leaves soon after budburst resulting in a very tatty appearance (Rees *et al*. 1995).	Yes (AICN 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
DIPTERA (flies)					
Scaptomyza apicalis (Hardy, 1849) [Diptera: Drosophilidae]	No: This species is a leaf miner (Martin *et al.* 2006).	Not known to occur	Assessment not required	Assessment not required	
HEMIPTERA (aphids, leafhoppers, mealybugs, psyllids, scales, true bugs, whiteflies)					
Aphis gossypii Glover, 1877 [Hemiptera: Aphididae]	No: This species occurs on the underside of leaves (Capinera 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Aulacorthum solani (Kaltenbach, 1843) [Hemiptera: Aphididae]	No: This species is a foliage feeder (Awmack *et al.* 1997).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Lygus spinolae Mey., 1841 [Hemiptera: Miridae]	No: Feeds externally on buds, flowers, developing fruits and seeds, and young shoots (Eyles 1999).	Not known to occur	Assessment not required	Assessment not required	
Macrosiphum euphorbiae (Thomas, 1878) [Hemiptera: Aphididae]	No: This species causes direct plant damage to shoots and leaves (Goggin *et al.* 2001).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Metcalfa pruinosa (Say, 1830) [Hemiptera: Flatidae]	No: This species lays its eggs under the bark of host plants (Alma *et al.* 2005) and the whole life cycle is completed above ground (Mead 2008).	Not known to occur	Assessment not required	Assessment not required	
Myzus persicae (Sulzer, 1776) [Hemiptera: Aphididae]	No: This species feeds by sucking sap from the underside of leaves (Mau and Kessing 1991).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Nezara viridula (Linnaeus, 1758) [Hemiptera: Pentatomidae]	No: This species is a pod-sucking bug which occurs on flowers and fruits (Mau and Kessing 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Phorodon humuli (Schrank, 1801) [Hemiptera: Aphididae]	No: This aphid feeds on the leaf and cones (Mahaffee *et al*. 2009; Campbell 1985).	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Sidnia kinbergi (Stål, 1859) [Hemiptera: Miridae]	No: Mirinae are sucking insects which feed externally on buds, flowers and young shoots (Eyles 1999).	Yes (APPD 2010)	Assessment not required	Assessment not required	
HYMENOPTERA (wasps, ants)					
Anaphes iole Girault, 1911 [Hymenoptera: Mymaridae]	No: This species is parasitic on *Lygus* spp. (Manrique *et al.* 2005).	Not known to occur	Assessment not required	Assessment not required	
Gonatocerus capitatus Gahan, 1932 [Hymenoptera: Mymaridae]	No: Members of this genus are important parasites of sharpshooters and leafhoppers (Bayoun *et al.* 2008; Boyd and Hoddle 2006).	Not known to occur	Assessment not required	Assessment not required	
Gonatocerus latipennis Girault, 1911 [Hymenoptera: Mymaridae]		Not known to occur	Assessment not required	Assessment not required	
LEPIDOPTERA (moths, butterflies)					
Acronicta rumicis Linnaeus, 1758 [Lepidoptera: Noctuidae]	No: This species is a defoliating pest of a variety of plants (CABI 2010).	Not known to occur	Assessment not required	Assessment not required	
Acropolitis rudisana Walker, 1863 [Lepidoptera: Tortricidae]	No: Larvae are foliage feeders and live in nests made by rolling or webbing leaves. They shelter, feed and pupate within these nests, skeletonizing leaves in the process (Cordingley and Danthanarayana 1976).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Adoxophyes orana (Fischer von Röslerstamm, 1834) [Lepidoptera: Tortricidae]	No: This species affects the foliage and fruit of a variety of crop plants (Walker 2007).	Not known to occur	Assessment not required	Assessment not required	
Agrotis munda Walker, 1857 [Lepidoptera: Noctuidae]	No: Larvae of this species attack the stem of plant seedlings (Gu *et al.* 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Anavitrinella pampinaria Guenée, 1857 [Lepidoptera: Geometridae]	No: Feeds on leaves and pupates in loose cocoons in leaf litter or soil (Zhang 1994)	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Archips podana (Scopoli, 1763) [Lepidoptera: Tortricidae]	No: Larvae of this species over-winter in cocoons on twigs or buds (Cuthbertson and Murchie 2005).	Not known to occur	Assessment not required	Assessment not required	
Choristoneura rosaceana Harris, 1841 [Lepidoptera: Tortricidae]	No: This species is a foliar pest (Bélair *et al.* 1999).	Not known to occur	Assessment not required	Assessment not required	
Cnephasia longana Haworth, 1811 [Lepidoptera: Tortricidae]	No: This species tunnels into the tips of shoots, and potentially buds, making open channels (Gough 1952).	Not known to occur	Assessment not required	Assessment not required	
Diarsia intermixta Guenée 1852 [Lepidoptera: Noctuidae]	No: There is no evidence to suggest that this species is associated with hop propagative material.	Yes (APPD 2010)	Assessment not required	Assessment not required	
Epiphyas postvittana Walker, 1863 [Lepidoptera: Tortricidae]	No: This species webs together leaves of host plants (Hyink *et al.* 1998).	Yes (AICN 2004)	Assessment not required	Assessment not required	
Grapholita delineana Walker, 1863 [Lepidoptera: Tortricidae]	**Yes:** Eggs are laid on foliage and larvae bores in the stems producing (McPartland 2002) and also feed on inflorescences (Miller 1982).	Not known to occur	**Yes:** *Grapholita delineana* is present in Western Asia, Eastern Europe, India, Japan, Korea, and the USA (AgroAtlas 2009a) There are similar natural and built environments in areas of Australia that would be suitable for the establishment and spread of this pest.	**Yes:** *Grapholita delineana* is responsible for causing 30–40% loss of hemp seed in the Ukraine and 100% damage to the stalks of *Cannabis sativa* plants in the Ukraine (Meijerman and Ulenberg 2000) and Romania (McPartland 2002).	**Yes**
Helicoverpa armigera (Hübner, 1805) [Lepidoptera: Noctuidae]	No: Larvae are primarily foliage feeders; large larvae may eat the pods of some host plants (QDPI&F 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Helicoverpa punctigera Wallengren, 1860 [Lepidoptera: Noctuidae]		Yes (APPD 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Helicoverpa zea (Boddie, 1850) [Lepidoptera: Noctuidae]		Not known to occur	Assessment not required	Assessment not required	
Hydraecia immanis Guenée, 1852 [Lepidoptera: Noctuidae]	**Yes**: Larvae feed inside the stem and then in root stock (Šedivý *et al*. 2005).	Not known to occur	**Yes:** This species occurs in Canada (Hill 1987) and the US (Giebink *et al.* 1984). There are similar natural and built environments in areas of Australia that would be suitable for the establishment and spread of this pest.	**Yes:** This species has caused 25–50% damage to hop crops in the US (Giebink *et al.* 1984).	**Yes**
Hydraecia micacea (Esper, 1789) [Lepidoptera: Noctuidae]		Not known to occur	**Yes:** This species occurs throughout Europe, Asia and North America (Hill 1987). There are similar natural and built environments in areas of Australia that would be suitable for the establishment and spread of this pest. *Hydraecia micacea* feeds on more than 50 species of plants from 20 families (Šedivý *et al*. 2005).	**Yes:** In North America *Hydraecia micacea* has been of primary economic significance as a pest of corn. However, cultivated hop may be at risk should the pest be introduced into hop-growing regions of western United States (Mahaffee *et al*. 2009).	**Yes**
Hypena humuli (Harris, 1841) [Lepidoptera: Noctuidae]	No: Eggs of this species are laid near the veins of hop leaves; larvae are foliage feeders (Grasswitz and James 2008).	Not known to occur	Assessment not required	Assessment not required	
Inachis io (Linnaeus, 1758) [Lepidoptera: Nymphalidae]	No: This species lays its eggs in exposed silken webs at the top of host plants (Bryant *et al.* 2002).	Not known to occur	Assessment not required	Assessment not required	
Lacanobia subjuncta Grote & Robinson, 1886 [Lepidoptera: Noctuidae]	No: This species lays eggs on the underside of leaves and generally feeds on foliage (Doerr and Brunner 2007).	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Mamestra configurata Walker, 1856 [Lepidoptera: Noctuidae]	No: Bertha armyworms feed on foliage (Gent *et al.* 2010).	Not known to occur	Assessment not required	Assessment not required	
Neumichtis nigerrima (Guenée, 1852) [Lepidoptera: Noctuidae]	No: A polyphagous species, the larvae are foliage feeders (Herbison-Evans and Crossley 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Noctua pronuba (Linnaeus, 1758) [Lepidoptera: Noctuidae]	No: A polyphagous species, the larvae are foliage feeders on a wide range of cultivated and wild plants (CABI 2010).	Not known to occur	Assessment not required	Assessment not required	
Orgyia antiqua (Linnaeus, 1758) [Lepidoptera: Lymantriidae]	No: *Orgyia antiqua*, and other members of the genus, are foliage feeders (Sandre *et al.* 2007).	Not known to occur	Assessment not required	Assessment not required	
Orgyia leucostigma (J. E. Smith, 1797) [Lepidoptera: Lymantriidae]		Not known to occur	Assessment not required	Assessment not required	
Ostrinia furnacalis (Guenée, 1854) [Lepidoptera: Pyralidae]	**Yes**: Larvae of *Ostrinia* species are stem borers (Martel *et al.* 2003) and attack nearly any robust herbaceous plant with a stem large enough for the larvae to enter (Benedek *et al*. 1966; Capinera 2000).	Yes (AICN 2010)	Assessment not required	Assessment not required	
Ostrinia nubilalis Hübner, 1796 [Lepidoptera: Pyralidae]		Not known to occur	*Ostrinia nubilalis* has established in a variety of environments throughout Europe, northern Africa, North America and Russia (AgroAtlas 2009b). There are similarities in the natural and managed environments of these areas with those in the PRA area. The environmental conditions in the PRA area are likely to support the establishment and spread of *O. nubilalis*.	The pest is known to be polyphagous, attacking many herbaceous plants with stems large enough for the larvae to enter (Capinera 2000), including hop (Bourguet *et al*. 2000) and several weed species (Capinera 2000). *Ostrinia nubilalis* is considered a major biotic constraint for maize development and production (Krumm *et al*. 2008).	**Yes**
Peridroma saucia (Hübner, 1808) [Lepidoptera: Noctuidae]	No: This species is a polyphagous foliage feeding	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
	pest. It is a generalist feeder on vegetable crops, cereals, ornamentals, fruit and forage crops (Bibolini 1970).				
Plutella xylostella (Linnaeus, 1758) [Lepidoptera: Plutellidae]	No: Larvae of this species feed on leaves and pods (Gu *et al.* 2007).	Yes (AICN 2010)	Assessment not required	Assessment not required	
Proteuxoa atra Guenée, 1852 [Lepidoptera: Noctuidae]	No: Larvae of noctuids are generally foliage feeders (Nielsen *et al*. 1996).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Strymon melinus (Hübner, 1818) [Lepidoptera: Lycaenidae]	No: Larvae feed on foliage and adults feed on nectar from flowers (Opler *et* al. 2010)	Not known to occur	Assessment not required	Assessment not required	
Trichoplusia ni (Hübner, 1803) [Lepidoptera: Noctuidae]	No: Larvae of this species feed primarily on foliage (Metcalf *et al*. 1962).	Not known to occur	Assessment not required	Assessment not required	
Xestia c-nigrum (Linnaeus, 1758) [Lepidoptera: Noctuidae]	No: The larvae of this species feed on developing shoots and buds (Dibble *et al*. 1979).	Not known to occur	Assessment not required	Assessment not required	
Udea profundalis Packard, 1873 [Lepidoptera: Crambidae]	No: Larvae of this species feed on foliage (Powell and Hogue 1980).	Not known to occur	Assessment not required	Assessment not required	
NEUROPTERA (lacewings)					
Chrysoperla plorabunda (Fitch, 1855) [Neuroptera: Chrysopidae]	No: This species is a predator of aphid species (Limburg and Rosenheim 2001).	Not known to occur	Assessment not required	Assessment not required	
Hemerobius stigma Stephens, 1836 [Neuroptera: Hemerobiidae]	No: This species is a predator of scale insects (Miller *et al.* 2004).	Not known to occur	Assessment not required	Assessment not required	
Micromus variolosus Hagen, 1886 [Neuroptera: Hemerobiidae]	No: Other members of the genus are predators of scale insects (Miller *et al.* 2004).	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
ORTHOPTERA (grasshoppers, crickets)					
Dociostaurus maroccanus (Thunberg, 1815) [Orthoptera: Acrididae]	No: This species preferentially feeds on the leaf surfaces of graminaceous plants (El Ghadraoui *et al.* 2002).	Not known to occur	Assessment not required	Assessment not required	
Gryllotalpa gryllotalpa Linnaeus, 1758 [Orthoptera: Gryllotalpidae]	No: This species is a generalist foliage feeder (Sheppard 1995).	Not known to occur	Assessment not required	Assessment not required	
THYSANOPTERA (thrips)					
Frankliniella occidentalis (Pergande, 1895) [Thysanoptera: Thripidae]	No: This species feeds on flowers; it has a wide host range including many vegetable and ornamental crops (Sertkaya *et al.* 2006).	Yes (APPD 2010)	Assessment not required	Assessment not required	
PATHOGENS					
BACTERIA					
Pseudomonas syringae pv. *cannabina* (Sutic and Dowson 1959) Young *et al*. 1978 [Pseudomonadales: Pseudomonadaceae]	No[6]: Hop is not considered a natural host.	Not known to occur	Assessment not required	Assessment not required	
Rhizobium rhizogenes (Riker *et al.* 1930) Young *et al*. 2001 [Rhizobiales: Rhizobiaceae]	**Yes:** This species produce galls on hop bine and rhizome (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Xanthomonas campestris pv. *cannabis* Severin 1978 [Xanthomonadales:	No[7]: Hop is not considered a natural host.	Not known to occur	Assessment not required	Assessment not required	

[6] There has been reports of this bacterium on hop; however, recent studies on artificial inoculation indicate that the bacterium is unable to infect hop therefore hop is not considered a host of this bacterium (Mahaffee *et al*. 2009; Bull *et al.* 2010).

[7] Reports of this bacteria being a pathogen of hop are based on artificial inoculation studies (Mahaffee *et al*. 2009). Hop is not considered to be a natural host of *Xanthomonas campestris* pv. *cannabis* (Mahaffee *et al*. 2009).

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Xanthomonadaceae]					
FUNGI					
Actinomucor elegans (Eidam) C.R. Benj. & Hesselt [Mucorales: Mucoraceae]	No: This species occurs in soil and on organic substrates (Farr and Rossman 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Aecidium humuli Hotson[8] [Anamorphic Pucciniales]	No: *Aecidium humuli* is a rust fungus that infects foliage (McPartland 2003).	Not known to occur	Assessment not required	Assessment not required	
Alternaria alternata (Fr.) Keissl. [Anamorphic Pleospraceae]	No: *Alternaria* species generally associated with foliage (Phalip *et al.* 2006). *Alternaria alternata* causes damage to hop cones whereas *Alternaria humuli* attacks foliage (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Alternaria arborescens Simmons [Anamorphic Pleospraceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Alternaria brassicicola (Schwein.) Wiltshire [Anamorphic Pleospraceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Alternaria citri Ellis & N. Pierce [Anamorphic Pleospraceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Alternaria humuli Simmons [Anamorphic Pleospraceae]		Not known to occur	Assessment not required	Assessment not required	
Alternaria humuli-scandens Zhang *et al*. 2008 [Anamorphic Pleospraceae]		Not known to occur	Assessment not required	Assessment not required	
Alternaria tenuissima (Kunze) Wiltshire [Anamorphic Pleospraceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Ampelomyces humuli (Fautrey) Rudakov [Anamorphic Phaeosphaeriaceae]	No: This species is an antagonistic fungus which affects the growth of powdery mildews	Not known to occur	Assessment not required	Assessment not required	

[8] *Aecidium humuli* was listed as occurring on hops in Washington (Hoston 1925; Shaw 1973 cited in Farr and Rossman 2010). However in recent compendium of 'Hop diseases and pests' does not list this fungus occurring on hop (Mahaffee *et al*. 2009).

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
	(Szentivanyi *et al.* 2005).				
Apiosporina morbosa (Schwein.) Arx [9] [Pleosporales: Venturiaceae]	No: This species has been isolated from foliage of diseased hop plant (Phalip *et al*. 2006).	Not known to occur	Assessment not required	Assessment not required	
Armillaria mellea (Vahl) P. Kumm. [Agaricales: Physalacriaceae]	No: This fungus is a soil inhabitant and is considered a pathogen of hardwoods (Mahaffee *et al*. 2009).[10]	Not known to occur[11]	Assessment not required	Assessment not required	
Arxiomyces vitis (Fuckel) P.F. Cannon & D. Hawksw. [Melanosporales: Ceratostomataceae]	No: This species occurs on bark (Farr *et al.* 1989).	Not known to occur	Assessment not required	Assessment not required	
Ascochyta humuli Lasch [Anamorphic Mycosphaerellaceae]	No: Ascochyta species are associated with foliage causing leaf spot (Mahaffee *et al*. 2009). *Ascochyta humuli* overwinters on crop debris and is dispersed by splashing water and wind (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Ascochyta humuliphila Melnik [Anamorphic Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Aureobasidium pullulans var. *pullulans* (de Bary) G. Arnaud [Dothideales: Dothioraceae]	No: This species is thought to be a contaminant rather than a pathogenic agent on hop (Phalip *et al.* 2006).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Botryosphaeria rhodina (Berk. &	**Yes:** This species is associated	Yes (APPD 2010)	Assessment not required	Assessment not required	

[9] *Apiosporina morbosa* was identified as present on diseased hop foliage in France (Phalip *et al*. 2006). However in recent compendium of 'Hop diseases and pests' does not list this fungus occurring on hop (Mahaffee *et al*. 2009).

[10] *Armillaria mellea* was identified as causing root rot on hop in 1937. Since then, at least 10 other *Armillaria* species have been described and *Armillaria mellea* is now thought to be primarily a pathogen of hardwoods. It is unclear which species are pathogenic to hops, although the disease is caused known to be caused by *Armillaria* species other than *Armillaria mellea* (Mahaffee *et* al. 2009).

[11] Reports of *Armillaria mellea* in Australia have been shown to be mis-identifications of *A. luteobubalina* (Keane *et al.* 2000).

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
M.A. Curtis) Arx [Dothideales: Botryosphaeriaceae]	with root rots of tuberous plants (Phalip *et al.* 2006).				
Botrytis cinerea Pers. [Helotiales: Screotiniaceae]	No: Primarily infect cones and is a problem in moist climates during the time from flowering to harvest (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Cercospora cantuariensis E.S. Salmon & Wormald [Capnodiales: Mycosphaerellaceae]	No: *Cercospora* species are associated with foliage causing leaf spot (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Cercospora humuli Hori [Capnodiales: Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Cercospora humuligena Y. L. Guo & L. Xu [Capnodiales: Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Cercospora humuli-japonici Sawada [Capnodiales: Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Ceriospora dubyi Niessl. [Incertae sedis: Annulatascaceae]	No: This species is ubiquitous in temperate environments and lives saprophytically on decaying plant debris (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Cladosporium fumago f. *humuli-lupuli* Thüm. [Capnodiales: Davidiellaceae]	No: *Cladosporium* species are saprophytic (Phalip *et al.* 2006); and occur on fruits and leaves of a variety of plants (Farr *et al*. 1989). *Cladosporium fumago* and *C. herbarum* cause sooty mould and the appearance of sooty mould are linked to the presence and development of	Not known to occur	Assessment not required	Assessment not required	
Cladosporium herbarum (Pers.:Fr.) Link [Capnodiales: Davidiellaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Cladosporium magnusianum (Jaap) M.B. Ellis [Capnodiales: Davidiellaceae]		Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
	aphids (Mahaffee *et al*. 2009).				
Clavidisculum humuli (W. Phillips) Raitv. [Helotiales: Hyaloscyphaceae]	No: This fungus is associated with dead stems (Ellis and Ellis 1997).	Not known to occur	Assessment not required	Assessment not required	
Colletotrichum gloeosporioides (Penz.) Penz. & Sacc. [Phyllachorales: Hypocreomycetidae]	No: This species is associated with seedling blight (Farr and Rossman 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Cylindrosporium humuli Ellis & Everh. [Anamorphic Pyrenopeziza]	No: This species is ubiquitous in the environment and live saprophytically on decaying plant debris (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Diaporthe sarmenticia Sacc. [Diaporthales: Diaporthaceae]	No: There is no information to suggest that this species is associated with *Humulus* propagative material.	Not known to occur	Assessment not required	Assessment not required	
Didymella bryoniae (Fuckel) Rehm [Incertae sedis: Pleosporales]	**Yes**: This species causes stem canker (Phalip *et al.* 2006).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Epicoccum nigrum Link [Pleosporales: Pleosporaceae]	No: This species is an antagonistic fungus used to control twig blights in a variety of crops (Madrigal *et al*. 1994).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Fusarium culmorum (W. G. Smith) Sacc. [Hypocreales: Nectriaceae]	**Yes:** Many members of this genus are soil inhabiting species which cause vascular wilt by attacking roots (Farr *et al.* 1989). *Fusarium crookwellense* is commonly isolated from plant debris (Farr *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Fusarium crookwellense L.W. Burgess, P.E. Nelson & Toussoun [Hypocreales: Nectriaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Fusarium oxysporum Schltdl. [Hypocreales: Nectriaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Gibberella avenacea R.J. Cook	**Yes:** *Gibberella avenacea* and	Yes (APPD 2010)	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
[Hypocreales: Nectriaceae]	*Gibberella pulicaris*, cause cone tip blight and cankers on rhizomes, and are able to survive in soil or plant debris (Mahaffee *et al*. 2009; Ocamb 2009).				
Gibberella cyanogena (Desm.) Sacc. [Hypocreales: Nectriaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Gibberella pulicaris (Fr.) Sacc. [Hypocreales: Nectriaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Gibberella zeae (Schwein.) Petch [Hypocreales: Nectriaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Golovinomyces cichoracearum var. *cichoracearum* (DC.) V.P. Heluta [Erysiphales Erysiphaceae]	**Yes**: This species has been reported causing powdery mildew. However it is not clear whether these records reflect true infection of hop tissue (Mahaffee *et al*. 2009). These reports may be the results of mis-identifications or contaminating ascocarps being found on cones or leaves but not actually infecting these tissues (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Helicobasidium brebissonii (Desm.) Donk [Helicobasidiales: Helicobasidiaceae]	Yes: Root-rot fungus (Nakamura *et al*. 2004). This species is soil borne and spreads from plant to plant. This fungus is a weak pathogen (Koike *et al.* 2007).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Hymenoscyphus humuli var. *humuli* (Lasch) Dennis [Helotiales: Helotiaceae]	No: There is no information to suggest that this species is associated with *Humulus* propagative material.	Not known to occur	Assessment not required	Assessment not required	
Leptosphaeria dumetorum Niessl [Pleosporales: Leptosphaeriaceae]	No: *Leptosphaeria* are generally associated with foliage of host plants (Irwin and Davis 1985).	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Leptosphaerulina australis McAlpine [Incertae sedis: Pleosporales]	No: This species is saprophytic (Irwin and Davis 1985).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Leptoxyphium fumago (Woron.) R.C. Srivast. [Capnodiales: Capnodiaceae]	No: This species causes sooty mould on hop cones (Farr *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Lewia infectoria (Fuckel) M.E. Barr & E.G. Simmons [Pleosporales: Pleosporaceae]	No**:** This species occurs in the rhizosphere on roots; its preferred hosts are members of the Poaceae (Kwasna *et al.* 2006).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Macrophomina phaseolina (Tassi) Goid.[Botryosphaeriales: Botryosphaeriaceae]	**Yes**: This soil-borne fungus causes charcoal rot infecting the root and lower stem of host plants (Partridge 2003).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Mortierella hyalina var. *hyalina* (Harz) W. Gams [Mortierellales: Mortierellaceae]	No: This species occurs in the soil (Weber and Tribe 2003).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Mucor circinelloides Tiegh. [Mucorales: Mucoraceae]	No: These species are saprophytes (Phalip *et al.* 2006).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Mucor hiemalis Wehmer [Mucorales: Mucoraceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Paraconiothyrium sporulosum (W. Gams & Domsch) Verkley [Anamorphic Montagnulaceae]	No: This species is a soil inhabiting fungus (Verkley *et al.* 2004).	Not known to occur	Assessment not required	Assessment not required	
Penicillium glabrum (Wehmer) Westling [Anamorphic Trichocomaceae]	No: These species occur on foliage and in soil and may cause storage rots (Farr and Rossman 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Penicillium raistrickii G. Sm. [Anamorphic Trichocomaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Pezizella discreta (P. Karst.)	No: This fungus is associated	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Dennis [Helotiales : Hyaloscyphaceae]	with dead stems (Ellis and Ellis 1997).				
Phacidiopycnis tuberivora (Güssow & W.R. Foster) B. Sutton [Leotiales: Bulgariaceae]	**Yes:** This species causes root rot of tuberous plants (Farr and Rossman 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Phlyctaeniella humuli Petr. [Incertae sedis]	No: There is no information to suggest that this species is associated with *Humulus* propagative material.	Not known to occur	Assessment not required	Assessment not required	
Phoma aliena (Fr.) Aa & Boerema [Anamorphic Leptosphaereceae]	No: *Phoma* species are ubiquitous in the environment and live saprophytically on decaying plant debris (Mahaffee *et al*. 2009). *Phoma exigua* is associated with leaf spot and cone necrosis (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Phoma exigua Sacc. [Anamorphic Leptosphaereceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Phoma herbarum f. *Humuli* Sacc. [Anamorphic Leptosphaereceae]		Not known to occur	Assessment not required	Assessment not required	
Phyllactinia guttata[12] (Wallr.) Lév. [Erysiphales: Erysiphaceae]	No: Associated with foliage and stems (Farr and Rossman 2010).	Yes (Farr and Rossman 2010)	Assessment not required	Assessment not required	
Phyllosticta bractearum Oudem [Anamorphic Botryosphaeriaceae]	No: Members of the genus *Phyllosticta* cause foliar spots (Pandey *et al*. 2003; Farr *et al*. 1989). *Phyllosticta* species are ubiquitous in the environment and live saprophytically on decaying plant debris (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Phyllosticta decidua Ellis & Kellerm. [Anamorphic Botryosphaeriaceae]		Not known to occur	Assessment not required	Assessment not required	
Phyllosticta humuli Sacc. & Speg. [Anamorphic Botryosphaeriaceae]		Not known to occur	Assessment not required	Assessment not required	

[12] This species is recorded to occur on hops species (as a synonym of *P. suffulta*); however, it is not clear if these records represent true infections. Mahaffee *et al.* (2009) suggests that records of this species on hops could represent misidentifications or contamination from ascocarps and not true infections of hops plant tissue.

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Phyllosticta humuli var. *major* Ellis & Everh. [Anamorphic Botryosphaeriaceae]		Not known to occur	Assessment not required	Assessment not required	
Phyllosticta lupulina Bubák & Kabát [Anamorphic Botryosphaeriaceae]		Not known to occur	Assessment not required	Assessment not required	
Podosphaera fuliginea (Schltdl.) U. Braun & S. Takamatsu [Erysiphales: Erysiphaceae]	**Yes**: Obligate parasite causes powdery mildew on the foliage of hop plants (Farr and Rossman 2010).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Podosphaera macularis (Wallr.) U. Braun & S. Takamatsu [Erysiphales: Erysiphaceae]	**Yes:** This species is associated with rhizome, as it overwinters in rhizome and rhizome buds (Gent *et al.* 2008).	Not known to occur	**Yes:** Climate modelling data suggested that the disease would survive in conditions found in parts of the PRA area (Pethybridge *et al*. 2003).	**Yes:** Introduction of hop powdery mildew into Australia could severely affect production and significantly increase variable costs (Pethybridge *et al*. 2003).	**Yes**
Pseudocercospora humuli (Hori) YL Guo & XJ Liu [Anamorphic Mycosphaerellaceae]	No: Members of this genus cause foliar lesions (Beilharz and Cunnington 2003).	Not known to occur	Assessment not required	Assessment not required	
Pseudocercospora humuli-japonici Sawada ex Goh & WH Hsieh [Anamorphic Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Pseudoperonospora humuli (Miyabe & Takah.) G.W Wilson [Peronosporales: Peronosporaceae]	**Yes:** This fungus overwinters as mycelium in infected hop buds and rhizomes (Mahaffee *et al*. 2009; Johnson and Skotland 1983).	Not known to occur	**Yes:** CLIMEX modelling indicates the potential of establishment and spread in parts of the PRA area (Pethybridge *et al.* 2003).	**Yes:** Losses of up to 28% of plants have been recorded in the Czech Republic (Pethybridge *et al.* 2003).	**Yes**
Pseudopleospora petrakii (E. Müll.) Crivelli [Incertae sedis]	No: There is no information to suggest that this species is associated with *Humulus* propagative material.	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Rhizoctonia solani JG Kuhn [Ceratobasidiales: Ceratobasidiaceae]	**Yes:** This species is pathogenic on a number of plant species. It usually attacks the underground portion of the plant (Farr *et al.* 1989). It is also seed-borne in hop (Richardson 1990).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Rosellinia necatrix Berl. ex Prill. [Anamorphic: Xylariaceae]	No: *Rosellinia necatrix* is ubiquitous in the environment and live saprophytically on decaying plant debris (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Sclerotinia sclerotiorum (Lib.) de Bary [Helotiales: Sclerotiniaceae]	Yes: fungus infected bine and overwinters as sclerotia in soil and may infect rhizome (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Septoria divergens Bubák & Kabát [Capnodiales: Mycosphaerellaceae]	No: Members of this genus cause leaf spot (Farr *et al.* 1989; Farr and Rossman 2010). *Septoria humuli* cause leaf spot on older and lowers leaves of hop. The pathogen overwinters on crop debris and is dispersed by splashing water and wind (Mahaffee *et al*. 2009).	Not known to occur	Assessment not required	Assessment not required	
Septoria humuli Westend. [Capnodiales: Mycosphaerellaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Septoria humulina Bondartsev [Capnodiales: Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Septoria lupulina Ellis & Kellerm. [Capnodiales: Mycosphaerellaceae]		Not known to occur	Assessment not required	Assessment not required	
Sphaerella erysiphina (Berk. & Broome) Cooke [Capnodiales: Mycosphaerellaceae]	No: This species causes leaf spot and cone disorder (Pethybridge and Mahaffee 2007).	Not known to occur	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Stagonospora humuli-americani Fairm. [Pleosporales: Phaeosphaeriaceae]	No: *Stagonospora* species are generally associated with foliage (Farr and Rossman 2010).	Not known to occur	Assessment not required	Assessment not required	
Synchytrium aureum J. Schröt. [Chytridiales: Synchytriaceae]	*Synchytrium aureum* is ubiquitous in the environment and live saprophytically on decaying plant debris (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Trichothecium roseum (Pers.) Link [Anamorphic Bionectriaceae]	No: This species is a saprophytic or weakly parasitic mould that grows on various substrates (Farr *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Verticillium albo-atrum Reinke & Berthold (hop strain) [Incertae sedis: Plectosphaerellaceae]	**Yes:** Hop-infecting *Verticillium* strains can be carried in planting material as it colonises the vascular system (Radisek *et al.* 2003).	Not known to occur[13]	**Yes:** Hop-infecting *Verticillium* strains are present in UK and the USA (Pethybridge *et al*. 2003). There are similar natural and built environments in hop growing areas of Australia that would be suitable for the establishment and spread of these pathogens.	**Yes:** Hop wilt caused by *Verticillium* species is one of the most important diseases of hop causing considerable economic losses (Radisek *et al.* 2003).	**Yes**
Verticillium dahliae Kleb. (hop strain) [Incertae sedis: Plectosphaerellaceae]		Not known to occur			**Yes**
Verticillium nigrescens Pethybr. [Incertae sedis: Plectosphaerellaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Verticillium tricorpus I Isaac [Incertae sedis: Plectosphaerellaceae]		Not known to occur	**Yes**: Several *Verticillium* species are already established in Australia indicating this species may also establish and spread in Australia.	No: Only rarely isolated from hop and is generally considered not to be significant pathogen (OEPP/EPPO 2007).	

[13] Hops strain of *Verticillium* species are not known to occur in Australia (Walker 1990).

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
STRAMINOPILA					
Phytophthora cactorum (Lebert & Cohn) J. Schröt. [Peronosporales: Peronosporaceae]	**Yes:** These species cause crown and root rot on a variety of plants (Mahaffee *et al*. 2009; Gent *et al.* 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Phytophthora citricola Sawada [Peronosporales: Peronosporaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Phytophthora cryptogea Pethybr. & Laff. [Peronosporales: Peronosporaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Pythium intermedium de Bary [Pythiales: Pythiaceae]	No: *Pythium* species are saprophytic on dead plant material or are parasitic on plant roots of a variety of plant species (Packer and Clay 2003; Farr *et al.* 1989).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Pythium mamillatum Meurs [Pythiales: Pythiaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Pythium torulosum Coker & P. Patt. [Pythiales: Pythiaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Pythium ultimum Trow [Pythiales: Pythiaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
Pythium vexans de Bary [Pythiales: Pythiaceae]		Yes (APPD 2010)	Assessment not required	Assessment not required	
PHYTOPLASMA					
'*Candidatus* Phytoplasma asteris' (Group 16SrI-B)	**Yes:** This phytoplasma cause's shoot proliferation in hop. Little is known about the epidemiology of shoot proliferation disease of hop but phytoplasmas are known to be disseminated in soft wood cuttings and rhizomes taken from infected plants (Mahaffee *et al.* 2009)	Not known to occur	**Yes:** This species is present in Poland (Solarska *et al.* 2004). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	**Yes:** This disease causes infected plants to produce numerous weak shoots and leaves are small, distorted and chlorotic. Severely infected plants are stunted and do not produce flowers or produce only single malformed flowers (Mahaffee *et al.* 2009).	**Yes**

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
VIROIDS					
Apple fruit crinkle viroid (AFCVd-hop) hop type	**Yes:** This species is grafting transmissible (Mahaffee *et al*. 2009; Koganezawa 2001).	Not known to occur	**Yes:** This species is present in Japan (Koganezawa 2001). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	**Yes:** The hop type of this viroid is known to cause stunting and severe leaf curling in upper bines of hop plants (Pethybridge *et al*. 2008).	**Yes**
Hop latent viroid (HpLVd) [Pospiviroidae: Cocadviroid]	**Yes:** This viroid can be found in meristematic tissue (Matousek *et al.* 2003).	Yes (Pethybridge *et al.* 2008)	Assessment not required	Assessment not required	
Hop stunt viroid (HpSVd) (hop strain) [Pospiviroidae: Hostuviroid]	**Yes:** This viroid is transmitted by grafting (Sano *et al.* 1989). Found in rhizomes imported from Japan (Mahaffee *et al*. 2009).	Not known to occur [14]	**Yes:** Present in Japan, Korea and the United States (Pethybridge *et al.* 2008). There are similar natural and built environments in parts of Australia that would be suitable for the establishment and spread of the virus.	**Yes:** One of the serious diseases in the hop production areas of Japan. Hop plants infected by HpSVd produced fewer and smaller cones with yields 50% lower and alpha and beta acid levels 50 to 70% lower than in viroid free plants (Pethybridge *et al.* 2008).	**Yes**
VIRUSES					
Alfalfa mosaic virus (hop strain) (AMV) [Bromoviridae: Alfamovirus]	**Yes:** Transmitted by grafting and by mechanical inoculation (Brunt *et al.* 1996).	Not known to occur	**Yes:** This virus has been detected in China and the former Czechoslovakia (Yu and Liu 1987). There are similar natural and built environments in parts of	**Yes:** This strain causes chlorosis and distortion of the leaves, stunted growth; tip die-back and necrosis on the hop cultivar 'Styrian' (Yu and Liu 1989).	**Yes**

[14] Not present in hops in Australia. According to Koltunow *et al*. 1988 (p.9), symptoms characteristic of HpSVd infection have not been reported in hops in Australia (Koltunow *et al*. 1988). However, the viroid is reported in Australian grapevine cultivars (Koltunow *et al*. 1988 p.8). Transmission within hops is solely mechanical (Pethybridge *et al*. 2008) and transmission from grapevine to hops through mechanical means is unlikely to occur.

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
			Australia that would be suitable for the establishment and spread of this virus.		
American hop latent virus (AHLV) [Flexiviridae: Carlavirus]	**Yes:** Transmitted by mechanical inoculation and root grafting, and by an insect vector (Mahaffee *et al* 2009; Brunt *et al.* 1996).	Not known to occur [15]	**Yes:** Present in the United States and New Zealand (Pethybridge *et al.* 2008). There are similar natural and built environments in parts of Australia that would be suitable for the establishment and spread.	**Yes:** This virus occurs in mixed infections with other pathogens and can affect hop yields (Pethybridge *et al.* 2008). Natural infection reported only from hop (Barbara and Adams 1983).	**Yes**
Apple mosaic virus (ApMV) Hop isolate [Bromoviridae: Ilarvirus]	**Yes:** Transmitted by grafting and by mechanical inoculation (Brunt *et al.* 1996). Also transmitted by seed (Mahaffee *et al*. 2009).	Yes (Crowle *et al.* 2003)	Assessment not required	Assessment not required	
Apple mosaic virus intermediate isolate [Bromoviridae: Ilarvirus]	**Yes:** Transmitted by grafting and by mechanical inoculation (Brunt *et al.* 1996). Also transmitted by seed (Mahaffee *et al*. 2009).	Yes (Crowle *et al.* 2003)	Assessment not required	Assessment not required	
Arabis mosaic virus (hop strain) (ArMV-H) [Comoviridae: Nepovirus]	**Yes:** Transmitted by grafting, mechanical inoculation, by a nematode vector (Brunt *et al.* 1996) and by seed (Mahaffee *et al* 2009; Richardson 1990).	Not known to occur [16]	**Yes:** This strain has been eradicated from Australia as a result of the absence of its nematode vector (Pethybridge *et al*. 2008). Its historical presence in Australia suggests suitable climatic conditions in	**Yes:** Infection by ArMV-H has been associated with several diseases, including barebine or spidery hop, split leaf blotch, nettlehead, and hop chlorotic disease (Pethybridge *et al*. 2008). Nettlehead is one of the most damaging viral diseases	**Yes**

[15] This virus has been reported in Australia from breeding material in post-entry quarantine (Munro 1987); it is not known to occur outside of quarantine facilities in the wider environment.

[16] According to Pethybridge *et al*. (2008) there are historical, but no recent reports of ArMV-H in Australia, and this strain is now considered eradicated (Pethybridge *et al*. 2008, p. 329).

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
			Australia for the establishment and spread.	of hop (Pethybridge *et al*. 2008).	
Cherry leaf roll virus (hop strain) (CLRV) [Comoviridae: Nepovirus]	**Yes:** Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	Hop strain not known to occur	**Yes:** Climate modelling indicates that conditions in hop gardens in Australia are closely aligned to those of the UK and the USA (Pethybridge *et al*. 2003). This strain is present in the UK (Pethybridge *et al*. 2008), suggesting that the pathogen would probably establish if introduced into the hop production areas of Australia.	**Yes**: CLRV is an economically important virus due to its extensive host range and the economic losses it can cause (Buchhop *et al*. 2009). CLRV on hop is considered unlikely to be of major importance under field conditions (Clark 1975) but on walnut and birch it is considered important (Mircetich *et al*. 1980; Jalkanen *et al*. 2007).	**Yes**
Cucumber mosaic virus (CMV) [Bromoviridae: Cucumovirus]	**Yes:** Infected hop show distorted leaves and chlorotic spotting (Mahaffee *et al.* 2009). Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	Yes (APPD 2010)	Assessment not required	Assessment not required	
H-246 Hop virus	**Yes:** This species is systemic and causes necrosis of plant parts (Pethybridge *et al.* 2008).	Not known to occur	**Yes:** This species is present in Romania (Pethybridge *et al.* 2008). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	No: Reported on hop in Romania in 1979 and has not been classified since (Pethybridge *et al*. 2008). It is considered to be of minor significance.	
Hop latent virus (HpLV)	**Yes:** Hop latent virus is symptomless on hop (Mahaffee	Yes (Pethybridge	Assessment not required	Assessment not required	

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
[Flexiviridae: Carlavirus]	*et al.* 2009). Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	and Madden 2003)			
Hop mosaic virus (HpMV) [Flexiviridae: Carlavirus]	**Yes:** Hop mosaic virus is symptomless on hop (Mahaffee *et al.* 2009). Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	Yes (Pethybridge and Madden 2003)	Assessment not required	Assessment not required	
Humulus japonicus latent virus (HJLV) [Bromoviridae: Ilarvirus]	**Yes:** Transmitted by mechanical inoculation and by seed (Brunt *et al.* 1996). Introduced into UK through propagative material (Mahaffee *et al*. 2009)	Not known to occur	**Yes:** This species is present in China (Pethybridge *et al.* 2008). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	**Yes:** Symptomless infection of commercial hop plants is of concern because production losses from this virus are unknown (Gent *et al*. 2009).	**Yes**
Petunia asteroid mosaic virus (PetAMV) [Tombusviridae: Necrovirus]	**Yes:** PetAMV is found in the roots of host plants (Lovisolo 1990; Pfeilstetter *et al*. 1996) and therefore on the pathway.	Not known to occur	**Yes:** This species is present in the Czech Republic (Pethybridge *et al.* 2008), Germany, Canada and Switzerland (Pfeilstetter *et al*. 1996). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	**Yes**: PetAMV is associated with viral necrosis of sweet cherry. Viral necrosis of sweet cherry is a serious disease in Germany where heavily damaged trees have been observed showing canker-like deformations on the shoots as well as bark splits, necrosis of leaf mid-veins and misshapen fruits with necrotic spots	**Yes**

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
				(Pfeilstetter *et al*. 1996).	
Raspberry bushy dwarf virus (RBDV) [Idaeovirus]	**Yes:** Transmitted by mechanical inoculation, grafting, seed and by pollen (Brunt *et al.* 1996).	Yes (Brunt *et al.* 1996)	Assessment not required	Assessment not required	
Strawberry latent ringspot virus (SLRSV) [Comoviridae: Nepovirus]	**Yes:** *Strawberry latent ringspot virus* is symptomless on hop (Mahaffee *et al.* 2009). Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	Not known to occur[17]	**Yes:** This species is present in the several countries in Asia, Europe, Africa and North America (EPPO 2006). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	**Yes:** This species has a wide host range, including grapevine, hop, olive, peach, strawberry, raspberry and rose. In some crop plant species the virus induces severe decline in vigour causing significant losses in productivity (Murant and Lister 1987).	**Yes**
Tobacco mosaic virus (TMV) [Tombusviridae: Tobamovirus]	**Yes:** Viruses, as a rule, infect host plants systemically and all plant parts, including parts used for vegetative propagation are infected (Bos 1999).	Yes (APPD 2010)[18]	Assessment not required	Assessment not required	
Tobacco necrosis virus (TNV-H) Hop isolate [Tombusviridae: Necrovirus]	**Yes:** TNV-H has been detected in rhizome bud (Albrechtova *et al*. 1979) therefore is on the pathway.	Not known to occur	**Yes:** TNV has been described as having a worldwide distribution (Brunt and Teakle 1996; Uyemoto 1981). There are similar natural and built environments in parts of Australia that would be suitable for its establishment	**Yes:** Although TNV-H is considered a minor pathogen of hop (Pethybridge *et al.* 2008), TNVs cause rusty root disease of carrot, Augusta disease of tulip, stipple streak disease of common bean, necrosis diseases of cabbage, cucumber, soybean and	**Yes**

[17] In Australia, SLRSV has only once been reported from Rhubarb in South Australia (Cooke and Dube 1989). There have been no confirmatory is considered to be eradicated. The natural vector of SLRSV is also absent from Australia.

[18] A strain of Tobacco mosaic virus infecting hops was reported from China (Xie and Tian 1984; cited by Yu and Liu 1987) without references to symptomatology or serology and since then there is no published information on this virus. Therefore, it was not considered further in the analysis.

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
			and spread.	zucchini and ABC disease of potato (Zitikaitë and Staniulis 2009; Xi *et al*. 2008; Smith *et al*. 1988; Uyemoto 1981). Losses due to TNV have been recorded as high as 50% in tulips and glasshouse grown cucumbers (CABI 2010).	
Tobacco ringspot virus (TRSV) [Comoviridae: Nepovirus]	**Yes:** This virus is transmitted by grafting and mechanical inoculation (Diekmann and Putter 1996).	Yes (Brunt *et al.* 1996)	Assessment not required	Assessment not required	
Tomato spotted wilt virus (TSWV) [Bunyaviridae: Tospovirus]	**Yes:** Transmitted by mechanical inoculation, grafting and thrips (Brunt *et al.* 1996).	Yes (Brunt *et al.* 1996)	Assessment not required	Assessment not required	
DISEASES OF UNKNOWN AETIOLOGY					
Hop infectious sterility (unknown virus or viruslike agent)	No: This species cases sterility of hop plants (Pethybridge *et al.* 2008). There is no evidence to suggest it could be transmitted by *Humulus* propagative material.	Not known to occur	Assessment not required	Assessment not required	
NEMATODES					
Aphelenchoides besseyi Christie, 1942 [Rhabditida: Aphelenchoididae]	**Yes:** Members of this genus are ecto- and endo-parasites of leaves, stems and corms (Evans *et al.* 1993).	Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Ditylenchus destructor Thorne, 1945 [Rhabditida: Anguinidae]	**Yes:** This species is an endoparasitic nematode and all life stages can be found within	Not known to occur[19]	**Yes:** This species has a wide distribution in Asia, Europe and North America	**Yes:** This species occurs on a variety of commodities and is a quarantine pest to a number of	**Yes**

[19] *Ditylenchus destructor* was reported as present in Australia in 1958 on the basis of mis-identifications. It is now not considered to be present in Australia.

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
	plant tissue. It migrates through plant cells and lives within stems (Perry and Moens 2006; Mahaffee *et al*. 2009).		(CABI 2010). There are similar natural and built environments in parts of Australia that would be suitable for its establishment and spread.	Australia's trading partners (Evans *et al.* 1993, CABI/EPPO 1990). Presence of this species in Australia would impact upon Australia's ability to access overseas markets.	
Helicotylenchus dihystera (Cobb, 1893) Sher 1961 [Rhabditida: Haplolaimidae]	**Yes:** Members of the genus *Helicotylenchus* are ecto- and semi-endo- root parasites (Evans *et al.* 1993).	Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Heterodera humuli Filipjev, 1934 [Rhabditida: Heteroderidae]	**Yes:** Members of this genus are root gall nematodes (Evans *et al.* 1993).	Limited distribution and under official control[20]	**Yes:** This nematode is already established in Tasmania suggesting it is likely to establish and spread in Australia.	**Yes:** Reductions of up to 38% of hop cone weight have been attributed to this nematode experimentally (Mahaffee *et al.* 2009). Mortality rate of 20% was observed 146 days after inoculation (Hafez *et al*. 1988).	**Yes**
Longidorus attenuatus Hooper, 1961 [Dorlaimida: Longidoridae]	No: These species are ectoparasites (Mahaffee *et al*. 2009) and are primarily soil borne.	Not known to occur	Assessment not required	Assessment not required	
Longidorus caespiticola Hooper, 1961 [Dorlaimida: Longidoridae]		Not known to occur	Assessment not required	Assessment not required	
Longidorus elongatus (de Man, 1876) Thorne & Swanger, 1936 [Dorlaimida: Longidoridae]		Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Longidorus goodeyi Hooper, 1961 [Dorlaimida: Longidoridae]		Not known to occur	Assessment not required	Assessment not required	
Longidorus intermedius		Not known to occur	Assessment not required	Assessment not required	

[20] This species is listed on the Tasmanian Department of Primary Industries and Water's List B of pests present in Tasmania and under official control (DPIW 2010). It is not known to occur in any other state or territory of Australia. The Tasmanian Department of Primary Industries, Parks, Water and Environment (TDPIPWE, personal communication) is currently reviewing the quarantine and control status of this species; until this review is completed and the results adopted, the species will continue to be assessed as a List B (under official control) species.

Pest	Potential to be on pathway	Present within Australia	Potential for establishment and spread	Potential for economic consequences	Consider further in PRA
Kozlowska & Seinhorst, 1979 [Dorlaimida: Longidoridae]					
Longidorus leptocephalus Hooper, 1961 [Dorlaimida: Longidoridae]		Not known to occur	Assessment not required	Assessment not required	
Longidorus macrosoma Hooper, 1961 [Dorlaimida: Longidoridae]		Not known to occur	Assessment not required	Assessment not required	
Longidorus profundorum Hooper, 1961[Dorlaimida: Longidoridae]		Not known to occur	Assessment not required	Assessment not required	
Meloidogyne incognita (Kofoid & White, 1919) Chitwood, 1949 [Rhabditida: Meloidogynidae]	**Yes:** This species is a root endo-parasite (Evans *et al.* 1993).	Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Paralongidorus maximus (Bütschli, 1874) Siddiqi, 1964 [Dorlaimida: Longidoridae]	No: This species is an ectoparasite (Mahaffee *et al*. 2009).	Yes (APPD 2010)	Assessment not required	Assessment not required	
Pratylenchus crenatus Loof 1960 [Rhabditida: Haplolaimidae]	**Yes:** Members of this genus are migratory root endoparasites (Evans *et al.* 1993).	Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Pratylenchus penetrans (Cobb, 1917) Filipjev & Schuurmans-Stekhoven, 1941 [Rhabditida: Haplolaimidae]		Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Tylenchorhynchus dubius (Buetschli, 1873) Filipjev, 1936 [Rhabditida: Dolichodoridae]	No: This species is a migratory root ectoparasite (Evans *et al.* 1993).	Yes (McLeod *et al.* 1994)	Assessment not required	Assessment not required	
Xiphinema dentatum Sturhan, 1978 [Dorylaimina: Longidoridae]	No: *Xiphinema* species are ectoparasites, which do not enter the plant tissues, but feed upon the outer surface of roots (Perry and Moens 2006). Eggs are deposited in the soil and the primary pathway is soil (Perry and Moens 2006).	Not known to occur	Assessment not required	Assessment not required	
Xiphinema diversicaudatum (Micoletzky, 1927) Thorne, 1939 [Dorylaimina: Longidoridae]		Was present [21]	Assessment not required	Assessment not required	

[21] This species has been eradicated from Australia. Species was misidentified in Queensland from specimens of *Xiphinema basiri* (CABI 2010; EPPO 2006).

Appendix B: Additional quarantine pest data

Quarantine pest	*Prionus californicus* (Motschulsky)
Synonyms	*None*
Common name(s)	California apple root borer California Prionus Prionus
Main hosts	Hops, grapes, caneberries, fruit trees (sweet cherries) (Alston *et al.* 2007) and a variety of Californian forest trees (Evans and Hogue 2004). *Prionus californicus* feeds on at least 21 genera of woody perennials in 12 plant families (Barbour *et al*. 2007).
Distribution	Widely distributed along the Pacific coast in western North America from Baja California and Mexico to Alaska (Alston *et al.* 2007).
Quarantine pest	*Grapholita delineana* Walker
Synonyms	*Laspeyresia delineana* Walker *Grapholita apicatana* Walker *Grapholita mundana* Chr. *Grapholita quadristriana* Wlsm. *Grapholita sinana* Feld. *Grapholita terstrigana* Rag. *Grapholita tetragrammana* Stgr
Common name(s)	Hemp borer Eurasian hemp moth
Main hosts	*Cannabis sativa, Humulus japonicus* and *Humulus lupulus* (hop) (Meijerman and Ulenberg 2000).
Distribution	Present in Eastern Europe, India, Japan, Korea, the USA, and Western Asia (AgroAtlas 2010b).
Quarantine pest	*Hydraecia micacea* (Esper)
Synonyms	*Gortyna micacea* Esp.
Common name(s)	Boring moth
Main hosts	Occurs on 50 different species including *Humulus lupinus* (AgroAtlas 2010c).
Distribution	Central Asia, Eastern Europe, Europe, Japan, Kazakhstan, Mongolia, Northeast China, Northern America, Russia, and Turkey (AgroAtlas 2010c).
Quarantine pest	*Hydraecia immanis* Guenée
Synonyms	n/a
Common name(s)	Hop vine borer
Main hosts	*Humulus lupinus* (hop), *Lupinus microcarpus, Silphium* spp. and *Zea mays* (corn) (Godfrey 1981).
Distribution	North America (Godfrey 1981).
Quarantine pest	*Ostrinia nubilalis* (Hubner)
Synonyms	n/a
Common name(s)	European corn borer
Main hosts	*Ostrina nubilalis* attacks nearly all robust herbaceous plants with a stem large enough for the larvae to enter (Capinera 2000) including hop (Bourguet *et al.* 2000) and several weed species (Capinera 2000).
Distribution	This pest is present in Europe, North Africa and North America (Capinera 2000).

Quarantine pest	*Podosphaera macularis* (Wallr.) U. Braun & S. Takam.
Synonyms	*Erysiphe macularis* (Wallr.) Fr. *Sphaerotheca castagnei* auct. p.p. *Sphaerotheca humuli* (DC.) Burrill *Sphaerotheca macularis* (Wallr.) Lind
Common name(s)	Powdery mildew of hop
Main hosts	Occurs on species of the genus *Humulus* (Moraceae); major host is *Humulus lupulus.* Also occurs on *Humulus americanus* and *H. japonicus* (CABI 2010).
Distribution	Asia, Europe, Africa, North and South America (CABI 2010).
Quarantine pest	*Pseudoperonospora humuli* (Miyabe & Takah.) G.W. Wilson
Synonyms	*Pseudoperonospora celtidis var. humuli* Davis *Plasmopara humuli* Miyabe & Takahashi *Perenoplasmopara humuli* (Miyabe & Takahashi) Sacc.
Common name(s)	Downy mildew of hop Downy mildew
Main hosts	Obligate parasite specific to cultivated and wild hop (CABI 2010).
Distribution	Asia, Europe, North and South America (CABI 2010).
Quarantine pest	*Verticillium albo-atrum* Reinke & Berthold (hop strain)
Synonyms	*Verticillium albo-atrum var. caespitosum* Wollenw. *Verticillium albo-atrum var. tuberosum* Rudolph
Common name(s)	Verticillium wilt of hop
Main hosts	Hop (Walker 1990)
Distribution	Asia, Europe, Africa, north, central and south America, Oceania (CABI 2010). Not present in Australia (Walker 1990).
Quarantine pest	*Verticillium dahliae* Klebahn (hop strain)
Synonyms	n/a
Common name(s)	Verticillium wilt of hop
Main hosts	*Humulus lupulus* (hop) (CABI 2010).
Distribution	Asia (Azerbaijan), Europe (Belgium, Germany, Slovaka, Slovenia, UK), north America (California, Oregon) (CABI 2010).
Quarantine pest	*'Candidatus* Phytoplasma asteris'
Synonyms	Hop shoot proliferation phytoplasma
Common name(s)	Hop shoot proliferation disease
Main hosts	*Humulus lupulus* (hop) (Solarska *et al.* 2004)
Distribution	Poland (Solarska *et al.* 2004)
Quarantine pest	Apple fruit crinkle apscaviroid (AFCVd) (hop strain)
Synonyms	n/a
Common name(s)	Apple fruit crinkle diseases
Main hosts	Hop (Sano *et al.* 2004)
Distribution	This species is present in Japan (Sano *et al.* 2004)
Quarantine pest	Hop stunt hostuviroid (HSVd) hop strain
Synonyms	Cucumber pale fruit viroid
Common name(s)	Hop stunt diseases

Main hosts	Hop, cucumber, grapevine, citrus, plum, peach, pear, apricot and almond (El-Dougdoug *et al.* 2010)
Distribution	Europe, Asia, North America, Middle East, Jordan, Syria and Turkey (El-Dougdoug *et al.* 2010), Korea, Germany (CABI 2010). Hop strain is not present in Australia (Koltunow *et al*. 1988). The HSVd has been reported in Australian grapevine cultivars (Koltunow *et al*. 1988)
Quarantine pest	Alfalfa mosaic virus (hop strain)
Synonyms	n/a
Common name(s)	n/a
Main hosts	*Humulus lupulus* (hop) (Solarska *et al.* 2004).
Distribution	China, the former Czechoslovakia and the former Yugoslavia (Yu and Liu 1987; Novak and Lanzona 1976).
Quarantine pest	American hop latent virus (AHLV)
Synonyms	American hop latent virus Hop American latent virus Hop (American) latent virus Hop (New Zealand) virus
Common name(s)	Hop latent disease
Main hosts	*Humulus lupulus* (hop) (CABI 2010).
Distribution	Europe (Belgium), North America (CABI 2010).
Quarantine pest	Arabis mosaic virus (ArMV) (hop strain)
Synonyms	None
Common name(s)	Hop bare-bine Hop split leaf blotch virus
Main hosts	*Humulus lupulus* (hop) (Valdez *et al.* 1974; OEPP/EPPO 1994).
Distribution	Asia, Europe, South Africa, North America, Oceania (CABI 2010). Found, but with no evidence of spread, in North America (Brunt *et al.* 1996).
Quarantine pest	Cherry leaf roll virus (CLRV)
Synonyms	Ash mosaic virus Sambucus ringspot and yellow net virus
Common name(s)	walnut ringspot walnut yellow vein walnut black line berteroa ringspot dogwood ringspot elm mosaic golden elderberry red elder ringspot sambucus ringspot sambucus yellow net blackline disease of walnut
Main hosts	*Betula* spp., *Fagus* spp., *Fraxinus* spp., *Juglans* spp., *Ulmus* spp., *Rhamnus* spp., *Sambucus* spp., *Prunus* spp. as well as *Ligustrum vulgare*, *Ptelea trifoliata* and *Cornus florida* (Bandte and Büttner 2001; Rebenstorf *et al*. 2006; Buchhop *et al*. 2009).
Distribution	Europe, Russia, North America and New Zealand (Jones 1985) Many strains are known (Jones 1985); most of those from different natural host genera are serologically distinguishable from each other (Jones and Murant 1971). CLRV has only been reported from rhubarb and this isolate was identified using

	sequence; this showed it was substantially different from other important strain.
Quarantine pest	*Humulus japonicus* latent virus (HJLV)
Synonyms	None
Common name(s)	Humulus japonicus latent diseases
Main hosts	*Amaranthus caudatus, Beta vulgaris, Catharanthus roseus, Celosia cristata, Chenopodium album, Chenopodium amaranticolor, Chenopodium foetidum, Chenopodium foliosum, Chenopodium murale, Chenopodium quinoa, Cucumis melo, Cucumis sativus, Cucurbita maxima, Helianthus annuus, Humulus japonicus, Humulus lupulus, Nicandra physalodes, Nicotiana clevelandii, Nicotiana tabacum, Petunia × hybrida, Zinnia elegans* (Brunt *et al*. 1996).
Distribution	Spreads in China (Brunt *et al.* 1996)
Quarantine pest	Petunia asteroid mosaic virus (PetAMV)
Synonyms	n/a
Common name(s)	n/a
Main hosts	Cherry, *Humulus lupinus* (hop), petunia, plum and spinach (Mahaffee *et al.* 2009).
Distribution	Asia Europe, North America (Pfeilstetter *et al.* 1996) and the former Czechoslovakia (Mahaffee *et al.* 2009).
Quarantine pest	Tobacco necrosis virus (TNV)
Synonyms	n/a
Common name(s)	n/a
Main hosts	cabbage, common bean, cucumber, *Humulus lupinus* (hop), potato, soybean, tulip and zucchini (Zitikaitė and Staniulis 2009; Pethybridge *et al.* 2008; Xi *et al.* 2008; Smith *et al.* 1988; Uyemoto 1981).
Distribution	Europe, Japan, New Zealand, and the United States (Nyvall 1999).
Quarantine pest	Strawberry latent ringspot virus
Synonyms	Aesculus line pattern virus, rhubarb virus 5
Common name(s)	
Main hosts	Wide host range 126 species belonging to 27 families (Tzanetakis *et al*. 2006).
Distribution	Europe and Israel, New Zealand, North America and Turkey (EPPO 2010).
Quarantine pest	*Ditylenchus destructor* Thorne 1945
Synonyms	None
Common name(s)	Potato eelworm Potato tuber eelworm Potato tuber nematode Potato rot nematode
Main hosts	*Allium cepa* (onion), *Allium sativum* (garlic), *Arachis hypogaea* (groundnut), *Beta vulgaris* (beetroot), *Beta vulgaris var. saccharifera* (sugarbeet), *Camellia sinensis* (tea), *Capsicum annuum* (bell pepper), *Chrysanthemum morifolium* (chrysanthemum (florists')), *Citrus sinensis* (navel orange), *Cucumis sativus* (cucumber), *Cucurbita moschata* (pumpkin), *Dahlia* hybrids, *Daucus carota* (carrot), *Fragaria ananassa* (strawberry), *Gladiolus hybrids* (sword lily), *Glycine max* (soyabean), *Humulus lupulus* (hop), *Ipomoea batatas* (sweet potato), *Iris* (irises), *Lycopersicon esculentum* (tomato), *Mentha* (mints), *Panax ginseng* (Asiatic ginseng), *Solanum melongena* (aubergine), *Solanum tuberosum* (potato), *Trifolium* (clovers), *Triticum aestivum* (wheat), *Tulipa* (tulip), *Zea mays* (maize) (CABI 2010).
Distribution	Asia, Europe, South Africa, North America, Haiti, South America (Ecuador and Peru), Oceania (New Zealand) (CABI 2010).
Quarantine pest	*Heterodera humuli*
Synonyms	None

Common name(s)	Hop cyst eelworm Hop cyst nematode
Main hosts	*Cannabis sativa* (hemp), *Humulus lupulus* (hop) (CABI 2010).
Distribution	Europe (Former USSR, Spain, United Kingdom) (CABI 2010). This species is under official control in Tasmania and declared as a list B pest (pest that occurs in Tasmania and is under official control) (DPIW 2010).

Glossary

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

Term or abbreviation	Definition
Pathway	Any means that allows the entry or spread of a pest (FAO 2009).
Pest	Any species, strain or biotype of plant, animal, or pathogenic agent injurious to plants or plant products (FAO 2009).
Pest categorisation	The process for determining whether a pest has or has not the characteristics of a quarantine pest or those of a regulated non-quarantine pest (FAO 2009).
Pest Free Area	An area in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained (FAO 2009).
Pest free place of production	Place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained for a defined period (FAO 2009).
Pest free production site	A defined portion of a place of production in which a specific pest does not occur as demonstrated by scientific evidence and in which, where appropriate, this conditions is begin officially maintained for a defined period and that is managed as a separate unit in the same way as a pest free place of production (FAO 2009).
Pest Risk Analysis (agreed interpretation)	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (FAO 2009).
Pest risk assessment (for quarantine pests)	Evaluation of the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences (FAO 2009).
Pest risk management (for quarantine pests)	Evaluation and selection of options to reduce the risk of introduction and spread of a pest (FAO 2009).
Phytosanitary Certificate	Certificate patterned after the model certificates of the IPPC (FAO 2009).
Phytosanitary measure (agreed interpretation)	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO 2009).
Phytosanitary regulation	Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment of procedures for phytosanitary certification (FAO 2009).
Polyphagous	Feeding on a relatively large number of host plants from different plant families.
PRA area	Area in relation to which a Pest Risk Analysis is conducted (FAO 2009).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO 2009).
Regulated article	Any plant, plant product, storage place, packaging, conveyance, container, soil and any other organism, object or material capable of harbouring or spreading pests, deemed to require phytosanitary measures, particularly where international transportation is involved (FAO 2009).
Restricted risk	Risk estimate with phytosanitary measure(s) applied.
Rhizomes	A horizontal plant stem with shoots above and roots below serving as a reproductive structure. Rhizomes may also be referred to as creeping rootstalks, or rootstocks
Spread	Expansion of the geographical distribution of a pest within an area (FAO 2009).
Stakeholders	Government agencies, individuals, community or industry groups or organizations, whether in Australia or overseas, including the proponent/applicant for a specific proposal, who have an interest in the policy issues.
Unrestricted risk	Unrestricted risk estimates apply in the absence of risk management measures.

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