Import Risk Analysis: Onion (*Allium cepa* Liliaceae) Fresh Bulbs for Consumption from China

DRAFT FOR CONSULTATION

12 June 2009

Ministry of Agriculture and Forestry
Te Manatu Ahuwhenua, Ngaherehere
Pastoral House
25 The Terrace
P O Box 2526
Wellington
New Zealand

Telephone: +64 4 894 0504
Facsimile: +64 4 894 0733
Internet: http://www.maf.govt.nz

MAF Biosecurity New Zealand

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Approved for Consultation

Christine Reed
MAF Biosecurity New Zealand

Contributors

The following people provided significant input into the development of this risk analysis:

1. Primary Authors

Dr Mike Ormsby	Senior Adviser, Plants Risk Analysis	MAF Biosecurity New Zealand, Wellington
Dr Brenda Pottinger	Senior Environmental Risk Advisor	ERMA New Zealand, Wellington (on secondment to MAF Biosecurity New Zealand)

2. Secondary Contributors

Daniel Jones	Senior Adviser, Plants Risk Analysis	MAF Biosecurity New Zealand, Wellington

3. Scientific Review

Dr Nicholas Martin	Entomologist	The New Zealand Institute for Plant and Food Research Limited
Dr Bob Fullerton	Science Leader Applied Plant Pathology	The New Zealand Institute for Plant and Food Research Limited

Many others for MAF and other agencies assisted in advice and support and their contributions are gratefully appreciated.

Table of contents

Page

Executive summary

The Ministry of Agriculture and Forestry (MAF) has evaluated the nature and possible effect on people, the New Zealand environment, and the New Zealand economy of any organisms that may be associated with Onion (*Allium cepa*) bulbs imported for consumption from China.

Onions are believed to have originated from Afghanistan/Iran/USSR region and are now grown in over 175 countries worldwide. Records of onion cultivation date back to 3020 BC in Egypt indicating that onions have been grown continuously by communities for over 5000 years. Onions (*Allium cepa*) belong to the family Liliaceae, although they are also listed by some authors in their own family the Alliaceae. Like other members of these families, onions are perennial herbs, with a bulb and like other species in the genus *Allium* have an onion-like odour when fresh. The bulbs are covered with a tunic, the leaves sessile with a closed leaf sheath at the base. Flowers are bisexual, very rarely degenerating into unisexual (when plants are dioecious).

There are about 660 species in the genus *Allium* which are found naturally mainly in Asia but with some species in Africa and Central and South America. There are 138-recorded species (50 endemic, five introduced) in China. Most species of *Allium* are edible, and some have long been cultivated in China and elsewhere, e.g., *A. cepa* (onion), *A. chinense* (rakkyo), *A. fistulosum* (bunching onion), *A. porrum* (leek), *A. sativum* (garlic) and *A. tuberosum* (Chinese chive). Shallot has two main forms, either *Allium oschaninii* (the true or French shallot) or *Allium ascalonicum* otherwise known as *Allium cepa* var. *ascalonicum*. As this risk analysis is concerned with onion rather than shallot, depending on the taxonomic nomenclature is used for shallot, the scientific name of onion is either *Allium cepa* or *Allium cepa* var. *cepa*.

The description of the commodity on which this risk analysis has been completed takes account of existing industry practices and systems established in China. The commodity description for fresh onion (*Allium cepa*) bulbs exported from China is therefore as follows:

- During the growing season pests and diseases are controlled to limit impacts on onion (*Allium cepa*) yields.
- Consignments of onion bulbs may include bulbs of any size, fresh or cured, with some root material still attached. Aboveground leaf material will have been removed to at least 5 cm from the bulb.
- The bulbs will have been brushed clean of soil.
- Consignments of bulbs will have been graded to remove obviously damaged bulbs, plant material other than bulbs or from species other than *Allium cepa*, and bulb-size clumps of soil. The grading process is expected to be at least 95% effective in removing all but the clumps of soil for which 100% effectiveness is expected.
- Onion consignments will be shipped as bulk or in packages in a manner that provides sufficient ventilation to limit storage rotting.

Consignments of onion bulbs that do not, as a minimum, conform to this commodity description are not covered by this risk analysis.

The risk management options contained in this risk analysis take account of existing industry practices and systems established in China and New Zealand. Therefore it is expected that the management options provided can be incorporated into existing industry practices and may be seen as enhancements to the current biosecurity system. The following table provides a list of the management options that are considered to reduce adequately the risk assessed for each of the identified hazard organisms. In addition to the options presented, no phytosanitary measures may also be considered.

Hazard Organism (Scientific name and organism type)	Phytosanitary measures that are options for the management of the identified hazard organisms.
Bacteria	
Erwinia chrysanthemi pv. *chrysanthemi* *Pantoea ananatis*	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Systems approach involving a low pest prevalence requirement and a treatment involving cleaning of the bulbs by removing roots and the outer layers of skin, washing and sanitizing, and discarding of damaged or diseased bulbs.
Fungi	
Alternaria palandui *Cladosporium oxysporum* *Davidiella allii-cepae* *Penicillium oxalicum* *Phytophthora capsici* *Phytophthora cinnamomi* *Phytophthora drechsleri* *Phytophthora meadii* *Phytophthora porri* *Pythium intermedium* *Pythium vexans* *Stemphylium allii-cepae*	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Systems approach involving a low pest prevalence requirement and a treatment involving cleaning of the bulbs by removing roots and the outer layers of skin, washing and sanitizing, and discarding of damaged or diseased bulbs.
Cochliobolus eragrostidis	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Inspection of onion roots during harvest for symptoms of infection, and rejection of produced sourced from an infected field; c. Treatment involving cleaning of the bulbs by removing roots and outer layers of skin and discarding any damaged or diseased bulbs.
Puccinia asparagi	a. Treatment involving cleaning of the bulbs by removing the outer layers of skin; b. Restricting re-packaging in New Zealand to sites suitably distant from asparagus crops e.g. metropolitan areas; c. Restricting the importing of onion bulbs to those in retail-ready packaging.
Insects	
Atherigona orientalis *Bradysia odoriphaga* *Calliphora vomitoria* *Delia antiqua* *Delia floralis* *Euxesta notata*	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Methyl bromide fumigation at the rates specified; c. Treatment involving cleaning of the bulbs by removing roots and outer layers of skin and discarding any damaged or infested bulbs.
Frankliniella occidentalis *Thrips tabaci*	a. Methyl bromide fumigation at the rates specified; b. Systems approach involving a low pest prevalence requirement and a treatment involving cleaning of the bulbs by removing outer layers of skin, washing and discarding of damaged or infested bulbs.

Hazard Organism (Scientific name and organism type)	Phytosanitary measures that are options for the management of the identified hazard organisms.
Mites	
Rhizoglyphus setosus	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Systems approach involving a low pest prevalence requirement and a treatment involving cleaning of the bulbs by removing outer layers of skin, washing and sanitizing, and discarding of damaged or diseased bulbs.
Nematodes	
Meloidogyne graminicola	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. Inspection of onion roots during harvest for symptoms of infection, and rejection of produced sourced from an infected field; c. A heat treatment that involves pre-soaking bulbs in water at 24°C for 2 hours, then at 43°C-44°C for 4 hours; d. Treatment involving cleaning of the bulbs by removing roots and the outer layers of skin and discarding any damaged or infested bulbs.
Rotylenchulus reniformis	a. Pest free place of production (PFPP): onion bulbs are imported from places of production that are free of these organisms; b. A heat treatment that involves pre-soaking bulbs in water at 24°C for 2 hours, then at 43°C-44°C for 4 hours; c. Treatment involving cleaning of the bulbs by removing roots and the outer layers of skin and discarding any damaged or infested bulbs.
Plants (as seeds)	
Alopecurus myosuroides, Amaranthus blitum, Avena fatua, Borreria latifolia, Cenchrus echinatus, Cuscuta europaea, Cynodon dactylon, Cyperus esculentus, Cyperus rotundus, Echinochloa crus-galli, Emex australis Eragrostis cilianensis, Hordeum murinum subsp. *leporinum, Lolium temulentum, Medicago polymorpha, Melilotus indica, Orobanche ramosa, Panicum dichotomiflorum, Parthenium hysterophorus, Phalaris canariensis, Poa annua, Setaria verticillata, Setaria viridis, Sida acuta, Sorghum halepense, Tribulus terrestris*	a. Treatment of onion bulbs by removing outer loose layers of skin after harvest.

1. Introduction and process

1.1. Introduction

Onions are believed to have originated from Afghanistan/Iran/USSR region and are now grown in over 175 countries worldwide (Martech Consulting Group and New Zealand Institute for Economic Research 2005). Records of onion cultivation date back to 3020 BC in Egypt suggesting onions have been grown continuously by communities for over 5000 years. Onions are biennial monocots that are cultivated as annuals, a cool-season crop requiring temperatures of at least 10 degrees Celsius (50 degrees Fahrenheit) to emerge from seed. The volume of onions produced internationally is estimated to be about 52 million tonnes, about 34% of which is produced in China. New Zealand production accounts for only about 0.5% of world production (Eady 2004).

Onions (*Allium cepa*) belong to the family Liliaceae, although they are also listed by some authors in their own family the Alliaceae. Like other members of these families, onions are perennial herbs, with a bulb and like other species in the genus *Allium* have an onion-like odour when fresh. The bulbs are covered with a tunic, the leaves sessile with a closed leaf sheath at the base. Flowers are bisexual, very rarely degenerating into unisexual (when plants are dioecious). There are about 660 species in the genus *Allium* which are found naturally mainly in Asia but with some species in Africa and Central and South America. There are 138-recorded species (50 endemic, five introduced) in China. Most species of *Allium* are edible, and some have long been cultivated in China and elsewhere, e.g., *A. cepa* (onion), *A. chinense* (rakkyo), *A. fistulosum* (bunching onion), *A. porrum* (leek), *A. sativum* (garlic) and *A. tuberosum* (Chinese chive). Shallot has two main forms, either *Allium oschaninii* (the true or French shallot) or *Allium ascalonicum* otherwise known as *Allium cepa* var. *ascalonicum*. As this risk analysis is concerned with onion rather than shallot, depending on the taxonomic nomenclature used for shallot, the scientific name of onion is either *Allium cepa* or *Allium cepa* var. *cepa*.

Onion (*Allium cepa*) bulbs for consumption can currently be imported unprocessed into New Zealand from Australia, Japan, or the USA. Onion seeds, processed foods (such as pickled onions), or bulbs for planting (subject to post entry quarantine and other phytosanitary measures) can be imported from anywhere in the world.

This document presents an analysis of the biosecurity risks of importing into New Zealand for consumption, onion (*Allium cepa*) bulbs that have been produced in China, and identifies options for phytosanitary measures to manage the identified risks. The identified options for phytosanitary measures may then form the basis of a new import health standard for importing into New Zealand onion (*Allium cepa*) bulbs for consumption from China.

1.2. The risk analysis process

The following briefly describes the MAF Biosecurity New Zealand process and methodology for undertaking import risk analyses. For a more detailed description of the process and methodology please refer to the Biosecurity New Zealand Risk Analysis Procedures (Version 1 12 April 2006) which is available on the Ministry of Agriculture and Forestry web site[1]. The risk analysis process leading to the final risk analysis document is summarised in Figure 1.

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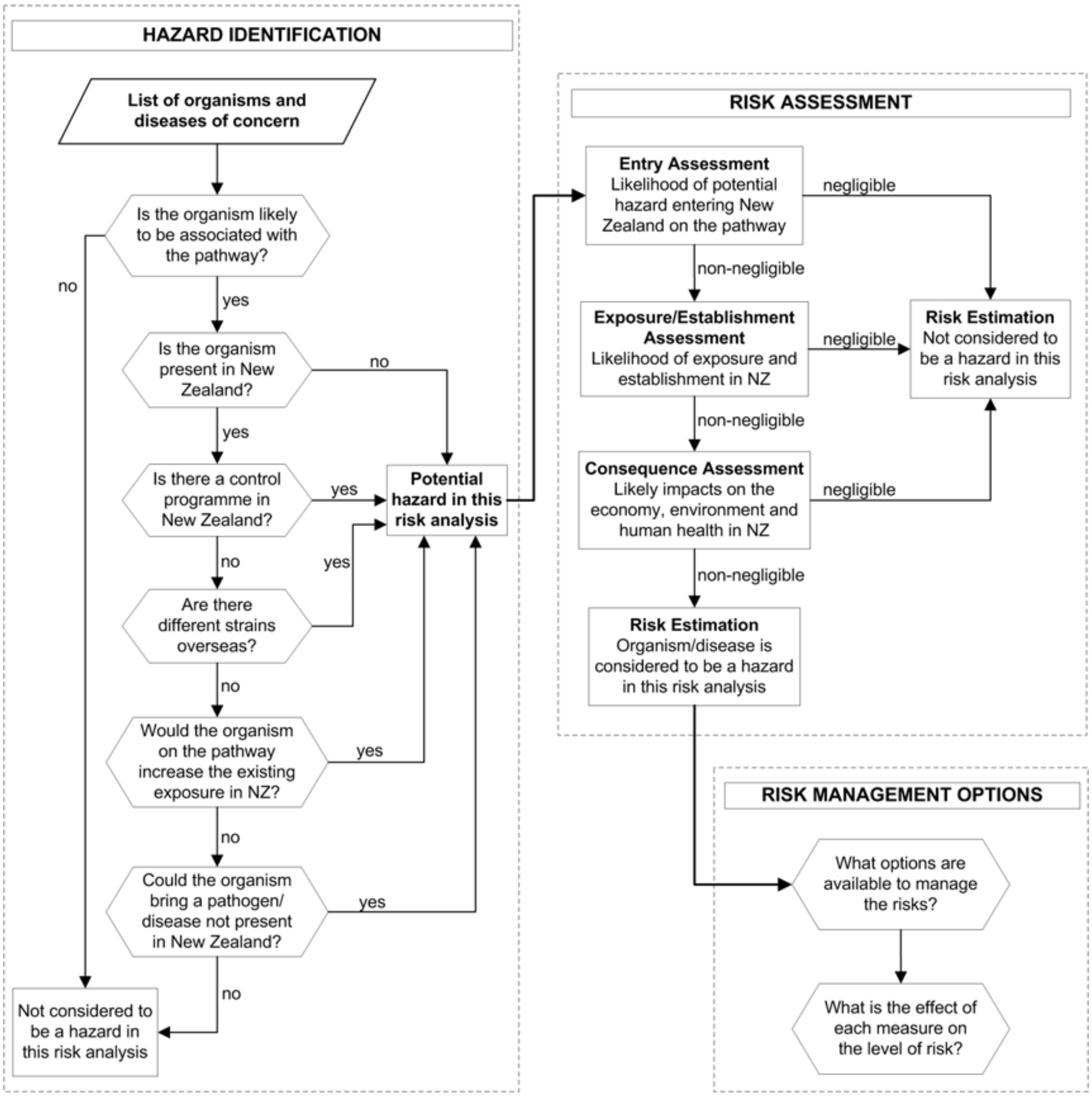
1 http://www.biosecurity.govt.nz/files/pests/surv-mgmt/surv/review/risk-analysis-procedures.pdf

Figure 1: Diagrammatic representation of the risk analysis process



The process outlined in Figure 1 is further supported by the following:

1.2.1. Assessment of uncertainties

In this aspect of the risk analysis process the uncertainties and assumptions identified during the preceding hazard identification and risk assessment stages are summarised. An analysis of these uncertainties and assumptions can then be completed to identify which are critical to the outcomes of the risk analysis. Critical uncertainties or assumptions can then be considered for further research with the aim of reducing the uncertainty or removing the assumption.

Where there is significant uncertainty in the estimated risk, a precautionary approach to managing risk may be adopted. In these circumstances the phytosanitary measures should be reviewed as soon as additional information becomes available[2] and be consistent with other phytosanitary measures where equivalent uncertainties exist.

2 Article 5.7 of the SPS Agreement states that "a Member may provisionally adopt sanitary …. measures" and that "Members shall seek to obtain additional information …. within a reasonable period of time." Since the plural noun "Members" is used in reference to seeking additional information a co-operative arrangement is implied between the importing and exporting country. That is the onus is not just on the importing country to seek additional information.

1.2.2. Risk management

For each organism classified as a hazard, a risk management step is carried out, which identifies the options available for managing the risk. In addition to the options presented, no phytosanitary measures may also be considered for each hazard. Feedback is sought from stakeholders on these options through consultation. Risk analyses are then be finalised following this consultation and will present options – refined if appropriate –for the Import health standard process to consider. Measures will only be recommended to the Chief Technical Officer for decision once the import health standard process is complete.

As obliged under Article 3.1 of the WTO Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement 1995), the measures adopted in IHSs will be based on international standards, guidelines and recommendations where they exist, except as otherwise provided for under Article 3.3 (where measures providing a higher level of protection than international standards can be applied if there is scientific justification, or if there is a level of protection that the member country considers is more appropriate following a risk assessment).

1.2.3. Review and consultation

Peer review is a fundamental component of a risk analysis to ensure the analysis is based on the most up to date and credible information available. Each analysis must be submitted to a peer review process involving appropriate staff within those government departments with applicable biosecurity responsibilities, and recognised and relevant experts from New Zealand or overseas. The critique provided by the reviewers is reviewed and where appropriate, incorporated into the analysis. If suggestions arising from the critique are not adopted the rationale must be fully explained and documented.

Once a risk analysis has been peer reviewed and the critiques addressed it is then published and released for public consultation. The period for public consultation is usually 6 weeks from the date of publication of the risk analysis.

All submissions received from stakeholders will be analysed and compiled into a review of submissions. Either a document will be developed containing the results of the review or proposed modifications to the risk analysis or the risk analysis itself will be edited to comply with the proposed modifications.

1.3. References for Chapter 1

Eady C (2004) Red onions. *Grower* 59 (8) 57-58.

MAF (2006) Biosecurity New Zealand risk analysis procedures. *Ministry of Agriculture and Forestry*, New Zealand, 201 pp. Available online at http://www.biosecurity.govt.nz/files/pests/surv-mgmt/surv/review/risk-analysis-procedures.pdf

Martech Consulting Group & New Zealand Institute for Economic Research (2005) Growing futures case study 17: Fresh Onions: a 5,000 year history – and New Zealand exports 200,000 tonnes each year. Last accessed 15 September 2008. Available online at http://www.growingfutures.com/files/fresh_onions_exports.pdf

SPS Agreement (1995) World Trade Organization Agreement on the Application of Sanitary and Phytosanitary Measures. World Trade Organization, Geneva

2. Commodity and pathway description

Cultivated types of *Allium cepa* fall into two broad horticultural groups: the "Common Onion Group" and the "Aggregatum Group" (Hanelt 1990). Bulbs of the "Common Onion Group" are large, normally single, and plants reproduce from seeds. In contrast, bulbs of the "Aggregatum Group", which are smaller than those of the common onions, are vegetatively propagated and form clusters of bulbs. Jones and Mann (1963) distinguished two bulb-forming sub-groups: multiplier or potato onions, and shallots, the latter being the most important sub-group of the Aggregatum Group.

The recent development of propagation of shallots by seed has reduced the usefulness of the current distinction of the two-cultivar groups within *A. cepa* (CPC 2008). For the purposes of this risk analysis only the common onion group will be considered as the commodity on this import pathway.

There are 3 main colour varieties grown in China, yellow, red-yellow and red. Currently around 520,000 tonnes of onion bulbs are exported annually from China, with onions going to Japan having their outer skins removed. China primarily exports onions to Japan, Russia and other S.E. Asian countries (see Appendix 3).

2.1. Onion production methods

Onions are a cool season biennial that grow best between 13-24ºC (55-75ºF) but tolerate temperatures ranging from 7-29ºC (45-85ºF). Early leaf growth is important for bulb size later in the season; however, even after leaves collapse the bulb will grow a further 10-20%. In the USA the time from seedling emergence to maturity averages about 100-140 days depending on the cultivar and the weather. Onions are usually planted from seed, with the USA industry standard for seed germination at around 70%. Some growers may plant sets (immature bulbs ripened during the previous season) rather than seeds; however, this is more costly and time consuming than planting seed. In North America and Europe planting begins in early August, September or January (there are several varieties suitable for each of these sowings). It takes about 13 days from seeding to emergence when soil temperatures are 10ºC (50ºF) (Hausbeck 2005).

Onion production in China's Shandong province commences with planting in October and ends with harvesting from June to August the following year (see Appendix 3).

2.1.1. China's regulatory framework for onion exports

In China onion production and processing for export is overseen by the Entry-Exit Inspection and Quarantine Bureau of the People's Republic of China (CIQ). CIQ are the government compliance organisation working to regulations enacted by the General Administration for Quality Supervision and Inspection and Quarantine of the People's Republic of China (AQSIQ). The system includes requirements for:

- Farm export registration and audit;
- Chemical use during production;
- Pest surveillance, identification and reporting;
- Pre-export inspection and food safety testing;
- Phytosanitary declarations;

- Non-compliance emergency action plans.

The production and processing companies are responsible for developing their own control system that regulates chemical and pest control activities and ensures compliance with international phytosanitary requirements and domestic regulations.

Farm blocks used for growing onion for export and their processing and storage facilities must be registered by CIQ before the season commences. Re-registration is required each year or if the company changes the crop in a block (field). Companies must also apply to CIQ for an export licence immediately prior to export any onions produced by these registered farms to ensure the government can provide the appropriate assurances that the consignments comply with the importing country's phytosanitary and food safety requirements (Appendix 3).

2.1.2. Pre-harvest operations

The condition of onion leaves is a good indicator of the maturity and general state of the bulb. Bulb onions which are to be stored are usually allowed to mature fully before harvest and this occurs when the leaves bend just above the top of the bulb and fall over. Farmers may conduct sample counts on the number of bulbs (tops) fallen over in a field; and when the percentage reaches about 70-80% then the entire crop may be harvested. Harvesting could commence earlier when 50-80% of the tops have gone over, before it is possible to see split skins exposing onion flesh. Storage losses at optimum maturity are normally lower than those harvested before the tops collapse (Opara 2003).

2.1.3. Harvesting and transport

Manual harvesting is the most common practice in most developing countries including China. This is normally carried out by levering the bulbs with a fork to loosen them and pulling the tops by hand. The harvesting techniques adopted are influenced by weather condition at harvest time. In areas where warm, dry weather occurs reliably, the curing and bagging of the crop can be done in the field (two phase harvesting). In wetter, temperate regions, artificial heating and ventilation for drying are essential for reliable production of high quality bulbs on a large scale (KTBL 1993, Opara 2003).

Harvested bulbs are placed in containers (basket, bins) or tied into bunches and placed directly on the floor of a trailer for transport. Both packaging and transport systems must be selected to ensure minimum handling damage to produce. Hard surfaces may be cushioned with leaves, foam or other appropriate force decelerators (Opara 2003).

2.1.4. Curing and drying

Both curing and drying excess moisture from the outer layers of the bulb is removed prior to storage. The dried skin provides a surface barrier to water loss and microbial infection, thereby preserving the main edible tissue in a fresh state. Drying also reduces shrinkage during subsequent handling, reduces the occurrence of sprouting, and allows the crop to ripen before fresh consumption or long-term storage (Opara & Geyer 1999). This process of dehydration is sometimes called 'curing', but the use of the word 'curing' for onion drying is rather inaccurate since no cell regeneration or wound healing occurs as in other root crops such as yam and cassava. Drying reduces bulb weight and since they are sold mostly on a weight basis, achieving the desired level of dehydration is critical. Weight losses of 3-5% are normal under ambient drying conditions and up to 10 % with artificial drying (Opara 2003).

In traditional small-scale operations, onion drying is carried out in the field in a process commonly called 'windrowing'. It involves harvesting the mature bulbs and laying them on their sides (in windrows) on the surface of the soil to dry for 1 or 2 weeks. In hot tropical climates, the bulbs should be windrowed in such a way to reduce the exposed surface to minimise damage due to direct exposure to the sun. In wet weather, the bulbs can take longer to dry and may develop higher levels of rot during storage. The side of the bulb in contact with wet soil or moisture may also develop brown strains or pixels, which reduce appearance quality and value. Obviously, successful windrowing is weather dependent and therefore cannot be relied upon for large-scale commercial onion production business. Bulbs harvested for storage require in total 14-20 days of ripening or drying before being stored. Harvested onions may also be placed in trays, which are then stacked at the side of the field to dry. In some tropical regions, the bulbs are tied together in groups by plaiting the tops, which are then hung over poles in sheds to dry naturally (Opara 2003).

Harvested bulbs can also be taken straight from the field and dried artificially either in a store, shed, barns, or in a purpose-built drier. This method is commonly used when crops are stored in bulk but it can also be applied to bags, boxed or bins. Under this method, bulbs are laid on racks and heated air is rapidly passed across the surface of the bulbs night and day (O'Connor 1979, Brice *et al.* 1997). Drying may take 7-10 days and is considered complete when the necks of the bulbs have dried out and are tight and the skins shriek when held in the hand. The control of humidity level in the store is critical. Under very high humidity, drying is delayed and fungal infection can increase. However, if relative humidity is too low (below 60%), excessive water loss and splitting of the bulb outer skins can occur, resulting in storage losses and reduction of bulb value. Placing onions on wire mesh in well-ventilated conditions and using air at about 30°C, 60-75% relative humidity and 150-m^3 h^{-1} m^{-3} is generally recommended for mechanical drying of onions (Opara 2003).

In storage, it is important to maintain relative humidity between 65-70% with adequate air circulation at 0ºC (32ºF) to prevent splitting, sprouting and disease. The bulbs are packed either at an on-farm site or sent in bulk containers to a packing facility (Hausbeck 2005). Onions can yield up to 5 tonnes per hectare under good growing and management conditions (Opara 2003).

2.1.5. Cleaning

Freedom from any impurity, which may materially alter the appearance or eating quality, is considered essential for quality purposes. Soil and other foreign materials are therefore usually removed and badly affected produce discarded. Cleaning may be carried out using air or by manually removing unwanted materials on the bulb surface. Care should be taken to avoid physical injury on the bulb during these operations (Opara, 2003).

Onions may also be stripped of their outer layers to ensure concealed damaged is identified. Onions that have had their out layers removed cannot be stored for any great length of time and so must be cool-stored and exported relatively quickly after stripping. To enhance storage life the onions are washed with an appropriate chlorine based sanitizing solution prior to packaging, cold storage and transport (see Appendix 3).

2.1.6. Onion packaging

2.1.6.1. General information

Good packaging for onions should meet the following criteria:

(a) strong enough to retain the required weight of onions under the conditions of transport and storage;

(b) allow sufficient ventilation for the air around the bulbs to maintain relative humidity in the required range, and

(c) in many circumstances, provide a means of displaying legally required and commercially necessary information (Brice *et al.* 1997).

There are many traditional methods of holding onions for transportation and/or storage that do not fit into conventional packaging classifications. These include ‘string of onions’, shelves and loose bulk. In ‘string of onions’ packing, the bulbs are tied together by means of their tops to produce a bunch of bulbs is also a form of packaging. Shelves for onion handling and storage are made from either wooden slats or metal mesh on a wooden or metal frame, and are usually fixed in position with the bulbs loaded and unloaded in the store. Ventilation (natural or forced) is usually achieved by passing air over the shelves. To achieve adequate aeration of the bulbs, the depth of bulbs on the shelves should be limited to 10 cm (Opara 2003).

Onions are also stored loose bulk (instead of containers) by heaping the bulbs directly on the floor or elevated platform. Because they are not restrained, the bulbs roll during store loading to fill completely the storage space. Bulk storage permits maximum utilisation of store space, and uniform aeration is easier to achieve than in stacks of bags or other rigid packaging. However, where bulk storage is implemented, the retaining walls must be strengthened when storing larger quantities of bulbs and arrangements need to be made for re-bagging before subsequent marketing. It is also difficult to inspect bulbs regularly under these storage conditions. Loose bulk handling of onion is most suitable for large-scale operations where forced ventilation can be provided during long-term storage. Soft cultivars (which are also generally sweet) should not be stored in loose bulk because of their high susceptibility to compression and impact damage (Opara 2003).

Onions can be packaged and stored in a variety of containers such as boxes, cartons, bags, bulk bins, pre-packs, plastic film bags, and stretch-wrapped trays. Packages typically contain 25 kg and above, especially for transporting crop from field to store and/or during storage. The same 25 kg bags or smaller bags may be used from store to market place. A problem with packaging onions in boxes, net bags and bulk bins is that if they are too large airflow patterns tend to be around rather than through them. Under this condition, the respiration heat of the bulb results in a warm, humid environment in the centre of the package, which can result in decay or sprouting. To avoid these problems in large stores, the capital investment in packaging may be quite substantial (Opara 2003).

Onions that have been stripped of their outer layers must be stored at around 0ºC and can be packaged in plastic bags (see Appendix 3).

2.1.6.2. Onion bags

Sacks and nets used for onion packaging fall into three groups:

- general-purpose jute sacks, as used for many agricultural commodities;
- open-weave sacks of sisal-like fibre;
- open-mesh nets, normally of plastic materials; and
- big bags, used alternatively to crates, containing up to 1000 kg.

Jute sacks are readily available in most developing countries, but their disadvantages include:

- generally too large - may contain 100 kg onions, hence difficult to handle and an increased risk of mechanical damage;
- bulbs are not visible through the fabric, and it is difficult to monitor condition during storage;
- there is some resistance to airflow if they are used in an aerated store;
- difficult to label effectively; and
- recycled sacks may encourage spread of post-harvest diseases.

Sisal sacks are made from sisal-like hard fibres and have an open weave, with thick threads spaced between about 10 and 15 cm apart. The rough nature of the fibre provides a sufficiently stable weave. These sacks are similar to jute sacks, but will allow limited visibility of the onions and impedance to airflow is less (Opara 2003).

Open-mesh nets are the most widely used package for onions, and they are normally red or orange in colour. The slippery nature of plastics can result in the movement of the threads allowing large holes to open up. To overcome this problem, alternative nets are industrially produced to give fully stable mesh and a stronger bag (Opara, 2003).

2.1.6.3. Rigid packages

A range of rigid containers is used to package onions for transportation, marketing, and/or storage (Opara & Geyer 1999). The principal rigid containers are trays (10-15 kg of onions each), boxes (up to 25 kg), and bulk bins (up to 1000 kg). These types of packaging enable segregation of onions into different cultivars or sources. Handling damage of bulbs during filling and emptying can be high, but damage is reduced during store loading and unloading operations in comparison with loose bulk handling and storage (Opara 2003).

Stacking of containers should be carried out with care to ensure that the ventilation air is forced through the containers of bulbs and not around them. One of the main advantages of rigid containers is that they facilitate regular inspection of produce, and when problems occur with the stack, the area affected is often limited to a few trays, boxes or bins which may be more easily isolated and removed than in loose bulk handling system (Opara 2003).

2.1.6.4. Onion pre-packs

In many countries including New Zealand onions are commonly sold in retail outlets in pre-packs with a capacity of 0.5-1.5 kg. The three main types of onion pre-packs are nets, plastic film bags, and stretch-wrapped trays (Opara 2003).

2.1.7. Bulk storage of onions

2.1.7.1. General requirements

The objectives of onion storage are to extend the period of availability of crop, maintain optimum bulb quality and minimise losses from physical, physiological, and pathological agents. Bulbs selected for storage should be firm and the neck dry and thin. Discard thick-necked bulbs because they are most likely to have high moisture content than optimum for storage, and therefore would have short storage life. Skin colour should be typical of the cultivar. Microbial infections such as *Aspergillus niger* occur during production of onions but these will only develop on the bulbs during storage where the storage environment is conducive for their growth. Prior to storage, crop must be cleaned and graded, and all damaged or diseased bulbs removed. Careful harvest and pre-storage treatments with minimal mechanical loads are important to achieve a long storage period. Storeroom temperature, relative humidity, and atmospheric composition affect the length of storage that can be achieved. Several technology options are available for bulk storage of onions, including low-temperate storage, high-temperature storage, 'direct harvest' storage and the use of controlled atmosphere (CA) stores. The recommended storage conditions under these systems are summarised below (Opara 2003).

2.1.7.2. Storage at low temperature

For successful low temperature storage, good ventilation and a low level humidity in the range of 70-75% is essential. To maintain good quality crop, the period of storage varies but may be up to 200 days. For maximum storage period and minimum losses bulbs should be fully mature at harvest, and dried until the 'neck' of the bulb is tight. For large-scale commercial storage, onions are usually stored under refrigeration and the most commonly recommended conditions are 0°C with 70-75% relative humidity. Regular ventilation and monitoring of both temperature and relative humidity in the store are necessary to avoid significant fluctuations in environmental conditions. During the first few days of storage the fans should provide an adequate airflow, to remove water in the outer skins and to dry bruises. High air speed is needed for a period of up to 1 week, until the skin of the upper onion layers in the bulk rustles. Excessive humidity in-store will lead to the development of roots and promote rotting while higher temperatures will result in sprouting and promote development of pathological disorders such as *Botrytis* rots (Thompson 1982).

Bulbs freeze below -3°C and a range of storage temperatures and relative humidity have been recommended for safe storage of onions. Spring (green) onions store best at about 0°C and very high humidity (95%). The maximum length of storage under these conditions varies from just a few days to about 3 weeks. Ventilation must be carefully applied inside the store to achieve the required temperature and humidity levels without inducing condensation of water on the surface (Opara 2003).

2.1.8. Transport to New Zealand

Onion bulbs that retain their hard or protective outer skin layers may be shipped in open containers to ensure adequate ventilation is maintained.

Onion bulbs that have been stripped and cleaned are likely to be shipped to New Zealand within refrigerated containers in either bulk packaging or in packing suitable for transfer straight to market. Refrigerated containers can maintain conditions suitable for bulk storage, namely 0ºC at relative humidity's of between 55-65%.

Shipping from China would be expected to take more than 14 days, with a further few days of transport in New Zealand before reaching the market.

2.1.9. Onion commodity description

Based on the information provided above, the commodity description upon which this risk analysis is based is described as follows:

Pre-harvest in-field inspections:	During the growing season pests and diseases are controlled to limit impacts on onion (*Allium cepa*) yields.
Plant material and life stage:	Includes onion (*Allium cepa*) bulbs of any size, fresh or cured, with some root material still attached. Aboveground leaf material is removed to at least 5 cm from the bulb.
General condition and cleanliness:	The bulbs have been brushed clean of soil. Consignments of bulbs have been graded to remove obviously damaged bulbs, plant material other than bulbs or from species other than *Allium cepa*, and bulb-size clumps of soil. The grading process is expected to be at least 95% effective for all but the clumps of soil, where 100% effectiveness is expected.
Transport conditions to market:	Onion consignments are shipped as bulk or in packages in a manner that provides sufficient ventilation to limit storage rotting.

Consignments of onion bulbs that do not, as a minimum, conform to this commodity description are not covered by this risk analysis.

2.2. The New Zealand onion industry

2.2.1. Onion production

The area in New Zealand planted in onions was estimated at 4855 hectares for the year ended 31 December 2006, up 13 percent on the previous years planting and almost back to the area grown in the year ended 31 December 2004. This increase in planted area was largely due to the ideal planting conditions at the time, rather than an expectation of improved prices (MAF Policy 2007).

The total production of onions in 2007/2008 is expected to be 245,000 tonnes, 34 percent (83,300 tonnes) of which is consumed on the domestic market. The volume of onions exported from New Zealand to the year ended 31 March 2007 was 162,000 tonnes, with a value of $99.6 million. Lower volumes of onions were sold on the Japanese market due to the relative value of the New Zealand dollar to the yen, and the availability of Chinese onions only two days away by ship and therefore at less risk of post-harvest disorders (MAF Policy 2007).

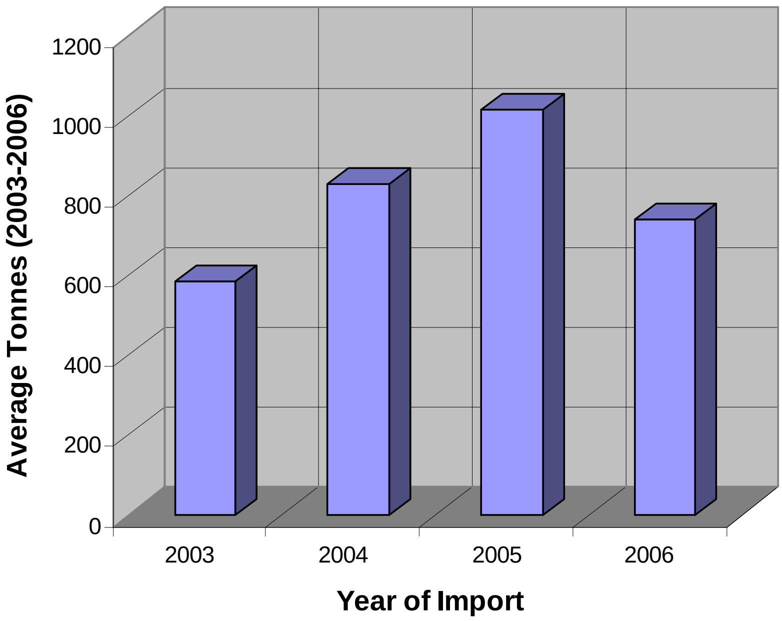
The Integrated Pest Management (IPM) strategy for onions has been revised to fit more closely the specific needs of New Zealand growers. It became apparent when IPM was first introduced into New Zealand that the threshold levels for spraying were too high and there was a high level of resistance in the thrips population to a number of insecticides used (MAF Policy 2007).

While onion production in New Zealand occurs primarily between January and May, onions can be held in cold storage over the period when no onion production occurs (MAF Policy 2007).

2.2.2. Imported onions

Onions (as fresh produce) can currently only be imported into New Zealand from Australia, Japan and USA, as these are the only countries covered by an existing import health standard. In reality the majority of onions are imported from the USA. Table 2.1 provides the approximate annual volumes of imported onions over a four-year period from 2003 to 2006 (MAF Policy 2007).

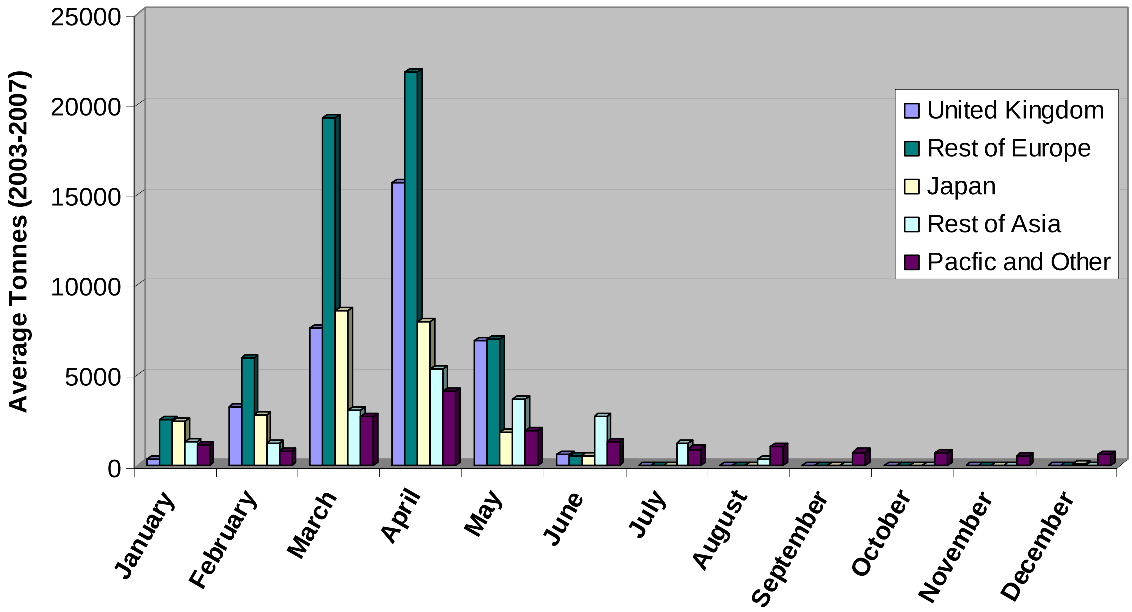
Table 2.1: Annual volumes of onions imported into New Zealand as fresh produce between 2003 and 2006.



2.2.3. Exported onions

Onions are exported from New Zealand to mainly to Europe and Japan, with reasonable volumes also going to other parts of Asia and the pacific region. As is evident from Table 2.2, the greatest volume of exports occurs over the peak periods of production in New Zealand (February to May) (Sofresh 2008, Statistics NZ 2008).

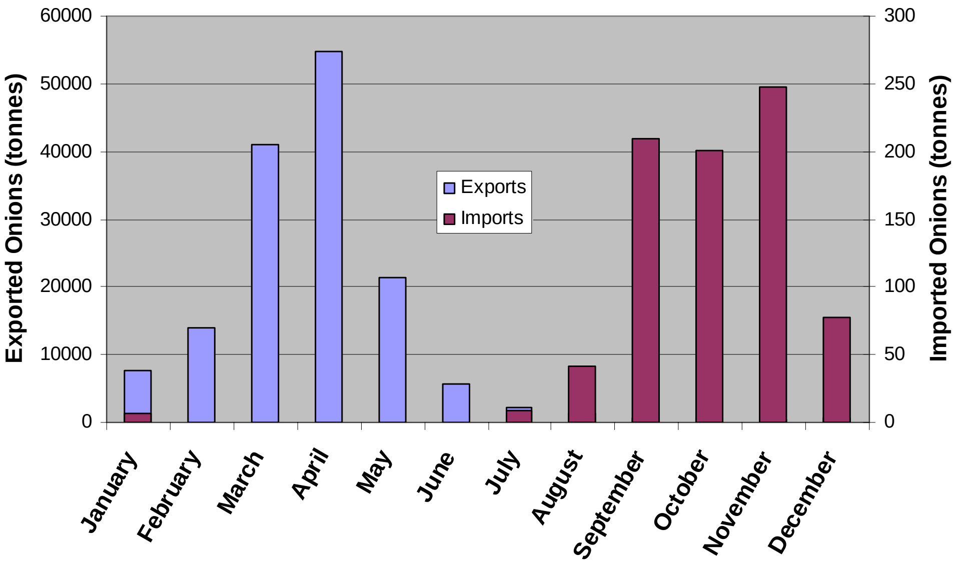
Table 2.2: Monthly export volumes of onion fresh produce from New Zealand (Average from 2003-2007).



2.2.4. New Zealand trading patterns in onions

Comparing the monthly export and import trading volumes of onions in New Zealand (Table 2.3), it is apparent that the low volume of imports (up to 1000 tonnes per annum) supplies the fresh onion market over the period that fresh New Zealand grown onions are not available. The bulk of the domestic market (around 80,000 tonnes per annum) is supplied from New Zealand grown onions held in storage.

Table 2.3: New Zealand monthly trade volumes of imported and exported onions



2.3. The New Zealand climate

New Zealand has a maritime climate which varies from warm subtropical in the far north to cool temperate in the far south, with severe alpine conditions in the mountainous areas.

Mountain chains extending the length of New Zealand's South Island provide a barrier for the prevailing westerly winds, dividing the country into two separate climatic regions. The West Coast of the South Island is the wettest, whereas the area to the east of the mountains, just over 100 km away, is the driest (NIWA 2006).

Most parts of the country get between 600 and 1600 mm of rainfall annually, with a dry period during the summer. At four locations on the west coast of the South Island (Westport, Hokitika, Mt Cook and Milford Sound) mean annual rainfall was between 2200mm and 6800mm for the period 1971-2000 (NIWA 2006). Over the northern and central areas of New Zealand more rain falls in winter than summer, whereas for much of southern New Zealand, winter is the season of least rainfall.

Mean annual temperatures range from 10°C in the south to 16°C in the north. The coldest month is usually July and the warmest month is usually January or February. Generally there is little variation between summer and winter temperatures, although inland and to the east of the ranges the variation is greater (up to 14°C). Temperatures also drop about 0.7°C for every 100 m of altitude (NIWA 2006).

Sunshine hours are relatively high in places sheltered from the west and most of New Zealand would have at least 2000 hours annually. Most snow falls in the mountain areas. Snow rarely falls at the coast of the North Island and west of the South Island, although the east and south coasts of the South Island may experience some snow in winter. Frosts can occur anywhere, and usually form on cold nights with clear skies and little wind (NIWA 2006).

2.3.1. Climate in northern New Zealand

The northern part of New Zealand is the most climatically suitable for the establishment of new pests and pathogens coming from tropical or subtropical regions. The area includes Kaitaia, Kerikeri, Whangarei, Auckland – the largest city in New Zealand, and Tauranga. The latter two cities both contain large active ports. Kerikeri is a well-known orcharding town with many varieties of citrus fruit grown there. This is a sub-tropical climate zone, with warm humid summers and mild winters. Typical summer daytime maximum air temperatures range from 22°C to 26°C, but seldom exceed 30°C, while winter daytime maximum air temperatures range from 12°C to 17°C.

Annual sunshine hours average about 2000 per year in many areas, with Tauranga for example, experiencing at least 2200 hours. Southwesterly winds prevail for much of the year while sea breezes often occur on warm summer days. Winter usually has more rain and is the most unsettled time of year. In summer and autumn, storms of tropical origin may bring high winds and heavy rainfall from the east or northeast (NIWA 2006).

Auckland has the highest rate of naturalised plants of any city in the country. The prime reasons for the high numbers of plant species are considered a moderate climate favouring species from many climatic zones and availability of habitats (Esler 1988). Auckland also has the largest population in the country, with the greatest influx of incoming goods and people and contains the largest seaports and airports.

2.4. Climate in China

China covers a land territory of approximately 9.6 million square kilometres and an adjacent sea area of some 4.73 million square kilometres. Although most of the country lies in the temperate belt, its climatic patterns are complex. China's climate is characterized by two distinct types, the continental monsoon climate and the complex climate. The precipitation in China varies markedly between the seasons, with rain falling mostly in summer, and is distributed very unevenly from region to region. Topographically, China slopes from the west to the east, forming three distinct terraces. Mountainous regions, hilly areas and plateaus comprise 66% of the total territory (National Coordination Committee on Climate Change 2004).

In terms of climate, China may be divided between the humid eastern region and the dry west. The humid east may be further subdivided between the warm and humid south and southeast and the temperate-to-cool, moderately humid north and northeast. Much of the humid eastern region of China exhibits a monsoonal pattern of temperature and precipitation. In a monsoon climate, the warm summer months are typically the months of maximum precipitation.

Onions can be grown in all provinces of China and processed for exporting. The provinces with large planting area include Fujian, Yunnan, Sichuan, Jiangsu, Shandong, Hebei, Henan, Gansu, Inner Mongolia, Heilongjiang and so on. Fujian, Yunnan, Shandong and Gansu are the leading onion growing provinces (China 2008).
The climate differs greatly in various regions in China, but the growing temperature of onion is relatively uniform. The seed and bulb start to sprout at 3-5ºC and sprouts rapidly at above 12ºC. The most suitable growing temperature for seedlings is 12-20ºC and that for roots and bulbs 10-15ºC and 21-27ºC (China 2008).

1. Sunshine: different onion varieties have different requirements for sunshine, ranging from 11.5h/day to 16h/day.
2. Water content: onion leaf is drought resistant, with suitable relative humidity of 60%-70%. The root system is shallow with poor water absorbency and requires comparatively higher soil moisture, especially during the leaf-growing period and the bulb-expansion period. Before the seedling survives the winter and turns green in early spring, it is necessary to control irrigation during bulb harvest. The soil drought is helpful to promote bulb growth. During the bulb storage period, low temperature and dry environmental conditions are necessary.

In general, onion is suitable for growing in temperatures between 15-25ºC in comparatively dry regions. The climate conditions of some main growing regions are shown in the following table (China 2008):

Growing regions	Air temperature and precipitation
Xiamen and Zhangpu in Fujian	The annual average temperature is 21 ºC, annual precipitation 1500 mm and the average frost-free period 318-349 days.
Yuanmou in Yunnan	The annual average temperature is 21.9 ºC, frost-free period in semi-mountainous areas 305-314 days and , 302-331 days in semi-mountainous areas, average frost period in dam areas 2 days, and average annual precipitation 613.8mm.
Jianshui in Yunnan	The annual average temperature is 19.8 ºC, average precipitation is 1751.5mm, and annual average frost-free period 260-365 days.
Fengxian County in Jiangsu and Jinxiang and Yutai Shandong.	The annual average temperature is 13.9 ºC, annual average precipitation 736.3mm, and annual average frost-free period 203 days.

Weifang in Shandong	650mm The annual average temperature 12 ºC, frost-free period 200 days, year precipitation 650mm
Jiuquan, Jiayuguan and Yumen in Gansu	The annual average temperature is 5-8 ºC, frost-free period 140-160 days, and annual precipitation less than 50mm.
Inner Mongolia	The annual average temperature is 6.2 ºC, annual precipitation 350-500mm, with short frost-free period of 130-150 days in plain areas and less than 100 days in northern mountainous areas.
Northeastern China	The annual average temperature is 3.5-8.5 ºC, frost-free period 150-200 days, and annul precipitation 100-250mm.

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3. Potential hazards and mitigation options

In this chapter the organisms and diseases potentially associated with onion bulbs in China are identified and assessed for their potential to be considered as hazards on this pathway. A discussion on potential phytosanitary measures for mitigating biosecurity risks is also provided.

3.1. Hazard identification

The first step in this process is to identify organisms and diseases that could potentially be associated with the pathway in question, Onion bulbs from China. There are a number of limitations on the information that is available for the development of such a list of organisms or diseases. These limitations include:

- The information must be considered at least reasonably reliable and therefore be sourced from the scientific literature rather than the popular media or other such sources.
- Many organisms and diseases associated with a commodity will not have been identified in any scientific (or other) sources of information. This will vary depending on how well the commodity in question has been studied, which itself is most often a reflection of the commodities economic importance to a region or country.
- Many organisms have yet to be discovered or identified and as such may not be reported. Crous and Groenewald (2005) estimated that only 7% of the fungal species thought to exist are known to science.
- Organisms or diseases that are considered insignificant on the commodity in question may be under-reported, even though they may be significant for other commodities.

One factor in favour of organism or disease identification is that any significant organisms or diseases on the commodity in question are more likely to have been reported.

3.1.1. Organisms and diseases associated with onion bulbs from China

Several sources of information are routinely referenced when developing hazard lists for most plant-based commodities. CAB International (CPC 2007) provides a web-based compendium of crop pests and diseases that can be used to compile hazard information on any plant host included in the supporting database. "Plant Viruses Online" (Brunt *et al.* 1996) and the Universal Virus Database (ICTVdB Management 2006) provide web-based interfaces into databases containing information on viruses including host associations. The "Fungal Databases" (Farr *et al.* 2008) is provided online by the United States Department of Agriculture, and contains extensive information on fungal and host associations.

From these and other sources a list was developed of organisms and diseases recorded as being both associated with onion plants and present in China (region). This list is provided in Appendix 2, and contains 228 organisms including 14 bacteria, 83 fungi, 73 invertebrates (including 47 insects, 11 mites and 15 nematodes), 1 mollusc, 1 phytoplasma, 48 plants, and 7 viruses. Included in Appendix 2 are the scientific and common names of these organisms and diseases, the key references sourced to link them with the commodity, their presence (or not) in New Zealand and their presence in China.

3.1.2. Organism association with onion bulbs in trade

Organisms have been intercepted on onion bulbs imported into New Zealand since interception records began in 1955 (Manson & Ward 1968). Organisms that have been recorded as being intercepted on bulbs imported into New Zealand since 1955 are provided in Appendix 1. The interceptions records are from the small samples taken of imported bulbs as they arrive in New Zealand and any intercepted organisms identified in Ministry of Agriculture (or predecessors) laboratories. The list, like all interception records, is likely to contain only a small proportion of the organisms that have been associated with this trade, and organisms of larger size and contrast and with diagnostic keys readily available will be over represented (MAFBNZ 2008). The list has been provided to indicate the types of organisms that are known to be associated with onion bulbs in international trade. A number of the organisms have been intercepted on multiple occasions, the most frequent of which include *Rhizoglyphus robini* with over 35 interceptions and *Thrips tabaci* with over 70 interceptions.

All plants to form associations with micro-organisms that are considered to be endophytes or saprobes (saprophytes). Ormsby (2008) reviewed the phytosanitary status of these endophytic or saprophytic organisms and concluded that they represent a negligible risk to the New Zealand economy, environment or human health. Therefore measures for organisms associated with plant material should be limited, where possible, to hazard organisms that may potentially be associated with the pathway (Ormsby 2008).

3.1.3. Organisms and diseases potentially on onions in China

Appendix 2 provides the answers to a series of questions that culminates in the decision as to the status of these organisms on the onion commodity, either as potential hazards or not potential hazards. A list of those organisms considered potential hazards is provided below in table 3.1. This table contains a total of 2 bacteria, 23 fungi, 38 insects, 3 mites, 1 mollusc, 8 nematodes, 1 phytoplasma, 26 plants, and 3 viruses.

Table 3.1: Potential hazards – Status determination

Scientific name	Common name	Primary reason for considering potential hazard	Section considered	Status
Bacteria				
Erwinia chrysanthemi pv. *chrysanthemi*	Lettuce marginal leaf blight	Not recorded in New Zealand	4.1	Hazard
Pantoea ananatis	Fruitlet rot of pineapple	Not recorded in New Zealand	4.2	Hazard
Fungi				
Alternaria palandui	Leaf spot	Not recorded in New Zealand	5.1	Hazard
Cladosporium oxysporum	Seedlings blight of passion fruit	Not recorded in New Zealand	5.2	Hazard
Cochliobolus eragrostidis	Leaf spot	Not recorded in New Zealand	5.7	Hazard
Davidiella allii-cepae	Black mould	Not recorded in New Zealand	5.2	Hazard
Diaporthe phaseolorum var. *sojae*	Pod blight: soyabean	Not recorded in New Zealand	5.3	Negligible risk on this commodity
Gliocladium catenulatum	Fungal antagonist	Not recorded in New Zealand	5.4	Negligible risk on this commodity
Glomerella cingulata	Anthracnose	Strains/host associations not recorded in New Zealand	5.5	Not a potential hazard on this commodity
Mycosphaerella olivaceum	Black mould	Not recorded in New Zealand	5.2	Invalid name
Olpitrichum tenellum	Black rot	Not recorded in New Zealand	5.6	Negligible risk on this commodity

Scientific name	Common name	Primary reason for considering potential hazard	Section considered	Status
Penicillium oxalicum	Blue mould	Not recorded in New Zealand	5.2	Hazard
Phomopsis longicolla	Pod and stem blight	Not recorded in New Zealand	5.3	Negligible risk on this commodity
Phyllosticta sp.	Leaf spot	Not recorded in New Zealand	5.7	Negligible risk on this commodity
Phytophthora capsici	Soft rot	Not recorded in New Zealand	5.8	Hazard
Phytophthora cinnamomi	Stem canker	Strains/host association not recorded in New Zealand	5.8	Hazard
Phytophthora drechsleri	Tuber rot	Not recorded in New Zealand	5.8	Hazard
Phytophthora meadii	Rubber leaf drop	Not recorded in New Zealand	5.8	Hazard
Phytophthora palmivora	Black rot	Not recorded in New Zealand	5.8	Negligible risk on this commodity
Phytophthora porri	White tip of leek	Not recorded in New Zealand	5.8	Hazard
Puccinia asparagi	Asparagus rust	Not recorded in New Zealand	5.9	Hazard
Pythium intermedium	Pythium root rot	Not recorded in New Zealand	5.10	Hazard
Pythium vexans	Pythium root rot	Not recorded in New Zealand	5.10	Hazard
Stemphylium allii-cepae	Leaf blight	Not recorded in New Zealand	5.3	Hazard
Thanatephorus cucumeris	Leaf blight	Strains/host associations not recorded in New Zealand	5.11	Not a potential hazard on this commodity
Insects				
Acrolepia manganeutis	Stone leek miner	Not recorded in New Zealand	6.6	Negligible risk on this commodity
Acrolepiopsis sapporensis	Stone leek miner	Not recorded in New Zealand	6.6	Negligible risk on this commodity
Alphitobius laevigatus	Black fungus beetle	Not recorded in New Zealand	6.4	Not a potential hazard on this commodity
Atherigona orientalis	Pepper fruit fly	Not recorded in New Zealand	6.2	Hazard
Autographa gamma	Silvery moth	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Bemisia tabaci	Tobacco whitefly	Strains/host associations not recorded in New Zealand	6.5	Not a potential hazard on this commodity
Bradysia odoriphaga	Chinese chive maggot	Not recorded in New Zealand	6.3	Hazard
Calliphora vomitoria	Bluebottle fly	Not recorded in New Zealand	6.3	Hazard
Delia antiqua	Onion fly	Not recorded in New Zealand	6.2	Hazard
Delia floralis	Turnip maggot	Not recorded in New Zealand	6.2	Hazard
Exomala orientalis	Oriental beetle	Not recorded in New Zealand	6.4	Not a potential hazard on this commodity
Euxesta notata	Cherry worm	Not recorded in New Zealand	6.3	Hazard
Frankliniella occidentalis	Western flower thrips	Strains/host associations not recorded in New Zealand	6.8	Hazard
Gryllotalpa africana	African mole cricket	Not recorded in New Zealand	6	Not a potential hazard on this commodity
Hadula trifolii	Clover cutworm	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Helicoverpa armigera	Cotton bollworm	Strains not recorded in New Zealand	6.7	Negligible risk on this commodity
Icerya seychellarum	Seychelles scale	Not recorded in New Zealand	6.5	Not a potential hazard on this commodity
Leptinotarsa decemlineata	Colorado potato beetle	Not recorded in New Zealand	6.4	Not a potential hazard on this commodity
Liriomyza bryoniae	Tomato leafminer	Not recorded in New Zealand	6.1	Negligible risk on this commodity

Scientific name	Common name	Primary reason for considering potential hazard	Section considered	Status
Liriomyza cepae	Miner, stone leek leaf	Not recorded in New Zealand	6.1	Negligible risk on this commodity
Liriomyza chinensis	Stone Leek Leafminer	Not recorded in New Zealand	6.1	Negligible risk on this commodity
Liriomyza huidobrensis	Serpentine leafminer	Not recorded in New Zealand	6.1	Negligible risk on this commodity
Liriomyza nietzkei		Not recorded in New Zealand	6.1	Negligible risk on this commodity
Liriomyza sativae	Vegetable leafminer	Not recorded in New Zealand	6.1	Negligible risk on this commodity
Liriomyza trifolii	American serpentine leafminer	Not recorded in New Zealand	6.1	Negligible risk on this commodity
Loxostege sticticalis	Beet webworm	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Luperomorpha suturalis	Flea beetle	Not recorded in New Zealand	6.4	Not a potential hazard on this commodity
Mamestra brassicae	Cabbage moth	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Peridroma saucia	Pearly underwing moth	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Phaedon brassicae	Leaf beetle	Not recorded in New Zealand	6.4	Not a potential hazard on this commodity
Sarcopolia illoba	Mulberry caterpillar	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Scirtothrips dorsalis	Chilli thrips	Not recorded in New Zealand	6.8	Not a potential hazard on this commodity
Spodoptera exigua	Beet armyworm	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Thrips palmi	Melon thrips	Not recorded in New Zealand	6.8	Not a potential hazard on this commodity
Thrips parvispinus	Melon thrips	Not recorded in New Zealand	6.8	Not a potential hazard on this commodity
Thrips tabaci	Onion thrips	Strains/host associations not recorded in New Zealand	6.8	Hazard
Trichoplusia ni	Cabbage looper	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Xestia c-nigrum	Spotted cutworm	Not recorded in New Zealand	6.7	Not a potential hazard on this commodity
Mites				
Aceria tulipae	Dry bulb mite	Vector of a hazard organism	7	Vectored virus not a potential hazard on this commodity
Rhizoglyphus setosus	Bulb mite	Not recorded in New Zealand	7.1	Hazard
Steneotarsonemus furcatus	Taro tarsonemid mite	Not recorded in New Zealand	7.1	Negligible risk on this pathway
Mollusca				
Lissachatina fulica	Giant African snail	Not recorded in New Zealand	8.1	Not a potential hazard on this commodity
Nematodes				
Aphelenchoides besseyi	Rice leaf nematode	Not recorded in New Zealand	9	Not associated with this commodity
Ditylenchus dipsaci	Stem and bulb nematode	Strains/host associations not recorded in New Zealand	9	Recorded on onion in New Zealand
Heterodera glycines	Soybean cyst nematode	Not recorded in New Zealand	9.1	Negligible risk on this commodity
Meloidogyne graminicola	Rice root knot nematode	Not recorded in New Zealand	9.1	Hazard
Paratrichodorus minor	Stubby root nematode	Vector of a hazard organism	9	Vectored virus not a potential hazard on this commodity
Paratrichodorus porosus	Stubby root nematode	Vector of a hazard organism	9	Vectored virus not a potential hazard on this commodity

Scientific name	Common name	Primary reason for considering potential hazard	Section considered	Status
Pratylenchus zeae	Root lesion nematode	Not recorded in New Zealand	9.2	Negligible risk on this commodity
Rotylenchulus reniformis	Reniform nematode	Not recorded in New Zealand	9.2	Hazard
Phytoplasma				
Candidatus phytoplasma *asteris*	Onion yellows phytoplasma	Not recorded in New Zealand	10.1	Not a potential hazard on this commodity
Plants				
Alopecurus myosuroides	Black-grass	Not recorded in New Zealand	11.1	Hazard
Amaranthus blitum	Livid amaranth	Not recorded in New Zealand	11.1	Hazard
Avena fatua	Wild oat	Vector of other hazards	11.1	Hazard
Borreria latifolia	Broadleaf buttonweed	Not recorded in New Zealand	11.1	Hazard
Cenchrus echinatus	Southern sandbur	Under official control	11.1	Hazard
Cuscuta europaea	European dodder	Under official control	11.1	Hazard
Cynodon dactylon	Bermuda grass	Vector of other hazards	11.1	Hazard
Cyperus esculentus	Yellow nutsedge	Under official control	11.1	Hazard
Cyperus rotundus	Purple nutsedge	Under official control	11.1	Hazard
Echinochloa crus-galli	Barnyard grass	Vector of other hazards	11.1	Hazard
Emex australis	Doublegee	Under official control	11.1	Hazard
Eragrostis cilianensis	Stink grass	Vector of other hazards	11.1	Hazard
Hordeum murinum subsp. *leporinum*	Hare barley	Vector of other hazards	11.1	Hazard
Lolium temulentum	Darnel	Vector of other hazards	11.1	Hazard
Medicago polymorpha	California burclover	Vector of other hazards	11.1	Hazard
Melilotus indica	Indian sweet clover	Not recorded in New Zealand	11.1	Hazard
Orobanche ramosa	Branched broomrape	Under official control	11.1	Hazard
Panicum dichotomiflorum	Fall panicum	Vector of other hazards	11.1	Hazard
Parthenium hysterophorus	Parthenium weed	Under official control	11.1	Hazard
Phalaris canariensis	Canary grass	Vector of other hazards	11.1	Hazard
Poa annua	Annual meadowgrass	Vector of other hazards	11.1	Hazard
Setaria verticillata	Bristly foxtail	Vector of other hazards	11.1	Hazard
Setaria viridis	Green foxtail	Vector of other hazards	11.1	Hazard
Sida acuta	Sida	Not recorded in New Zealand	11.1	Hazard
Sorghum halepense	Johnsongrass	Under official control	11.1	Hazard
Tribulus terrestris	Puncture vine	Under official control	11.1	Hazard
Viruses				
Onion mite-borne latent allexivirus	OMbLV	Not recorded in New Zealand	12.1	Not a potential hazard on this commodity
Shallot yellow stripe potyvirus	SYSV	Not recorded in New Zealand	12.2	Not a potential hazard on this commodity
Tobacco rattle tobravirus	TRV	Strains not in New Zealand	12.3	Not a potential hazard on this commodity

3.2. Potential options for risk mitigating

The following chapter provides some general information about options that may be available to manage any risks that are considered of sufficient concern to require mitigation. As the nature and strength of any phytosanitary measures will need to reflect the nature and strength of the identified risks, actual mitigation options will be discussed within the risk management sections of each hazard risk analysis chapter.

3.2.1. Important generic risk factors

The following paragraph discusses various pathway and risk characteristics that are generic to the consideration of the biosecurity risks of the identified potential hazards.

3.2.1.1. Disposal of onions otherwise imported for consumption

Damaged or inedible parts of an onion will be discarded rather than consumed, thereby creating a potential pathway for introduction of hazard organisms. The likely volume of discarded onion material is therefore an important risk factor to consider.

Commercial onion production in New Zealand is only economically viable if planting is based on disease-indexed seed or sets (seedlings). It is therefore extremely unlikely that commercial growers would use onion bulbs imported for consumption as seeding material for production. Even in the unlikely event that a commercial seed producer was to propagate small volumes of imported onions to supplement the genetic stock used in their breeding programmes, any resulting seed would be subject to relatively rigorous disease indexing.

Domestic consumers purchasing imported onion bulbs for consumption would be expected, in the majority of instances, to consume the goods. Consumers are likely, however, to discard whole or parts of onion bulbs that they consider are not appropriate for consumption. For the purposes of this risk analysis three categories of disposed onions will be considered:

- **a.** Onion waste generated from removing parts of the onion not normally consumed, such as the hard outer skin and each end of the onion.
- **b.** Onion waste that includes parts of the onion normally considered appropriate for consumption, such as rotting of damaged onion flesh, or onions that have sprouted while being stored at home. This material is more likely to include hazard organisms.

Waste generated at re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets, is likely to include both rotting of severely damaged bulbs and the outer layer of dry skin. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (Martin pers. com. 2008). Onion waste generated at commercial re-packaging plants would be disposed of through commercial or private landfills.

- **c.** Onion bulbs planted for seed harvesting in domestic gardens. This is expected to occur extremely rarely and as such will be considered of negligible likelihood and not discussed further in this analysis.

The only information available on household waste disposal patterns considered relevant to this analysis was generated in 2007 in the United Kingdom (WRAP 2008). The total volume of onions consumed in the UK is reported to be around 630,000 tonnes (DEFRA 2008) from which an estimated 149,700 tonnes (or 24%) was disposed as waste (WRAP 2008). In the UK only 12% of waste is disposed at home through composting, animal feed, or down the sink (WRAP 2008). Assuming composting accounts for only a third of this home waste, the total volume of waste onions composted at home in the UK was only 1% of the total volume of onions purchased.

3.2.2. Generally applicable phytosanitary measures options

For each organism classified as a hazard, a risk management step is carried out, which identifies the options available for managing the risk. In addition to the options presented, no phytosanitary measures may also be considered for each hazard. Measures will only be recommended to the Chief Technical Officer for decision once the import health standard process is complete

The following phytosanitary measures options are generally applicable for organisms or diseases potentially associated with imported goods and known to be regionally distributed internationally.

3.2.2.1. Pest free area (PFA)

The International Standards for Phytosanitary Measures number 4: *Requirements for the establishment of pest free areas* (ISPM No 4) describes the requirements for the establishment and use of PFAs as a risk management option for meeting phytosanitary requirements for the import of plants. The standard identifies three main components or stages that must be considered in the establishment and subsequent maintenance of a PFA:

- systems to establish freedom
- phytosanitary measures to maintain freedom
- checks to verify freedom has been maintained.

Normally PFA status is based on verification from specific surveys such as an official delimiting or detection survey. It is accepted internationally that organisms or diseases that have never been detected in, or that have been detected and eradicated from, and area should not be considered present in an area if there has been sufficient opportunity for them to have been detected.

When sufficient information is available to support a PFA declaration, this phytosanitary measure is usually considered to provide a very high level of protection.

3.2.2.2. Pest free place of production (PFPP)

The International Standards for Phytosanitary Measures number 10: *Requirements for the establishment of pest free places of production and pest free production sites* (ISPM No 10) describes the requirements for the establishment and use of pest free places of production as a risk management option for meeting phytosanitary requirements for the import of plants. A pest free place of production is defined in the standard as a "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". Pest freedom is established by surveys and/or growing season inspections and maintained as necessary by other systems to prevent the entry of the pest into the place of production.

When sufficient information is available to support a PFPP declaration, this phytosanitary measure is usually considered to provide a high level of protection depending on the epidemiological characteristics of the organism or disease in question.

3.2.3. Specific phytosanitary measures options

The following options include treatments or activities focused on particular types of potential risks.

3.2.3.1. System or production based phytosanitary measures

Farm pests and diseases can be reduced through the application of pesticides and fungicides as well as integrated pest management activities. On a visit to an onion farm in China's Shandong province close to Qingdao it was reported that farms use a fungicide dip of seedling roots before planting to target potential *Peronospora schleidenii (destructor)* infections (Appendix 3). Plastic sheeting can also be applied to onion rows at planting to reduce drought stress and weed growth and competition (Appendix 3).

Field inspections prior to harvesting can confirm that pest or disease rates are suitably low and, if combined with other phytosanitary measures such as processing or treatment, can ensure adequate levels of mitigation are achieved.

3.2.3.2. Post-harvest processing based phytosanitary measures

Freedom from any impurity, which may materially alter the appearance or eating quality, is considered essential for market quality purposes. In normal commercial operations it should be expected that large clumps or clods soil and other foreign materials would be removed and badly affected or damaged produce discarded. Cleaning may be carried out using air or by manually removing unwanted materials on the bulb surface, while bulbs that have their outer layers removed can be washed in a Sodium hypochlorite (NaClO) solution or equivalent prior to packaging (see Appendix 3).

The visual inspection of bulbs for pests or symptoms of disease either immediately after harvesting or during processing for export could also be integrated into post-harvest systems. Assuming the pest or disease symptoms can be readily detected on visual inspection; visual inspection by a trained inspector can be used in three main ways for managing biosecurity risks on goods being imported into New Zealand:

- As a biosecurity measure, where the attributes of the goods and hazard organism provide sufficient confidence that an inspection will be able to achieve the required level of detection efficacy
- As an audit, where the attributes of the goods, hazard organisms and function being audited provide sufficient confidence that an inspection will confirm that risk management has achieved the required level of efficacy
- As a biosecurity measure in a systems approach, where the other biosecurity measures are not able to provide sufficient efficacy alone or have significant levels of associated uncertainty.

3.2.3.3. Methyl bromide fumigation

The FAO Manual of Fumigation Control (Bond 1984) provides a methyl bromide schedule for fresh fruit and vegetables (Table 3.2). While onions are included on the list of leafy vegetables that are tolerant to the treatment, the information on tolerance is based on vegetable reaction only and is given for guidance. It is not implied that the fumigant is necessarily effective under the given conditions aginst all the pests found in or on the vegetable. The FAO manula states: "*Tests should always be made to deal with specific problems under local conditions*" (Bond 1984).

Table 3.2: Methyl bromide fumigation schedule for the control insects in or on leafy vegetables under atmospheric conditions.

Temperature (^{O}C)	Rate (g/m^3)	Treatment Duration (hours)	C/T Value* (g h/m^3)
4 to 7^{O}C	64 g/m^3	2	90
8 to 10^{O}C	56 g/m^3	2	82
11 to 15^{O}C	48 g/m^3	2	76
16 to 20^{O}C	40 g/m^3	2	64
21^{O}C and above	32 g/m^3	2	51

*C/T values are calculated based on time decay rates experienced under tarpaulin.

The methyl bromide treatment schedule provided in table 3.3 has been derived from schedules for surface insects provided in the FAO Manual of Fumigation Control (Bond 1984) and the USDA Treatment Manual (Davis & Venette 2004). The actual level of efficacy of this treatment has yet to be determined against all but a few insect species, but it is implied by the authors to be effective against a greater range of organisms (Davis & Venette 2004) than the schedule provided in table 3.2.

Table 3.3: Methyl bromide fumigation schedule for surface feeding insect infestations (foliated dormant plants under atmospheric conditions).

Temperature (^{O}C)	Rate (g/m^3)	Treatment Duration (hours)	C/T Value* (g h/m^3)
4 to 10^{O}C	64 g/m^3	3	114
11 to 15^{O}C	64 g/m^3	2.5	102
16 to 20^{O}C	64 g/m^3	2	90
21 to 25^{O}C	48 g/m^3	2	76
26 to 29^{O}C	40 g/m^3	2	64
30 to 32^{O}C	32 g/m^3	2.5	48

*C/T values are calculated based on time decay rates experienced under tarpaulin.

The methyl bromide treatment schedule provided in table 3.4 has been taken from the USDA Treatment Manual (updated 22 September 2008) (T101-q-2 MB at NAP) and is specifically for internal feeders (leafminers) in onion bulbs in international trade. This treatment schedule is described as being suitable for tarpaulin or chamber fumigations however no treatment efficacy level is provided.

Table 3.4: Methyl bromide fumigation schedule for internal feeders (and leafminers) in onion bulbs.

Temperature (^{o}C)	Rate (g/m^3)	Minimum Concentration Readings (g/m^3) at:					C/T Value* (g h/m^3)
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	
33 ^{o}C or above	32	26	19	—	—	—	51
26-32 ^{o}C	40	32	24	—	—	—	64
21-25 ^{o}C	48	38	29	—	—	—	77
16-20 ^{o}C	48	38	26	26	—	—	92
11-15 ^{o}C	48	38	26	—	26	—	104
4-10 ^{o}C	48	38	26	—	—	26	117

*C/T values are calculated based on time decay rates experienced under tarpaulin.

At the time of completing this analysis the level of phytotoxicity of methyl bromide against onion bulbs was unknown. Care should be taken to ensure phytotoxicity levels are acceptable before applying any chemical treatments to plant material.

3.2.3.4. Irradiation treatments

Irradiation treatments have been used successfully as method for decontaminating bulbs or tubers of insects (250-1000 Gy) and micro-organisms (5-10 kGy), for inhibiting sprouting (20-150 Gy) or extending storage life (250-750 Gy) (IAEA 1997). Irradiation doses in excess of 1 kGy are not recommended for fresh onion bulbs, as they are likely to reduce bulb quality (IAEA 1997). To be consistently effective, low dose treatments to inhibit sprouting (20-70 Gy) need to be applied to onion bulbs 2-4 weeks after harvest during the dormancy period (IAEA 1997). There is no information available that indicates the level of efficacy of the sprout inhibiting treatments.

Gamma irradiation of eggs and first larval stages of *Liriomyza trifolii* at doses of 40-50 Gy provided effective control according to Yathom *et al*. (1991), but lower doses were considered ineffective. Yathom *et al*. (1991) exposed 1630 1st instar larvae (the most resistant life stage tested) to 40-50 Gy of gamma irradiation. Pupation occurred normally however adult emergence from pupae was around 50% in controls compared to around 1% for treated pupae, and all emerged flies from treated pupae were impaired. Adjusting the results for the 50% emergence in controls, the calculated efficacy of this irradiation treatment on *Liriomyza trifolii* in beans was 99.6319% (or 1 survivor in 272) at the 95% level of confidence (Couey & Chew 1986). These examples indicate that an irradiation treatment could be developed for disinfesting onion bulbs of invertebrate hazards.

Food Standards Australia New Zealand (FSANZ) has approved and given food safety clearance to the use of irradiation as a phytosanitary treatment for the following imported fresh produce only: Mango, Rambutan, Longan, Lychee, Papaya, Custard apple, Breadfruit and Carambola. Along with these fruits the only other products available in New Zealand, and permitted to be irradiated in prescribed doses set out in the Foods Standards Code, are herbs and spices and herbal infusions, excluding tea. Foods are not allowed to be irradiated unless they have been through a pre-market safety assessment process conducted by FSANZ (NZFSA 2008) (accessed 05/12/2008). As such onion bulbs imported into New Zealand for consumption at this time are not permitted to be irradiated.

3.2.3.5. Cold treatments

Cold treatments (0ºC) combined with a relative humidity of between 65% and 70% are primarily applied to extend storage life by both extending dormancy and reducing rotting (IAEA 1997). Subfreezing storage (-1 to -2ºC) of onion bulbs can be used to suppress sprouting when chemical or other sprout inhibitors cannot be used. Populations of micro-organisms are unlikely in many cases to be significantly reduced by these low-temperature treatments. A number of arthropod families are known to be susceptible to low-temperature treatments and may be able to be managed by the application of a cold treatment.

3.2.3.6. Heat treatments

In some production systems, onion sets may receive a heat treatment (32-35ºC) over a number of days to prevent seeding after planting. Temperatures of 35ºC or higher are known to significant reduce mildew (Peronosporaceae) infections when applied to onions after harvest (Diekmann 1997). The USDA Treatment Manual (05/2008-25) offers only one heat treatment for *Allium* bulbs, against infestations of the nematodes *Ditylenchus dipsaci* and *D. destructor*. Treatment T552-1 involves pre-soaking bulbs in water at 75°F (24°C) for 2 hours, then at 110°F–111°F (43°C-44°C) for 4 hours. No information is available on the level of efficacy this treatment may provide.

3.2.3.7. Chemical treatments

Various pesticide treatments are available to reduce contamination levels of arthropods or micro-organisms on onion plants in the field or post-harvest onion bulbs. The availability and suitability of these pesticides will be discussed as appropriate within each of the following hazard risk analyses.

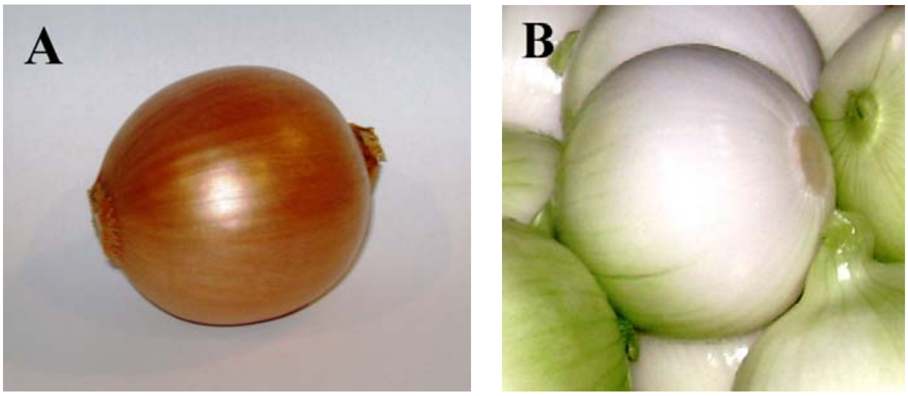
A standard sanitizing wash (e.g. >0.02% a.i. sodium hypochlorite (NaClO) buffered to pH 6.9, >0.0053% a.i. chlorobromohydantoin (BCDMH) buffered to pH 8.4) after the bulbs have been cleaned of any soil and/or decaying plant material is a good general hygene measure to protect onion bulbs from bacterial or fungal injury during storage and transport. This wash could also potentially be a useful part of a set of phytosanitary measures to reduce the prevalence of hazard fungi or bacteria on otherwise symptomless onions. As such use of this treatment may be considered when developing any post-harvest risk management systems.

3.2.3.8. Physical treatments

Physical cleaning of onion bulbs for quality purposes is a relatively common treatment applied in commercial operations. Depending on the commercial requirements of the final product, onions can be physically cleaned of their outer loose skin layers (see figure 3.1a) or of all of the outer hardened skin layers (see figure 3.1b).

It is important in both cases that no root material is left on the base of the bulb and the stalk at the top of the bulb is trimmed back to within a few millimetres of the bulb surface. A cleaning process that removes the outer layers should also include a sanitizing wash (see section 3.2.3.7), and any bulbs showing discolouration or other damaged after cleaning should be removed from the export consignment.

Figure 3.1: Physically cleaned onions by a) removing outer loose skin layers or b) removing all outer layers



Removal of all outer skin layers (figure 3.2b) and the provision of "consumer ready" onion packages would also considerably reduce the amount of onion waste available for home composting in New Zealand (see section 3.2.1.1).

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4. Analysis of potential hazards - Bacteria

4.1. *Erwinia chrysanthemi* pv. *chrysanthemi*

4.1.1. Hazard identification

4.1.1.1. Aetiologic agents

Erwinia chrysanthemi pv. *chrysanthemi* Burkholder *et al.* 1953: Bacteria: Gracilicutes.

4.1.1.2. New Zealand status

Erwinia chrysanthemi pv. *chrysanthemi* is not recorded as present in New Zealand (PPIN 2008, NZFungi 2007).

4.1.1.3. Biology and epidemiology

Pathovars

Erwinia chrysanthemi (bacterial soft rot) is divided into six pathovars: pv. *chrysanthemi*; pv. *dianthicola*; pv. *dieffenbachiae*; pv. *paradisiaca*; pv. *parthenii*; and pv. *zeae* (NZFungi 2008, EPPO/CABI 1997). A pathovar has been defined as an infrasubspecific term referring to a group of phytopathogenic bacteria principally on the basis of their host range (Dye *et al.* 1980). However, because *E. chrysanthemi* strains have been isolated from more than 50 plant species (Bradbury 1986), pathogenic differences between the strains appear to be based more on biochemical differences rather than host specificity (in Ngwira & Samson 1990).

Erwinia chrysanthemi pv. *dianthicola*, pv. *dieffenbachiae* and pv. *zeae* are present in New Zealand (PPIN 2008). *Erwinia chrysanthemi* pv. *chrysanthemi*, pv. *paradisiaca* and pv. *parthenii* are not present in New Zealand (PPIN 2008). *Erwinia chrysanthemi* pv. *paradisiaca* and pv. *parthenii* are not recorded as present in China or as pathogens of onions (CPC 2007, Samson *et al.* 2005).

Biology and ecology

Erwinia chrysanthemi pv. *chrysanthemi* is a Gram-negative, non-sporing, facultative anaerobic, straight rod bacterium with rounded ends. It is an opportunistic necrotrophic pathogen that causes bacterial soft rot in many plants in tropical and subtropical regions (CPC 2007). *Erwinia chrysanthemi* affects storage organs and succulent leaves of vegetables, field crops, and ornamental plants (Aysan *et al.* 2003, Pérombelon 2002, Pérombelon & Kelman 1980). *Erwinia chrysanthemi* causes bacterial soft rot in several *Allium* spp. Evidence suggests that *E. chrysanthemi* pv. *chrysanthemi* causes soft rot in onion (*Allium cepa*) (CPC 2007).

Erwinia chrysanthemi produces pectolytic enzymes (e.g., pectate lyase, polygalacturonase, cellulose, and protease) that cause severe soft-rot disease through tissue maceration, electrolyte leakage and cell death (Matsumoto *et al.* 2003, Mark *et al.* 2002). Additional pathogenicity-associated characters may also be involved in the establishment of the bacteria in plant tissues and in free-living or saprophytic life phase (Pérombelon 2002). In addition to causing local disease, the bacteria may enter vascular elements of infected plants, thereby moving rapidly through the host (Yang *et al.* 2004, EPPO/CABI 1997).

Epidemiology

Disease development *E. chrysanthemi* is favoured by heavy rain and by temperatures between 20 and 30^{o}C (Mohan & Ocamb 2008, Anon. 1998, van der Wolf & Duriat 2008). Disease caused by *E. chrysanthemi* usually occurs in a severe form on succulent plant organs at high temperatures, under humid conditions, and a high level of nitrogen. Some literature indicates that the optimum temperature for pathogenesis is 32°C (Mark *et al.* 2002) while others indicate that disease symptoms caused by the bacterium are usually destructive at temperatures at, or above, 28°C (CPC 2007).

The primary sources of inoculum are planting material, soil and crop residues (EPPO/CABI 1997, van der Wolf & Duriat 2008). Long distance spread of *E. chrysanthemi* is mainly through infected vegetative propagating material (EPPO/CABI 1997).

Erwinia chrysanthemi can enter the onion bulb through wounds produced by harvesting methods, pruning, cutting and senescent leaves. Free water is essential for access into and spread of the bacteria in onions (UC IPM 2006). The bacteria can also be introduced and spread in the onion bulb through onion maggot (*Delia antiqua*) activity (Mohan & Ocamb 2008).

Symptoms

Symptoms often appear in onions just before or at the time of harvest or at storage (UC IPM 2006, van der Wolf & Duriat 2008) and infection can continue when bulbs are stored at temperatures greater than 3^{o}C (Mark *et al.* 2002).

Initial symptoms of *E. chrysanthemi* infection on onion bulbs can be soft, water rot of individual scales and the appearance of a yellow discoloration of the affected tissue. As the disease advances, the entire bulb may rot and a brown discoloration may appear that progresses lengthwise in the infected bulbs (UC IPM 2006' van der Wolf & Duriat 2008). A foul-smelling viscous fluid may ooze from the neck of the onion if squeezed (van der Wolf & Duriat 2008). Onion bulbs infected with *E. chrysanthemi* may completely dissolve the inner bulb tissues so that when the bulb is pulled it separates from the basal plates, which remains in the soil (Mark *et al.* 2002).

No information is available about disease development in onions with the outer dry scale removed versus the outer dry scale intact. However, it would be expected that disease symptoms would be detected with greater accuracy if the outer dry scale was removed.

Host range

In addition to *A. cepa*, recorded hosts of *E. chrysanthemi* pv. *chrysanthemi* include bell pepper (*Capsicum annuum*), cabbage (*Brassica oleracea* var. *capitata*), chicory (*Cichorium intybus*), *Chrysanthemum* spp., cucurbits (*Cucurbitaceae*), endives (*Cichorium endivia*), eggplant (*Solanum melongena*), lettuce (*Lactuca sativa*), *Petunia* × *hybrida*, Primrose (*Primula*), poinsettia (*Euphorbia pulcherrima*), sweet potato (*Ipomea batatas*) (Sherf & McNab 1986), taro (*Colocasia esculenta*), tomato (*Lycopersicon esculentum*), and tobacco (*Nicotiana tabacum*) (CPC 2007). All of these plant species are present in New Zealand (PBI 2008).

4.1.1.4. Hazard identification conclusion

Based on the accepted absence of *E. chrysanthemi* pv. *chrysanthemi* in New Zealand, the potential ability of this bacteria to be imported on onion bulbs from China, and the potential ability of this bacteria to cause disease symptoms on onion and a wide range of host plants in New Zealand, it is proposed that *E. chrysanthemi* pv. *chrysanthemi* be considered a potential hazard requiring further assessment.

4.1.2. Risk assessment

Much of the information provided in the previous section relates to *E. chrysanthemi* as there is only a limited amount of information specific to *E. chrysanthemi* pv. *chrysanthemi*. Although there are some biochemical differences between the pathovars, overall mechanisms for pathogenicity are considered similar to that of *E. chrysanthemi*; therefore, assumptions will be made on this basis in terms of the following risk assessment.

4.1.2.1. Entry assessment

The likelihood of entry of *E. chrysanthemi* pv. *chrysanthemi* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *E. chrysanthemi* pv. *chrysanthemi* in China.

There are several factors that would influence the prevalence of *E. chrysanthemi* pv. *chrysanthemi* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because *E. chrysanthemi* pv. *chrysanthemi* is a soil-borne pathogen that can over-winter on plant/crop debris or on alternative hosts. Secondly, there is opportunity for the pathogen to enter the onion plant through wounds produced during harvesting methods (section 2.1.2). Thirdly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *E. chrysanthemi* pv. *chrysanthemi*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels are conducive for *E. chrysanthemi* pv. *chrysanthemi* infection (20-30^{o}C) (Mohan and Ocamb, 2008, Anon. 1998, van der Wolf & Duriat 2008). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *E. chrysanthemi* pv. *chrysanthemi* in the field, the pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible, e.g., at temperatures below 20^{o}C (CPC 2007). Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., <5^{o}C). Under such conditions, it would be expected that *E. chrysanthemi* pv. *chrysanthemi* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *E. chrysanthemi* pv. *chrysanthemi* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

4.1.2.2. Assessment of exposure

Should onion bulbs infected with *E. chrysanthemi* pv. *chrysanthemi* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of the bacteria in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying bacteria destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *E. chrysanthemi* pv. *chrysanthemi* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Infected soil or crop residues distributed from compost over host plants would act as a primary source of inoculum. Free water is essential for access into and spread of the bacteria in host plants (UC IPM 2006). The bacteria can also be introduced and spread through insect browsing activity (Mohan & Ocamb 2008).

The likelihood of exposure of *E. chrysanthemi* pv. *chrysanthemi* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

4.1.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *E. chrysanthemi* pv. *chrysanthemi* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *E. chrysanthemi* pv. *chrysanthemi*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

E. chrysanthemi pv. *chrysanthemi* has a very wide host range including cabbage, lettuce, cucurbits, tomato and taro. All these crops are commonly found in home gardens (taro is particularly common in gardens in South Auckland) and, apart from tomato and taro, crops extensively planted in field rotation with onions in the major onion-growing area of Pukekohe. The close juxtaposition (in some cases) of susceptible hosts in home gardens and commercial fields significantly increases the chances of establishment of a chance importation of *E. chrysanthemi* pv. *chrysanthemi* (Fullerton pers. com. 2009).

The likelihood of *E. chrysanthemi* pv. *chrysanthemi* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

4.1.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *E. chrysanthemi* pv. *chrysanthemi* could spread within the private garden area via rain, heavy irrigation (Mohan & Ocamb 2008), or movement of infested crop debris or alternative hosts. The likelihood for *E. chrysanthemi* pv. *chrysanthemi* to spread within these established areas, i.e., private gardens or garden waste areas, is considered moderate and is therefore non-negligible.

It is also likely that *E. chrysanthemi* pv. *chrysanthemi* would spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *E. chrysanthemi* pv. *chrysanthemi* would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered unlikely for the majority of private gardens that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *E. chrysanthemi* pv. *chrysanthemi* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore non-negligible.

It is noted that *E. chrysanthemi* pv. *chrysanthemi* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., cabbage, cucurbits, endives, lettuce, sweet potato, taro or tomato. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic consequences

Specific information about the economic impact of *E. chrysanthemi* pv. *chrysanthemi* on onion or its alternative hosts is not available. If the pathogen was to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *E. chrysanthemi* pv. *chrysanthemi* would have economic consequences on private gardeners.

In contrast, significant economic consequences could result in the warmest areas on New Zealand if *E. chrysanthemi* pv. *chrysanthemi* was to spread from private gardens to commercial production areas. Disease symptoms often appear in onions just before or at the time of harvest or at storage (UC IPM 2006, van der Wolf & Duriat 2008) and infection can continue when bulbs are stored at temperatures greater than 3°C (Mark *et al.* 2002). Onion bulbs infected with *E. chrysanthemi* may completely dissolve the inner bulb tissues so that when the bulb is pulled it separates from the basal plates, which remains in the soil (Mark *et al.* 2002). In onion growing areas of New York (USA) (which has a similar climate to that of New Zealand onion growing areas) yield losses due to *Erwinia* spp. can be as high as 75% in severely affected areas (Stivers 1999).

Based on the above information, the likelihood is high that *E. chrysanthemi* pv. *chrysanthemi* would have moderate economic consequences. It is noted that both conventional and organic commercial growers of cabbage, cucurbits, endives, lettuce, onion, sweet potato, taro or tomato could also be affected.

Environmental consequences

While there is no evidence of *E. chrysanthemi* pv. *chrysanthemi* acting as a pathogen on New Zealand native flora, this pathogen has a wide host range that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species (e.g. *Brassica*, *Lactuca*, *Ipomea*, *Colocasia*, *Lycopersicon* etc). As such, the likelihood is low that *E. chrysanthemi* pv. *chrysanthemi* could establish on a native species or significant urban species and have an unwanted environmental impact within New Zealand.

Human health consequences

Erwinia chrysanthemi pv. *chrysanthemi* is not known to be of any significance to human health.

4.1.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *E. chrysanthemi* pv. *chrysanthemi* spread from private gardens to commercial growing areas, it could cause moderate economic and low environmental consequences to New Zealand.

4.1.2.6. Risk estimation

The likelihood estimate is moderate that *E. chrysanthemi* pv. *chrysanthemi* would be associated with onion bulbs on entry into New Zealand; low that *E. chrysanthemi* pv. *chrysanthemi* would be exposed to the environment; moderate that any *E. chrysanthemi* pv. *chrysanthemi* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *E. chrysanthemi* pv. *chrysanthemi* would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in unwanted economic consequences; and low for environmental consequences to New Zealand.

As a result, the risk estimate for *E. chrysanthemi* pv. *chrysanthemi* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

4.1.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *E. chrysanthemi* pv. *chrysanthemi* on onion (i.e., much of the information is based on *E. chrysanthemi*, not pv. *chrysanthemi*). As such, the risk assessment should be reviewed once further relevant information becomes available.

4.1.3. Risk management

4.1.3.1. Risk evaluation

Since the risk estimate for *E. chrysanthemi* pv. *chrysanthemi* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

4.1.3.2. Option evaluation

There are a number of biosecurity risk management options available for *E. chrysanthemi* pv. *chrysanthemi* on onion bulbs imported from China for consumption. The following risk management options are assessed:

a. Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *E. chrysanthemi* pv. *chrysanthemi*;

b. Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *E. chrysanthemi* pv. *chrysanthemi*;

c. Inspection of onion plants or bulbs for *E. chrysanthemi* pv. *chrysanthemi*;

d. Treatment of onion bulbs for *E. chrysanthemi* pv. *chrysanthemi* by a suitably efficacious method;

e. Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *E. chrysanthemi* pv. *chrysanthemi* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *E. chrysanthemi* pv. *chrysanthemi* in the absence of human assistance is limited to relatively small distances, and symptoms of *E. chrysanthemi* pv. *chrysanthemi* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *E. chrysanthemi* pv. *chrysanthemi* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *E. chrysanthemi* pv. *chrysanthemi*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *E. chrysanthemi* pv. *chrysanthemi*, inspection of healthy bulbs for *E. chrysanthemi* pv. *chrysanthemi* would not be an effective phytosanitary measure.

E. chrysanthemi pv. *chrysanthemi* infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *E. chrysanthemi* pv. *chrysanthemi* symptoms and tested as appropriate. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *E. chrysanthemi* pv. *chrysanthemi* without also negatively affecting the condition of the onion bulbs. Bacteria would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Bactericides applied at the doses required to achieve adequate levels of efficacy are likely to exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *E. chrysanthemi* pv. *chrysanthemi* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *E. chrysanthemi* pv. *chrysanthemi*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should therefore be considered an effective phytosanitary measure for *E. chrysanthemi* pv. *chrysanthemi* on onion (*Allium cepa*) bulbs imported from China for consumption:

- **a)** Field survey just prior to harvesting to ensure *E. chrysanthemi* pv. *chrysanthemi* disease levels are very low (e.g. 0.01%)[3]; and
- **b)** Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8); and
- **c)** Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and
- **d)** Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic *E. chrysanthemi* pv. *chrysanthemi* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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3 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

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4.2. *Pantoea ananatis*

4.2.1. Hazard identification

4.2.1.1. Aetiologic agents

Pantoea ananatis (Serrano 1928) Mergaert *et al.* (1993): Enterobacteriales; Enterobacteriaceae.

Other names include *Erwinia ananas* pv. *uredovora* (Pon *et al.* 1954) Dye (1978); *Erwinia herbicola* var. *ananas* (Serrano) Dye (1969); *Pantoea ananatis* pv. *uredovora* (Pon *et al.* 1954) Mergaert *et al.* (1993).

4.2.1.2. New Zealand status

Pantoea ananatis is not recorded as present in New Zealand (PPIN 2008, NZFungi 2007).

4.2.1.3. Biology and epidemiology

Pantoea ananatis (centre rot of onion) was first reported on onion in Georgia, USA, in 1997 and then later reported in Colorado and Michigan (Goszczynska *et al.* 2006b). It is a Gram-negative, facultative anaerobic bacterium that utilises glucose in both an oxidative and a fermentative manner. The ability to produce indole, and its lack of phenylalanine deaminase and nitrate reductase is characteristic to this bacterium. The bacterium is also ice-nucleation-active (Abe *et al.* 1989). No pathovars or biovars have been described for *P. ananatis*.

Pantoea ananatis is seed-borne and seed-transmitted in onions, indicating that seed is important in disseminating the pathogen (Walcott *et al.* 2002) and should be considered a potentially important stage in the epidemiology of centre rot (Walcott *et al.* 2002; Goszczynska *et al.* 2006a-b).

Pantoea ananatis has been identified as an epiphyte from 25 asymptomatic weed species including crabgrass, sicklepod, yellow nutsedge and from crop plants such as cowpea (*Vigna unguiculata*), soybean (*Glycine max*) (Gitaitis *et al.* 2002), rice (*Oryza sativa*) (Watanabe *et al.* 1996), maize (*Zea mays*) (Paccola-Meirelles *et al.* 2001), barley (*Hordeum vulgare*), buckwheat (Coplin & Kado 2001), mulberry (*Morus alba*) (Takahashi *et al.* 1995) and poplar trees (*Populus* spp.) (Zeng *et al.* 1999).

Pantoea ananatis is commonly found in the gut microflora of brown planthoppers (*Nilaparvata lugens*) (Watanabe *et al.* 1996), mulberry pyralid (*Glyphodes pyloalis*) (Waleron *et al.* 2002, Watanabe and Sato 1999, Takahashi *et al.* 1995) from mulberry and tobacco thrips (*Frankliniella fusca*) in onion fields (Gitaitis *et al.* 2002). *Nilaparvata lugens* has been recorded in China on rice but not on onion (CPC 2007). *Frankliniella fusca* is not recorded as present in China while there is one unconfirmed report of *G. pyloalis* on mulberry in China (CPC 2007). None of these insects have been recorded in New Zealand (PPIN 2008).

Little is known about the disease caused by *P. ananatis*. On onions, disease development appears greatest at bulb formation, when moisture is high and temperatures range between 28 to 35°C (Schwartz *et al.* 2003). The bacterium is able to enter the host through flowers (Serrano 1928), wounds caused by mechanical injury, storm damage (Schwartz *et al.* 2003) and plant to plant contact during high winds (Azad *et al.* 2000, Cother *et al.* 2004). *Pantoea* *ananatis* is appears to be favoured by prolonged periods of rain, high humidity, and dew (Schwartz 2003, Schwartz *et al*. 2000).

Pantoea ananatis can be carried internally or externally on fruits; leaves; seedlings or micropropagated plants; and on above ground stems, shoots, trunks or branches. The pathogen is able to survive via bacterial cells, crop debris, and sets. It is not visible to the naked eye when carried on these plant parts (CPC 2007).

Symptoms

Symptoms of *P. ananatis* infection include the rapid death of the two centre leaves followed by soft rot of the centre of the bulb (Hausbeck 2002). The pathogen also causes leaf blight, leaf lesions, abnormal leaf fall, stem stalk rot with external discoloration or dieback, bulb decay (central rot), or seedling blight (Gitaitis & Gay 1997). Symptoms generally include white streaks with water-soaked margins running the length of the leaf. Over time the streaks may darken to a light brown or gray colour. Symptoms first appear as one or two infected leaves in the centre of the plant. As the disease develops, severely infected plants may wilt (Gitaitis *et al.* 2002).

Invasion of bulb tissues does not appear to be related to the degree of foliar disease severity. Asymptomatic, mildly diseased, and severely diseased plants are all prone to postharvest rots associated with *P. ananatis* (Gitaitis *et al.* 2002).

Asymptomatic, mildly diseased or and severely diseased plants are all prone to post harvest rots associated with *P. ananatis*. By itself, *P. ananatis* does not cause an extensive amount of damage, and it does not appear to have pectinolytic enzymes. However, infected bulbs are frequently colonised by secondary microbes that liquefy tissues and produce a foul odour. Consequently, centre rot is not only an important disease in the field, but is of great consequence as part of a postharvest disease complex (Gitaitis *et al.* 2002).

Host range

Recorded hosts of *P. ananatis* include shining gum (*Eucalyptus nitens*), tomato (*L. esculentum*), maize (*Zea mays*) (CPC 2007), apricot trees (Yan *et al.* 2007, Zai *et al.* 2000), poplar (*Populus*) (Ti *et al.* 2001a-b, Peng *et al.* 1999) and rice (Lin 2001). All of these plant species are recorded as present in New Zealand (PBI 2007).

4.2.1.4. Hazard identification conclusion

Based on the accepted absence of *P. ananatis* in New Zealand, the potential ability of this bacteria to be imported on onion bulbs from China, and the potential ability of this bacteria to cause disease symptoms on onion and a several other host plants in New Zealand, it is proposed that *P. ananatis* be considered a potential hazard requiring further assessment.

4.2.2. Risk assessment

4.2.2.1. Entry assessment

The likelihood of entry of *P. ananatis* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *P. ananatis* in China.

There are several factors that would influence the prevalence of *P. ananatis* in onions in the field and thus impact on the likelihood of entry into New Zealand. Firstly, there is opportunity for infection because *P. ananatis* is able to survive via bacterial cells, crop debris, and sets. Secondly, there is opportunity for the pathogen to enter the onion plant through wounds produced by harvesting methods (section 2.1.2), through flowers, or plant-to-plant (epiphyte) contact during high winds. Thirdly, *P. ananatis* may be vectored into onion plants through feeding activity of tobacco thrips (*Frankliniella fusca*). Fourthly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *P. ananatis*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C; however they can tolerate temperature ranges between 7-29^{o}C Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels could be conducive for *P. ananatis* infection (28 to 35°C). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *P. ananatis* in the field, the pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible, e.g., at temperatures below 20^{o}C (CPC 2007). Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., <5^{o}C). Under such conditions, it would be expected that *P. ananatis* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *P. ananatis* into New Zealand on onion bulbs from China is considered moderate and therefore is non-negligible.

4.2.2.2. Assessment of exposure

Should onion bulbs infected with *P. ananatis* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of the bacteria in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying bacteria destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *P. ananatis* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Infected soil or crop residues distributed from compost over host plants would act as a primary source of inoculum. *P. ananatis* can be carried internally or externally on crop residues or as free bacterial cells in soil (CPC 2007).

The likelihood of exposure of *P. ananatis* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

4.2.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *P. ananatis* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga).

For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *P. ananatis*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

The likelihood of *P. ananatis* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

4.2.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *P. ananatis* could spread within the private garden area via rain, heavy irrigation, or movement of infested crop debris or alternative hosts. The likelihood for *P. ananatis* to spread within these established areas, i.e., private gardens or garden waste areas is considered moderate and is therefore non-negligible.

P. ananatis should be able to spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *P. ananatis* would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered unlikely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *P. ananatis* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore non-negligible.

It is noted that *P. ananatis* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., shining gum, tomato, maize, apricot trees, or poplar. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic consequences

Specific information about the economic impact of *P. ananatis* on onion or its alternative hosts is not available. If the pathogen was to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *P. ananatis* would have economic consequences on private gardeners.

P. ananatis outbreaks in Georgia in 1997 resulted in 25 to 100% losses for onion growers, and between 1998 and 2001, it is estimated that 10% pre- and post-harvest yield losses were experienced. In some fields, the disease was devastating and accounted for 100% loss (Gitaitis & Gay 1997). Other economically import plants are also hosts of *P. ananatis* and would be expected to suffer some economic impacts e.g. species in the genera *Eucalyptus*, *Lycopersicon, Populus, Prunus*.

The likelihood is therefore high that *P. ananatis* would have moderate economic consequences in New Zealand. It is noted that both conventional and organic commercial growers of tomato, maize, apricots, or onions could be affected.

Environmental consequences

While there is no evidence of *P. ananatis* acting as a pathogen on New Zealand native flora, this pathogen has a wide host range that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species (e.g. *Eucalyptus*, *Lycopersicon, Populus, Prunus* etc). As such, the likelihood is low that *P. ananatis* could establish on a native species or significant urban species and have an unwanted environmental impact within New Zealand.

Human health consequences

There has been one case reported in which a 73-year-old diabetes mellitus type II patient developed a bacteremic infection with *P. ananatis* after colonoscopy (De Baere *et al.* 2004). There is no other evidence of *P. ananatis* causing bacteremic infection in humans. As such, the likelihood is low that *P. ananatis* would have health consequences in New Zealand.

4.2.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *P. ananatis* spread from private gardens to commercial growing areas it could cause high economic and low environmental consequences to New Zealand.

4.2.2.6. Risk estimation

The likelihood estimate is moderate that *P. ananatis* would be associated with onion bulbs on entry into New Zealand; low that *P. ananatis* would be exposed to the environment; moderate that any *P. ananatis* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *P. ananatis* would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in unwanted economic consequences; and low for environmental consequences to New Zealand.

As a result, the risk estimate for *P. ananatis* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

4.2.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *P. ananatis* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

4.2.3. Risk management

4.2.3.1. Risk evaluation

Since risk estimate for *P. ananatis* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

4.2.3.2. Option evaluation

There are conceivably a number of management options available for *P. ananatis* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *P. ananatis*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *P. ananatis*;
- **c.** Inspection of onion plants or bulbs for *P. ananatis*;
- **d.** Treatment of onion bulbs for *P. ananatis* by a suitably efficacious method;
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *P. ananatis* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *P. ananatis* in the absence of human assistance is limited to relatively small distances, and symptoms of *P. ananatis* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *P. ananatis* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *P. ananatis*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *P. ananatis*, inspection of healthy bulbs for *P. ananatis* would not be an effective phytosanitary measure.

P. ananatis infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *P. ananatis* symptoms and tested as appropriate. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *P. ananatis* without also negatively affecting the condition of the onion bulbs. Bacteria would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Bactericides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *P. ananatis* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *P. ananatis*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should therefore be considered an effective phytosanitary measure for *P. ananatis* on onion (*Allium cepa*) bulbs imported from China for consumption:

- **a)** Field survey just prior to harvesting to ensure *P. ananatis* disease levels are very low (e.g. 0.01%)[4]; and
- **b)** Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).
- **c)** Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and
- **d)** Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic *P. ananatis* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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4 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

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5. Analysis of potential hazards – Fungi (or fungi-like)

5.1. *Alternaria palandui*

5.1.1. Hazard identification

5.1.1.1. Aetiologic agents

Alternaria palandui Ayyangar 1928: Ascomycota; Pleosporaceae.

5.1.1.2. New Zealand status

Alternaria palandui has not been recorded in New Zealand (PPIN 2008, NZFungi 2007).

It is noted that Farr *et al.* (2008) lists *A. dauci* f. sp. *porri* (J.G. Kühn) J.W. Groves & Skolko 1944 as a pathogen of onion. However, extensive searches indicate that the correct name for this pathogen appears to be *Alternaria porri* (Ell.) Neerg. 1938, which is considered widely established in New Zealand (PPIN 2008, Neergaard 1945).

5.1.1.3. Biology and epidemiology

There is no information available for *A. palandui* as a pathogen of onion. Therefore, information for *A. palandui* on other plant hosts, where available, *Alternaria* spp. or *Alternaria porri* (Ellis) Cif. has been provided where it is lacking for *A. palandui*.

Biology and ecology

Many *Alternaria* species are common saprobes found in a various habitats and are ubiquitous agents of decay (Alternaria Online 2003). Mycelium is dark in colour and in older diseased tissue it produces short, simple, upright conidiophores that bear single or branched chains of conidia. The conidia are large, dark, long or pear shaped and multicellular, with both transverse and longitudinal cross walls (Agrios 2005). *Alternaria porri* enters mature onion leaves and bulbs through wounds, i.e., through insect damage (Miller & Lacy 2008).

A. porri overseasons in crop debris and in symptomless bulbs, surviving for at least 12 months when infected leaf debris was buried at a depth of 5 cm. Conidia are carried by rainsplash and possibly thrips to the leaves where they germinate by several germ tubes. The optimum temperature for conidial germination and lesion development is 25°C and a relative humidity of above 90% is required for any significant sporulation to occur (CPC 2007).

Alternaria species have no sexual spore stage. The nuclei result from mitosis and the spores are genetically identical and therefore, asexual (Thomma 2003).

Epidemiology

Disease symptoms caused by *A. palandui* in onion include small, whitish, sunken lesions on succulent leaf tissue. Lesions first appear towards the leaf tip and later at lower plant levels. Over time lesions enlarge, several of them coalescing to cover large patches of leaves and to girdle the succulent leaf. As the disease advances, the leaves are blighted and the infection spreads to the bulb, resulting in decay. The affected plants fail to flower and the damage is considerable when the fungus is carried with the bulb into storage (Rangaswami & Mahavevan 2004).

Host range

There is no information available about the host range of *A. palandui*. Inoculation experiments on a number of plants (e.g., radish (*Raphanus sativus*), *Daturu*, cotton (*Gossypium hirsutum*), cabbage (*Brassica oleracea*), and *Dianthus*) indicated that of the plants tested only onions were susceptible to infection caused by *A. palandui* (Ayyangar 1928).

5.1.1.4. Hazard identification conclusion

Based on the accepted absence of *Alternaria palandui* in New Zealand, the potential ability of this fungus to be imported on onion bulbs, and its potential ability to cause disease symptoms on onion, it is proposed that *A. palandui* be considered a potential hazard requiring further assessment.

5.1.2. Risk assessment

The information provided in the previous section relates to either *Alternaria* spp. or *A. porri* as there is little information for *A. palandui* on onion. Despite this, overall mechanisms for pathogenicity are considered similar; therefore assumptions will be made on this basis in the following risk assessment.

5.1.2.1. Entry assessment

The likelihood of entry into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *A. palandui* in China.

Several factors would influence the prevalence of *A. palandui* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because *A. palandui* over winters as mycelium in infected plant debris or as mycelium or spores in, or on, seeds. Secondly, *A. palandui* is able to enter the onion plant through wounds produced during harvesting methods (section 2.1.2) or directly penetrate susceptible tissue. Thirdly, environmental conditions conducive for onion production in China could also be conducive for infection of onions *A. palandui*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges (16-25^{o}C) and precipitation levels are conducive for *A. palandui*. In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *A. palandui* in the field, these pathogens could go undetected at the time of harvest or prior to export if conditions conducive for disease development (e.g., cool weather combined with low rainfall) are not experienced. Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g. <5^{o}C). Under such conditions, it would be expected that *A. palandui* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *A. palandui* into New Zealand on onion bulbs from China is considered moderate and therefore is non-negligible.

5.1.2.2. Assessment of exposure

Should onion bulbs infected with *A. palandui* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of this fungus in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying fungi destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *A. palandui* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Infected soil or crop residues distributed from compost over host plants would act as a primary source of inoculum. *A. porri* over seasons in crop debris and in symptomless bulbs, surviving for at least 12 months when infected leaf debris was buried at a depth of 5 cm. Conidia are carried by rain splash and possibly thrips to the leaves where they germinate by several germ tubes (CPC 2007).

The likelihood of exposure of *A. palandui* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.1.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *A. palandui* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *A. palandui*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

As conidia are released from disease plant material and spread by wind currents to other plants or nearby fields, plant material that is discarded in a diseased condition would be expect to act as sources of inoculum for other hosts nearby. The optimum temperature for conidial germination and lesion development is 25°C and a relative humidity of above 90% is required for any significant sporulation to occur (CPC 2007).

The likelihood of *A. palandui* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered low and is therefore non-negligible.

5.1.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *A. palandui* could spread within the private garden area via rain, irrigation, or movement of infested crop debris. The likelihood of *A. palandui* spread within these established areas (i.e. private gardens or garden waste areas) is considered moderate and is therefore non-negligible.

It is likely that once established *A. palandui* would spread from private gardens or garden waste areas to the wider environment, including commercial horticultural production areas. However, several factors in combination would be required for this to occur. For example, material infected with *A. palandui* would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of this pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered unlikely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood of *A. palandui* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore non-negligible.

It is noted that *A. palandui* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic consequences

Specific information about the economic impact of *A. palandui* on onion or its alternative hosts is not available. If these pathogens were to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *A. palandui* would have economic consequences on private gardeners.

Within commercial fields, affected plants fail to flower and the damage is considerable when the fungus is carried with the bulb into storage (Rangaswami & Mahavevan 2004). As such the likelihood is high that *A. palandui* would have moderate economic consequences in New Zealand. It is noted that both conventional and organic commercial growers of any alternative hosts could also be affected by *A. palandui*.

Environmental consequences

There is no evidence of *A. palandui* acting as a pathogen on New Zealand native flora, and this pathogen may have a host range restricted to onions or the *Allium* genus. As such, the likelihood is low that *A. palandui* could establish on a native species or significant urban species (aside from onions) and have an unwanted environmental impact within New Zealand.

Human health consequences

A. palandui is not known to be of any significance to human health.

5.1.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *A. palandui* spread from private gardens to commercial growing areas it could cause moderate economic and low environmental consequences to New Zealand.

5.1.2.6. Risk estimation

The likelihood estimate is moderate that *A. palandui* would be associated with onion bulbs on entry into New Zealand; low that these fungi would be exposed to the environment; moderate that any *A. palandui* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that these fungi would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in moderate unwanted economic consequences and low for environmental consequences to New Zealand.

As a result, the risk estimate for *A. palandui* associated with onion bulbs imported from China for consumption is non-negligible and should be considered a hazard.

5.1.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is a high level of uncertainty in terms of epidemiology, spread and symptoms of *A. palandui* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

5.1.3. Risk management

5.1.3.1. Risk evaluation

Since the risk estimate for *A. palandui* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.1.3.2. Option evaluation

There are conceivably a number of management options available for *A. palandui* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *A. palandui*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *A. palandui*;
- **c.** Inspection of onion plants or bulbs for *A. palandui*;
- **d.** Treatment of onion bulbs for *A. palandui* by a suitably efficacious method;
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *A. palandui* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *A. palandui* in the absence of human assistance is limited to relatively small distances, and symptoms of *A. palandui* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *A. palandui* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *A. palandui*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *A. palandui*, inspection of healthy bulbs for *A. palandui* would not be an effective phytosanitary measure.

A. palandui infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *A. palandui* symptoms and tested as appropriate. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *A. palandui* without also negatively affecting the condition of the onion bulbs. Fungi would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *A. palandui* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *A. palandui*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for *A. palandui* on onion (*Allium cepa*) bulbs imported from China for consumption:

- **a)** Field survey just prior to harvesting to ensure *A. palandui* disease levels are very low (e.g. 0.01%)[5]; and
- **b)** Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).
- **c)** Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and
- **d)** Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

5 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

While this phytosanitary measure would not necessarily prevent an asymptomatic *A. palandui* infection from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

5.1.4. References

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5.2. *Cladosporium oxysporum, Davidiella allii-cepae, Mycosphaerella olivaceum,* and *Penicillium oxalicum*

5.2.1. Hazard identification

5.2.1.1. Aetiologic agents

Cladosporium oxysporum Berk & M A Curtis 1868; Ascomycota: Davidiellaceae.

Davidiella allii-cepae (M M Jord., Maude & Burchill) Crous & U Braun 2003 (anamorph *Cladosporium allii-cepae*); Ascomycota: Davidiellaceae.

Mycosphaerella olivaceum; Ascomycota: Mycosphaerellaceae.

Penicillium oxalicum, Currie & Thom; Ascomycota: Trichocomaceae.

5.2.1.2. New Zealand status

Cladosporium oxysporum, *Davidiella allii-cepae* and *Penicillium oxalicum* have not been recorded in New Zealand (PPIN 2008, NZFungi 2008).

Mycosphaerella olivaceum is not recorded as present in New Zealand (PPIN 2008) however no records could be found to confirm the name of this organism.

Cladosporium species are anamorphic to *Mycosphaerella* and *Davidiella*. As both *Davidiella* and *Mycosphaerella* are genera in the Mycosphaerellaceae (Lindau 1897) family, in this analysis it will be assumed that an assessment of the risks associated with *Cladosporium oxysporum* and *Davidiella allii-cepae* will be appropriate to *Mycosphaerella olivaceum*.

5.2.1.3. Biology and epidemiology

As with many plant pathogenic fungi, in nature the teleomorph stage is often rarer than the anamorph stage. As such, entry of the pathogen into New Zealand and the economic and environmental consequences of the pathogen to New Zealand will likely be more pertinent for *C. allii-cepae*, the anamorph stage of *D. allii-cepae*. It is noted that although the information provided in this risk assessment was published for *C. allii-cepae*, it also pertains to *D. allii-cepae*.

Limited information is available for *C. oxysporum* or *Penicillium oxalicum* as pathogens of onion. Information for *Cladosporium* spp. or effects of *C. oxysporum* on other hosts has been provided where it is lacking for *C. oxysporum* on onion.

Biology and ecology

Cladosporium is one of the most widespread moulds. It includes approximately 40 species naturally found in the air, soil, as saprophytes and as plant pathogens. *Cladosporium* species are also commonly found on food, paint, textiles and other organic matters (El-Morsy 2000, Brown *et al.* 1998). *D. allii-cepae* causes leaf blotch of onion, which can cause infection in a wide range of cultivated and wild *Allium* species (Hill 1996).

Cladosporium species are generally non-pathogenic as many are common endophytes as well as phylloplane fungi (Stohr & Dighton 2004, Lee & Hyde 2002, Jager *et al.* 2001). *C. oxysporum* has been recorded as one of several mycoflora present on onion leaf surface in

Taiwan (Chang *et al.* 2007) and India (Sahu 1995). Some *Cladosporium* species are described as being colonisers of lesions of plant pathogenic fungi. For example, wound lesions produced through *Thrips parvispinus* on young developing papaya leaves provided the infection site for invasion by *C. oxysporum*, described as normally as a saprophytic fungus (Lim 1989).

Cladosporium species are classified as a dermatiacae group of fungi, that is, they contain melanin in the cellular wall of conidia and/or hyphae, which gives a characteristic colour to colonies, ranging from olive-grey to black (Tasic & Tasic 2007).

Most *Cladosporium* species are considered to be host-specific. For example, *Cladosporium colocasiae* is a pathogen of Araceae and taro; *Cladosporium effusum* is a pathogen of pecan; *Cladosporium macrocarpum* is a pathogen of sweet cherry and sorghum; *Cladosporium paeoniae* is a pathogen of peonies; *Cladosporium spongiosum* is a pathogen of betelnut palm and wheat; *Cladosporium tenuissimum* is a pathogen of cucumber; *Cladosporium vignae* is a pathogen of cowpea; and passionfruit and papaw are listed as major and minor hosts, respectively, of *C. oxysporum* (CPC 2007).

Laboratory studies indicate *D. allii-cepae* can enter the leaf tissue usually through stomata but occasionally it penetrated the cuticle. Invasion of the palisade and mesophyll tissues led to the formation of a leaf cavity after 7 days, and after 30 days the pathogen sporulated on the leaf surface (Hall & Kavanagh 1984). Other *in vitro* studies indicate that *D. alli-cepae* is slow growing with the maximum temperature for growth occurring between 15-20^{o}C and 28^{o}C (Hall & Kavanagh 1984). A minimum of 8 hours darkness was necessary for optimum conidiation on lesions of onion but conidiophores were produced in light and dark conditions after 2-12 hours incubation at greater than 90% relative humidity (RH) (Jordan *et al.* 1990). Sporulation was most abundant at 10-15^{o}C and enhanced by exposure to near UV light. Spores germination was greatest at 15-20^{o}C and in air at 100% RH at 20^{o}C degrees. Greatest growth occurred at pH 6.5 (Jordan *et al.* 1990, Hall & Kavanagh 1984) with maximum sporulation occurring between 5 and 8.5 (Hill 1996). Free water reduces the percentage conidial germination. Young, healthy leaves are more resistant to infection than older leaves, leaf tips and wounds (Hill 1996).

Field studies of *D. allii-cepae* on onions showed that pseudothecia developed on sterile lesions from early autumn until spring, when conidiophores developed from within some of the pseudothecia and produced conidia. The disease appeared to be confined to visible lesions and no evidence was found of latent infection. Only a low incidence of disease occurred when an onion crop was planted in fields which had borne an infected onion crop, suggesting that there was no evidence that soil-borne inoculum was the source of the outbreak (Maude & Presly 1982).

P. oxalicum, like all species of *Penicillium*, produces conidia that spread by wind and infest soil between crops. Increasing soil inoculum density increased the number of *P. oxalicum* conidia resulting in increasing severity of damping-off and seedling blight.

Epidemiology

Cladosporium spp. over winter as mycelium or conidia in debris or twig lesions. Following periods of high humidity, conidia are dispersed by water or air currents (Agrios 2005).

Optimum temperature for growth of *C. oxysporum* is between 19 and 24°C (Manicom *et al.* 2002) but has been observed at 4°C. In pepper (*Capsicum annuum*), disease is widespread in humid conditions (77-98%) and temperatures ranging between 24-29°C while lesions are restricted under dry, hot weather (Hammouda 1992).

Conidia and pseudothecial stromata of *D. allii-cepae* may survive in the soil for 35 and 56 days, respectively. However, there is no evidence of over wintering in soil or infected debris. Infected debris is important in local transmission between successive and adjacent crops, especially between over-wintered and spring-grown onions (Hill 1996).

Penicillium spp. have a very broad host range and, as causal agents of storage rot or mould, may be found on the seeds or fruit of virtually all plants (CPC 2007). *Penicillium oxalicum* is seed-transmitted in sweetcorn, causing disease and mortality in sweetcorn seedlings which necessitates treatment of the seeds with a strong mixture of fungicides (CPC 2007). Infected seedlings are yellow and show retarded growth. Ears show a blue-green powdery growth on and between kernels which also forms on the cob surface, usually near the tip. Seeds may be bleached and streaked. In storage, the fungus fruits below the pericarp in the germ, producing the condition known as blue eye (CPC 2007).

As soil temperature increased from 9 to 25°C, seedling emergence from seed inoculated with *P. oxalicum* was progressively reduced, with a decrease of nearly 50% at 25°C. It is concluded that *P. oxalicum* has the greatest potential to reduce seedling stand when infected sweetcorn seeds are sown in warm, dry soil. *P. oxalicum* lost its viability in seeds after storage at room temperature (20-25°C) for 1 year (CPC 2007).

Non-pathogenic strains of *P. oxalicum* can be used as a biocontrol agent against *Fusarium* wilt of tomato (*Lycopersicon esculentum*) (Larena *et al.* 2002).

Spread

The concentration of *Cladosporium* conidia in the air is affected by climatic factors such as temperature, rainfall, relative humidity (RH) and wind. Highest concentrations of airborne *Cladosporium* spores have been recorded during summer while lower levels have been recorded in winter (Sakiyan & Inceoglu 2002, Peternel *et al.* 2004). Highest concentration of spores have been observed when mean temperatures were above 24°C, RH was above 50%, precipitation was 17.1 mm and wind speed was 2.4 m/s (Sakiyan & Inceoglu 2002). Spores and colonies of *Cladosporium* are known to be very resistant to changes in the amount of water available, as they have been observed to resume growth after extended periods of drying (http://pollen.utulsa.edu/Spores/Cladosporium.html).

Laboratory and field experiments showed that maximum sporulation of *D. allii-cepae* on onion leaf lesions occurred in the late autumn with a secondary peak in the early spring. Conidia were intermittently detected in the air over diseased onion crops. The pattern of spore release showed maximum and minimum concentrations of conidia recorded during late-morning early afternoon (10:00-14:00 h) and during the night, respectively. There was a significant correlation between concentration of conidia trapped and increasing light intensity and to a lesser extent with temperature. Mechanical disturbance of the crops by rain, wind and human activity resulted in isolated increases in spore concentration (Jordan *et al.* 1990).

Symptoms

In pepper, *C. oxysporum* causes a leaf spot with irregular brown lesions between 1-4 mm in diameter (Hammouda 1992). In glasshouse-grown tomato, *C. oxysporum* caused dark brown, angular lesions on lower, older leaves of 4-month-old plants. Chlorosis frequently developed around the lesions. The irregularly shaped sessions varied in size from 1to 5 mm, frequently with tan-coloured centres. Conidia developed in the centre of the lesions, primarily on the outer or adaxial side of the leaf, but were infrequent on the abaxial surface (Lamboy & Dillard 1996).

D. allii-cepae produces leaf spots are elliptical in shape, with the long axis being parallel to the leaf veins. Lesions, which measure approximately 2.5 x 1.5 cm, are initially yellow and then turn brown to blackish-brown due to the production of conidiophores and conidia (Kirk 1998). Symptoms on onion leaves can also appear as depressed spots with a greenish powder developing in the centre. *In vitro* studies showed that sporulation occurred by inoculation of leaf tissues at 13-17^{o}C in a moist chamber (Hill 1996, Boff 1994). The disease can occur at any stage but normally is found after bulb formation and more commonly after leaves start to senesce (Hill 1996).

Host range

Passionfruit (*Passiflora edulis*) has been listed as a major host and papaw (*Carica papaya*) is a minor host of *C. oxysporum* (CPC 2007). *C. oxysporum* has also been reported on greenhouse tomato (*Lycopersicon esculentum*) (Lamboy & Dillard 1996) and pepper (Hammouda 1992). *D. allii-cepae* is a pathogen of various *Allium* spp., including onions, leek and chives (Kirk 1998).

P. oxalicum has been recorded as causing Penicillium stem rot on cucumber (*Cucumis sativus*) (Jarvis & Ferguson 1992), storage rot in yam (*Discorea rotundata*) (Yusuf & Okusanya 2008), blue ear in maize (*Zea mays*) (CPC 2007), and blue mould on tomato (*Lycopersicon esculentum*) (Kwon *et al.* 2008).

5.2.1.4. Hazard identification conclusion

Based on the accepted absence of *Cladosporium oxysporum*, *Davidiella allii-cepae* and *Penicillium oxalicum* from New Zealand, the potential ability of these fungi to be imported on onion bulbs, and their potential ability to be associated with onion and a pathogen of other host plants in New Zealand, it is proposed that *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* be considered potential hazards requiring further assessment.

As *Mycosphaerella olivaceum* could not be confirmed as a valid name it will be assumed that it is a synonym or invalid name of another fungus in that family (e.g. *Davidiella allii-cepae*) and will not be considered further.

5.2.2. Risk assessment

Much of the information provided in the previous section relates to *Cladosporium* spp. generally, or in some cases to specific *Cladosporium* species and *D. allii-cepae*, because there is limited information specific to *C. oxysporum* or *P. oxalicum* on onion. Although there will be some biological differences between *Cladosporium* species, overall mechanisms for pathogenicity are considered similar therefore assumptions will be made on this basis in the following risk assessment.

5.2.2.1. Entry assessment

Entry of *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* into New Zealand may occur through infected onion bulbs imported from China. The likelihood of entry into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* in China.

Several factors would influence the prevalence of these pathogens in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because conidia are the most abundant airborne spore types (Marshall 1997) and are frequently isolated from soil and other organic materials. Conidia and pseudothecial stromata of *D. allii-cepae* may survive in the soil for 35 and 56 days; however, it is acknowledged that there is no evidence of over wintering in soil or infected debris. Secondly, there is opportunity for the fungus to enter the onion plant through wounds caused by insects (Lim *et al.* 1989) or those produced during harvesting (section 2.1.2). Thirdly, environmental conditions conducive for onion production (optimum temperatures range between 13-24^{o}C but can occur between 7-29^{o}C) in China are also conducive for infection caused by *Cladosporium* spp. (24-29^{o}C), *C. allii-cepae* (15-20^{o}C) or *P. oxalicum* (10-30^{o}C).

Although onions may be infected with these pathogens in the field, they could go undetected at the time of harvest or prior to export if conditions conducive for disease development are experienced (e.g., warm temperatures, rainfall and high RH). Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., <5^{o}C). Under such conditions, it would be expected that *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

5.2.2.2. Assessment of exposure

Should onion bulbs infected with *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of these fungi in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying fungi destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

An alternative pathway is through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets. This pathway is likely to generate considerable waste from which spores could disperse to surrounding host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (Martin pers. com. 2008).

Infected soil or crop residues distributed from compost over host plants would act as a primary source of inoculum. *Cladosporium* spp. over winter as mycelium or conidia in debris or twig lesions. Following periods of high humidity, conidia are dispersed by water or air currents (Agrios 2005). Conidia and pseudothecial stromata of *D. allii-cepae* may survive in the soil for 35 and 56 days, respectively. Infected debris is important in local transmission between successive and adjacent crops, especially between over-wintered and spring-grown onions (Hill 1996). *P. oxalicum*, like all species of *Penicillium*, produces conidia that spread by wind and infest soil between crops.

The likelihood of exposure of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.2.2.3. Assessment of establishment

Environmental conditions most suitable for these pathogens would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for the growing of onions and other host plants, are also conducive for disease development by *C. oxysporum*, *D. allii-cepae* or *P. oxalicum*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

Optimum temperature for growth of *C. oxysporum* is between 19 and 24^{o}C (Manicom *et al.* 2002) but has been observed at 4^{o}C. In pepper (*Capsicum annuum*), disease is widespread in humid conditions (77-98%) and temperatures ranging between 24-29^{o}C while lesions are restricted under dry, hot weather (Hammouda 1992).

The likelihood of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

5.2.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* could spread within the private garden area via rain, irrigation, wind currents, or movement of infested crop debris or alternative hosts. The likelihood of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* spread within these established areas, i.e. private gardens or garden waste areas is considered moderate and is therefore non-negligible.

In contrast significant economic consequences could result if *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* was to spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *Cladosporium*-infected plants would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels and/or wind speeds sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. In addition, infected material would need to be moved during a timeframe in which conidia or pseudothecial stromata were still viable, e.g., 35 to 56 days. It is considered unlikely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *C. oxysporum* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore non-negligible.

It is noted that *Cladosporium* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., passionfruit or papaw for *C. oxysporum*; leeks or chives for *D. allii-cepae*; or cucumber, yam, maize or tomato for *P. oxalicum*. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic consequences

Specific information about the economic impact of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* on onion or its alternative hosts is not available. If these pathogens were to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *C. oxysporum* or *D. allii-cepae* would have economic consequences on private gardeners.

In contrast, more significant economic consequences could result if *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* was to spread from private gardens to commercial production areas. *C. oxysporum* is between 19 and 24°C (Manicom *et al.* 2002) but has been observed at 4°C. In pepper (*Capsicum annuum*), disease is widespread in humid conditions (77-98%) and temperatures ranging between 24-29°C. *D. allii-cepae* produces lesions on onion leaves and varies in incidence. *P. oxalicum* causes damping-off and seedling blight in host plants including maize and sweet corn.

As such, the likelihood is high that *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* would have moderate economic consequences in New Zealand. It is noted that both conventional and organic commercial growers of other *Allium* species could also be affected.

Environmental consequences

While there is no evidence of these fungi acting as pathogens on New Zealand native flora, these pathogens has host ranges that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species (e.g. *Cucumis*, *Lycopersicon*, *Discorea*, *Zea* etc). As such, the likelihood is low that *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* could establish on a native species or significant urban species and have an unwanted environmental impact within New Zealand.

Human health consequences

Cladosporium spores are important aeroallergens, and prolonged exposure to elevated spore concentrations can cause chronic allergies and asthma (Zheng *et al.*, 2006). A 66-year-old woman with Cushing syndrome and a one-year history of papulo-nodular lesions was diagnosed with subcutaneous phaeohyphomycosis (a group of mycotic infections) due to *C. oxysporum*, which was successfully treated with antifungal medications (Romano *et al.*, 1999). Mycotic keratitis (corneal fungal infections) have been linked to several soil inhabiting fungi, including *C. oxysporum* (Chang *et al.*, 2007; Matsumoto and Ajelio, 1991) and *P. oxalicum* (Rodríguez de Kopp & Vidal 1998).

Although a proportion of the population could be allergic to *C. oxysporum or P. oxalicum* spores, it is predicted that the fungus would not contribute significant levels of inoculum above background levels of *Cladosporium* or *Penicillium* spores are already prevalent in the atmosphere and to which the general population is routinely exposed. Therefore, the likelihood is low that *C. oxysporum* or *P. oxalicum* could have a health impact within New Zealand.

D. allii-cepae is not known to be of any significance to human health.

5.2.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* spread from private gardens to commercial growing areas it could cause moderate economic and low environmental consequences to New Zealand. *C. oxysporum* or *P. oxalicum* under the same conditions could cause low human health consequences in New Zealand.

5.2.2.6. Risk estimation

The likelihood estimate is moderate that *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* would be associated with onion bulbs on entry into New Zealand; low that *C. oxysporum* or *D. allii-cepae* would be exposed to the environment; moderate that any of these fungi that are exposed to the environment would successfully establish in private gardens in New Zealand; low that these fungi would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in unwanted economic consequences; and low for environmental consequences to New Zealand.

As a result, the risk estimate for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

5.2.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is a high level of uncertainty in terms of epidemiology, spread and symptoms of *C. oxysporum* on onion (i.e., much of the information is based on *Cladosporium* species). As such, the risk assessment should be reviewed once further relevant information becomes available.

5.2.3. Risk Management

5.2.3.1. Risk evaluation

Since the risk estimate for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* associated with imported onion bulbs is non-negligible, options for phytosanitary measures are provided for consideration.

5.2.3.2. Option evaluation

There are conceivably a number of management options available for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* on onion bulbs imported from China for consumption. The following risk management options are assessed:

a. Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*;

b. Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*;

c. Inspection of onion plants or bulbs for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*;

d. Treatment of onion bulbs for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* by a suitably efficacious method;

e. Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* in the absence of human assistance is limited to relatively small distances, and symptoms of *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*, inspection of healthy bulbs for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* would not be an effective phytosanitary measure.

C. oxysporum, *D. allii-cepae* and *P. oxalicum* infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* symptoms and tested as appropriate. This inspection could be used in with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* without also negatively affecting the condition of the onion bulbs. Fungi would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* on onion (*Allium cepa*) bulbs imported fromChina for consumption:

- **a)** Field survey just prior to harvesting to ensure *C. oxysporum*, *D. allii-cepae* and *P. oxalicum* disease levels are very low (e.g. 0.01%)[6]; and
- **b)** Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).
- **c)** Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and
- **d)** Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic infection of *C. oxysporum*, *D. allii-cepae* or *P. oxalicum* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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6 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

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5.3. *Diaporthe phaseolorum* var. *sojae, Phomopsis longicolla, Stemphylium allii-cepae*

5.3.1. Hazard identification

5.3.1.1. Aetiologic agent

Diaporthe phaseolorum var. *sojae* (Lehman) Wehm; Ascomycota: Diaporthaceae

Phomopsis longicolla Hobbs 1985; Ascomycota: Diaporthaceae

Stemphylium allii-cepae Zhang & Zhang 2003; Ascomycota: Pleosporaceae.

5.3.1.2. New Zealand status

D. phaseolorum var. sojae, *P. longicolla* and *S. allii-cepae* have not recorded as being present in New Zealand (NZFungi 2008, PPIN 2008).

5.3.1.3. Biology and epidemiology

Very little information specific to *D. phaseolorum* var. sojae or *P. longicolla* on onion is available. Most of the information available pertains to soybean; therefore, this has been included in this section of the risk assessment.

P. longicolla (Phomopsis seed decay), which is worldwide in distribution, is the primary pathogen causing seed decay of soybean. *P. longicolla* is one of three fungal pathogens within the Diaporthe/Phomopsis complex attacking soybean. *D. phaseolorum* var. *sojae* causes pod and stem blight and *D. phaseolorum* var. *caulivora* and *D. phaseolorum* var. *meridionalis* cause stem canker (Sinclair 1993, Dorrance *et al.* 2009).

P. longicolla is seedborne and can therefore, cause seedling disease. The significance of seed as a source of inoculum for disease outbreaks is not known; however, infected seeds can introduce the pathogen into non-infested areas and so are important in the long-range dissemination of the pathogen (Sinclair 1999). *P. longicolla* can also colonise debris on other crops and weeds in the field, including onion, garlic, green bean, pepper and tomato (Sinclair 1999).

Stemphylium species are dematiaceous filamentous fungi that are widely distributed on decaying vegetation and in the soil. The teleomorph of *Stemphylium* is *Pleospora*. *Stemphylium* species have been described as diurnal sporulators, that is, they require an alternating light and dark cycle for spore development (Boss & Day 2000). Diseases caused by *Stemphylium* spp. predominantly occur under warm, moist conditions (Fritz *et al.* 2005, Suheri & Price 2000, Clarke 1999, RPD No. 113 1991, McRitchie 1984). In asparagus, *S. vesicarium* spores are spread by wind and water to newly developing plants (Fritz *et al.* 2005). There is no information available on the extent of disease resulting from *S. allii-cepae* infection on onion or any other host species.

Epidemiology

Prolonged periods of warm, wet weather during flowering and pod fill favour the development of pod and stem blight (Sweets *et al.* 2008, Christensen 2003, RPD No. 504 1996).

Infested crop debris and soil are the major sources of primary inoculum for *P. longicolla* (Sinclair 1999, Sweets *et al.* 2008). As plants reach maturity, conidia formed in pycnidia and ascospores formed in perithecia serve as primary inoculum and are rain splashed to susceptible tissue, i.e. pods, stems and leaves. These spores account for short distance spread of the pathogen. Infection may occur at any time but the fungus remains dormant and symptoms do not become evident until the host begins to senesce. Pycnidia may be limited to small patches near the nodes or may cover dead stems and pods. On stems, pycnidia are usually arranged in linear rows while they are randomly scattered on pods. The fungi, including *P. longicolla*, may grow through the pod walls and infect the seed causing Phomopsis seed decay (Sweets *et al.* 2008).

Seeds are a minor inoculum source compared to crop residues in areas where the disease is already established (CPC 2007). Soybean pods can become infected at any time after they are formed, but significant seed infections do not occur before physiological maturity (Sinclair 1999). Pods are the primary pathway for infection of the seed (McGee 1986). Because infections of green stem tissues remain localized, systemic infection of seeds from stems seems unlikely (Hill *et al.* 1981, Wu & Lee 1985).

Spread

Conidia and ascospores are rain splashed to susceptible tissue and account for short distance spread of the pathogen (Sweets *et al.* 2008). Pods are the primary pathway for infection of the seed (McGee 1986). Bulbs, tubers, corms and rhizomes are not known to carry *P. longicolla* in trade or transport (CPC 2007).

Symptoms

Severely infected soybean seeds are shrivelled, elongated, cracked and appear white and chalky. Affected seeds usually do not germinate or are slow to germinate. Seeds may be infected without showing symptoms (CPC 2007). *P. longicolla* initially colonizes seed coats followed by the cotyledons and plumules. Mycelium invades the ovule and developing seeds and once within the seed, the fungi colonize all tissues of the seed coat and cotyledons and eventually the radicle and plumule (Hartman 2008).

Seed infection may cause pre- and post-emergence dampening-off, and under severe conditions, stands can be reduced enough to lower yield (Sinclair 1999). Seedlings infected with *P. longicolla* become blighted and die. For those seedlings that survive, cotyledon’s have colourless or bright red to orange lesions, ranging in size from pinpoints to lesions that cover the whole cotyledon. Small reddish brown streaks, 1.5 cm long, form on hypocotyls.

Senescent tissues of stems and petioles are covered with minute, black conidiomata, which are usually arranged linearly on stems. Affected leaves have abnormal colours while stems may have external discoloration and dieback. Conidiomata are scattered on dry, poorly developed pods and may also occur on mature pods. Whole plants will show signs of seedling blight (RPD No. 509 1997, CPC 2007).

Host range

The major host of *D. phaseolorum* var. sojae and *P. longicolla* is recorded as soybean (*Glycine max*) and minor hosts are recorded as okra (*Abelmoschus esculentus*), onion (*A. cepa*), garlic (*Allium sativum*), groundnut (*Arachis hypogaea*), chilli (*Capsicum frutescens*), lupins (*Lupinus*), tomato (*L. esculentum*), runner bean (*Phaseolus coccineus*), common bean (*Phaseolus vulgaris*), pea (*P. sativum*), purple clover (*Trifolium pratense*), and cowpea (*Vigna unguiculata*) (CPC 2007).

5.3.1.4. Hazard identification conclusion

Based on the accepted absence of *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* in New Zealand, the potential ability of these fungi to be imported on onion bulbs, and the potential ability of these fungi to cause disease symptoms on onion and a wide range of host plants in New Zealand, it is proposed that *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* be considered potential hazards requiring further assessment.

5.3.2. Risk assessment

5.3.2.1. Entry assessment

The likelihood of entry of *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* in China.

Several factors would influence the prevalence of *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because *D. phaseolorum* var. *sojae*, *P. longicolla* and (presumably) *S. allii-cepae* can over winter on plant/crop debris or on alternative hosts. Secondly, there is opportunity for the pathogen to infect susceptible tissue. Thirdly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *D. phaseolorum* var. *sojae*, *P. longicolla* and (presumably) *S. allii-cepae*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels are conducive for *P. longicolla* infection (warm, wet conditions). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* in the field, these pathogens could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible. Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., $<5^{o}$C). Under such conditions, it would be expected that *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

5.3.2.2. Assessment of exposure

Should onion bulbs infected with *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of these fungi in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying fungi destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Infested crop debris and soil are the major sources of primary inoculum for *P. longicolla* (Sinclair 1999, Sweets *et al.* 2008). As plants reach maturity, conidia formed in pycnidia and ascospores formed in perithecia serve as primary inoculum and are rain splashed to susceptible tissue, i.e. pods, stems and leaves. These spores account for short distance spread of the pathogen (Sweets *et al.* 2008). The epidemiology of *S. allii-cepae* on onions is unknown however this fungus can become widely distributed in decaying vegetation and the soil. As such the likelihood of exposure of *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.3.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *D. phaseolorum* var. *sojae*, *P. longicolla* and *S. allii-cepae*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

The likelihood of *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

5.3.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* could spread within the private garden area via rain, heavy irrigation, or movement of infested crop debris. The likelihood of *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* spreading within these established areas, i.e., private gardens or garden waste areas is considered moderate and is therefore non-negligible.

D. phaseolorum var. *sojae*, *P. longicolla* or *S. allii-cepae* may spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *S. allii-cepae* would need to be in close proximity to a commercial growing area. As spores are spread by wind and water to newly developing plants, spread during the planting season is more likely than during harvest periods. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. As such, the likelihood for *S. allii-cepae* spreading from private gardens or garden waste areas to commercial production areas is considered moderate and is therefore non-negligible.

Longer distance spread of *D. phaseolorum* var. sojae and *P. longicolla* is through infected seed. Due to the relatively restricted host range of these fungi the likelihood for *D. phaseolorum* var. sojae or *P. longicolla* spreading from private gardens or garden waste areas to commercial production areas is considered negligible.

Economic consequences

Specific information about the economic impact of *S. allii-cepae* on onion or their alternative hosts is not available. If these pathogens were to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *S. allii-cepae* would have economic consequences on private gardeners.

In contrast, more significant economic consequences could result if *S. allii-cepae* was to spread from private gardens to commercial production areas. Diseases caused by *Stemphylium* spp. predominantly occur under warm, moist conditions. There is no information available on the extent of disease resulting from *S. allii-cepae* infection on onion or any other host species. Therefore, the likelihood is low that *S. allii-cepae* would have low economic consequences on the New Zealand onion industry because of the low profit margins and the pathogen's potential adverse effects on host tissue (see Section 5.3.1.3). It is noted that both conventional and organic commercial growers of capsicums could also be affected.

Environmental consequences

There is no evidence of *S. allii-cepae* acting as a pathogen on New Zealand native flora, and this pathogen may have a narrow host range restricted to species in the *Allium* genus. As such, the likelihood is very low that *S. allii-cepae* could establish on a native species or significant urban species (other than Alliums) and have an unwanted environmental impact within New Zealand.

Human health consequences

S. allii-cepae is not known to be of any significance to human health.

5.3.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *S. allii-cepae* spread from private gardens to commercial growing areas it could cause moderate economic consequences to New Zealand.

5.3.2.6. Risk estimation

The likelihood estimate is moderate that *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* would be associated with onion bulbs on entry into New Zealand; low that these fungi would be exposed to the environment; moderate that any *D. phaseolorum* var. *sojae*, *P. longicolla* or *S. allii-cepae* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *S. allii-cepae* and negligible the *D. phaseolorum* var. *sojae* or *P. longicolla* would spread from private garden areas to commercial onion production areas; and low that *S. allii-cepae* spread to commercial production areas would result in low unwanted economic consequences.

As a result, the risk estimate for *S. allii-cepae* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard. The risk estimate for *D. phaseolorum* var. *sojae* or *P. longicolla* associated with imported onion bulbs for consumption is negligible and they should not be considered a hazard.

5.3.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *P. longicolla* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

5.3.3. Risk management

5.3.3.1. Risk evaluation

Since the risk estimate for *S. allii-cepae* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.3.3.2. Option evaluation

There are a number of biosecurity risk management options available for *S. allii-cepae* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *S. allii-cepae*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *S. allii-cepae*;
- **c.** Inspection of onion plants or bulbs for *S. allii-cepae*;
- **d.** Treatment of onion bulbs for *S. allii-cepae* by a suitably efficacious method;
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Normally PFA status is based on verification from specific surveys such as an official delimiting or detection survey. Visual examination may reveal infected plants in the field, but the absence of symptoms does not exclude latent infection. It therefore, should be considered that a reliable PFA determination may not be feasible. Should an appropriate detection and identification method be identified, a PFA declaration could be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *S. allii-cepae* in the absence of human assistance is limited to relatively small distances, and symptoms of *S. allii-cepae* infestation are readily apparent over a season, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *S. allii-cepae* in New Zealand are relatively restricted (a low likelihood of exposure), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *S. allii-cepae*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *S. allii-cepae*, inspection of healthy bulbs for *S. allii-cepae* would not be an effective phytosanitary measure.

S. allii-cepae infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *S. allii-cepae* symptoms and tested as appropriate. This inspection could be used in with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *S. allii-cepae* without also negatively affecting the condition of the onion bulbs. Fungi would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *S. allii-cepae* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *S. allii-cepae*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for *S. allii-cepae* on onion (*Allium cepa*) bulbs imported fromChina for consumption:

- **a)** Field survey just prior to harvesting to ensure *S. allii-cepae* disease levels are very low (e.g. 0.01%)[7]; and
- **b)** Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).
- **c)** Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and

7 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

d) Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic infection of *S. allii-cepae* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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5.4. *Gliocladium catenulatum*

5.4.1. Hazard identification

5.4.1.1. Aetiologic agents

Gliocladium catenulatum Gilman & E.V. Abbott 1927; Ascomycota: Hypocreaceae.

5.4.1.2. New Zealand status

Gliocladium catenulatum is not recorded in New Zealand (NZFungi 2008, PPIN 2008)

5.4.1.3. Biology and epidemiology

Gliocladium catenulatum was one of eight main pathogens in pea root rot complex (Wu *et al.* 1992) but has not been identified as a pathogen of onion. However, there is no information specific to *G. catenulatum* on onion. The majority of information is based on the biopesticide product Prestop (Primastop), which contains *G. catenulatum* (strain J1446), and is recommended for control of soilborne pathogens that cause seed, root, and stem rot, and wilt disease in ornamental, tree (Rose & Punja 2003, McSpadden & Fravel 2002) and vegetable crops (Canada Health 2008). The information provided for this risk assessment, therefore, is based on *G. catenulatum* as a biological control agent of soilborne pathogens.

Biology and ecology

Gliocladium catenulatum is a fungus that grows on dead organic matter and is commonly found in soil worldwide. This fungus is not generally considered a disease-causing agent (Canada Health 2008). *Gliocladium catenulatum* has shown potential for biological control of *Alternaria alternata* (ref); *Botrytis aclada* on onion (Köhl *et al.* 1997); *Botrytis allii* on onion leaves (Köhl *et al.* 1995); *Botrytis cinerea* on alfalfa (Li 1999) and strawberry (Lahdenperä 2006), Fusarium root and stem rot in cucumber (Rose *et al.* 2003), bean and tomato plants (Elead *et al.* 1994), *Pythium ultimum* (Mcquilken *et al.* 2001) and Rhizoctonia solani (Lahdenperä 2000); *Sclerotinia sclerotiorum* (Zhen *et al.* 2004), *Sclerotium cepivorum* in onion (Tsigbey *et al.* 1999); and Witches' Broom Disease of Cacao (*Theobroma cacao* L.) (Rubini *et al.* 2004).

The mode of action for *G. catenulatum* is through hyperparasitism, enzyme activity and rhizosphere competence (Lahdenperä 2000). There is evidence of killing the host by direct hyphal contact without penetration, which can be considered as indirect mycoparasitism. However, there are studies that show the penetration of the hyphal tips of *G. catenulatum* into *Rhizoctonia solani* without any coiling or appressorium formation. More often, *G. catenulatum* hyphae loosely coil around the host hyphae. Certain enzyme activity (e.g. chitinase and glucanase) may also be involved as destruction of the cells of pathogens has been observed. In organic substrates, root colonisation appears to be a particularly important mod of action of *G. catenulatum*. As the first coloniser, *G. catenulatum* inhibits the penetration of the pathogen into the host cells (Lahdenperä 2000).

Epidemiology

As a biological control agent, *G. catenulatum* has been shown to be highly efficient under continuously wet conditions but have low to moderate efficiency when leaf wetness periods had been interrupted 16 h after application of the antagonists (Köhl *et al.* 1995).

In the environment, *G. catenulatum* strain J1446 spreads through mycelial growth, chlamydospore production and release of conidia. Its mobility in soil is limited to rainwater runoff, soil movements due to human or animal activity. On foliar surfaces, *G. catenulatum* strain J1446 mobility increases through the dispersion of plant detritus by wind and animal activity (Canada Health 2008).

Hosts

Gliocladium catenulatum has been isolated from diseased or dead plants as a potential causal agent of infection in coffee, pea and some ornamental trees. However, it is likely that *G. catenulatum* appeared on the diseased plant material as a secondary (saprophytic) organism. Efficacy studies conducted on *G. catenulatum* strain J1446 as a biological control agent indicated that no phytotoxic or phytopathogenic effects were observed (Canada Health 2008).

5.4.1.4. Hazard identification conclusion

Although *G. catenulatum* has been isolated from onions, it is considered a mycoparasite of either soilborne or foliar plant pathogens. Health Canada's Pest Management Regulatory Agency conducted a detailed risk analysis for *G. catenulatum* strain J1446 in order to apply for full registration (for sale and use) for suppression of a number of fungal diseases of vegetables, herbs and ornamentals.

Gliocladium virens GL-21 (SoilGard™) is targeted as a biological control agent for controlling damping-off diseases caused by *Rhizoctonia solani* and *Pythium ultimum* in vegetable and ornamental greenhouses (Eyal *et al.* 1997). *Gliocladium roseum* has shown potential for biological control of *Botrytis cinerea* in cyclamen and of *Botrytis squamosa* (James & Sutton 1996) and *Botrytis aclada* in onion (Köhl *et al.* 1997).

There is no evidence to suggest that *G. catenulatum*, or any pathovars, are pathogenic to onion. In addition, evidence provided in a risk analysis for registration of *G. catenulatum* strain J1446 as a biological control agent indicated that there were no environmental or human health and safety risks associated with this organism. As such, a risk assessment for *G. catenulatum* is not warranted and the organism should not be considered a hazard to New Zealand from onion bulbs imported from China.

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5.5. *Glomerella cingulata*

5.5.1. Hazard identification

5.5.1.1. Aetiologic agent

Glomerella cingulata (Stoneman) Spauld. & H. Schrenk; Ascomycota: Glomerellaceae.

Other names include anamorph *Colletotrichum gloeosporioides*.

5.5.1.2. New Zealand status

Glomerella cingulata (anamorph *Colletotrichum gloeosporioides*) is widespread in New Zealand (PPIN 2008, NZFungi 2007) however; there are strains that are not recorded here.

In all the criteria that have been used for differentiating taxa in *Colletotrichum*, it is clear that *C. gloeosporioides* shows excessively wide variation. Although often referred to under the teleomorph name, many isolates of *C. gloeosporioides* do not produce the *Glomerella* state, and both homothallic and heterothallic strains exist (CPC 2007).

As *Colletotrichum gloeosporioides* has been recorded on onions (*Allium cepa*) in New Zealand (PPIN 2008), this analysis will assume that strains associated with onion are present in New Zealand.

5.5.1.3. Hazard identification conclusion

Based on the assumed presence of onion-associated *C. gloeosporioides* strains in New Zealand, it is proposed that *C. gloeosporioides* is not considered a potential hazard and as such does not require further assessment.

5.5.1.4. Assessment of uncertainty

There is some uncertainty in terms of epidemiology, spread and symptoms of specific strains of *C. gloeosporioides* on onion because of the limited information specific to this commodity. As such, the risk assessment should be reviewed once further relevant information becomes available.

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5.6. *Olpitrichum tenellum*

5.6.1. Hazard identification

5.6.1.1. Aetiologic agent

Olpitrichum tenellum (Berk. & M.A. Curtis) Hol.-Jech. 1975; Anamorphic Ascomycetes.

Other names include the synonym *Oidium tenellum*.

5.6.1.2. New Zealand status

Olpitrichum tenellum is not recorded as present in New Zealand (PPIN 2008).

5.6.1.3. Biology and epidemiology

There is no information available for the epidemiology of *O. tenellum* (or the synonym *Oidium tenellum*) on onion. *Oidium* spp. are described as powdery mildews and as such, the information presented for this risk assessment will be for *Olpitrichum* (*Oidium*) species where available or for powdery mildews in general.

Biology and ecology

Olpitrichum is a widespread mitosporic fungi commonly found in temperate areas on various plants. It is generally obligate to grain weathering, and has been known to be the cause of head rots. *Olpitrichum tenellum* has been identified as one of the causal agents of black rot of maize (*Zea mays*) in Yunnan Province, China (Chen *et al.* 2004) and grain mould (*Sorghum bicolor*) (Bandyopadhyay *et al.* 2008). *Olpitrichum tenellum* has also been described as a weak parasite and has often been associated with cotton-ball decay (EMLab P&K 2008).

As obligate parasites, powdery mildews produce mycelium that grow on the surface of plant tissues but does not invade the tissues themselves. Haustoria gain access to nutrients through plant epidermal cells. Mycelium produces short conidiophores on the plant surface, each of which produces chains of rectangular, ovoid or round conidia that are dispersed via air currents (Agrios 2005). Under unfavourable environmental or nutritional conditions, the fungus produces ascospores within a cleistothecium (Agrios 2005).

Olpitrichum tenellum is a biotrophic mycoparasite of *Alternaria alternata* (Zhang *et al.* 2003), *Fusarium moniliforme* and *Cladosporium* spp. (Li & Shen 1996). It contacts but does not penetrate its host hyphae by means of hook-shaped contact cells, which are believed to absorb nutrients and growth factors from living host cells (Li & Shen 1996).

Epidemiology

There is no information available for the epidemiology of *O. tenellum* on onion. *Oidium* species over winter as mycelium or conidia (Sen *et al.* 1999) in dormant buds, in the fork of branches, and twigs (Chauhan *et al.* 1999, Agrios 2005). Powdery mildew of onion, caused by *Leveillula taurica*, over winters as mycelium in crop debris on the leaf surface (Evans *et al.* 2008).

Powdery mildews are severe in warm, dry climates because the pathogen does not require free water on the leaf surface for infection to occur; however, relative humidity (RH) does need to be high for spore germination (Agrios 2005). Incidence of infection increases as relative humidity rises (Jacob *et al.* 2008, Sinha 2005, Agrios 2005) but it does not occur when leaf surfaces are wet (e.g. in the rainy season) (Agrios 2005). For example, in cucurbit, powdery mildew can occur over a wide range of RH levels and at temperature between 10 to 32°C (Sen *et al.* 1999). In tomato powdery mildew (caused by *Oidium neolycopersici*) laboratory experiments indicated that more conidia were produced at 20°C and 70 to 85% RH; optimum conditions for conidial germination occurred at 25°C and 99% relative humidity (RH); and optimal conditions for appressoria formation were 25°C and RH between 33 and 99%. Conidia survived and remained capable of germination for over four months when initially incubated at lower temperatures and higher RH, as compared with their fast decline under more extreme summer shade conditions (Jacob *et al.* 2008). In glasshouse experiments, severity of powdery mildew was positively correlated with the duration of temperatures between 15 and 25°C and negatively correlated with the duration of temperatures in the low and high ranges (i.e. 5 to 15°C and 35 to 40°C) (Jacob *et al.* 2008).

Powdery mildew conidia contain 52 to 75% water and high lipid content, which prevents desiccation and allows germination in areas of low RH. The disease cycle is completed in 3 to 7 days and several rapid cycles in a season result in production of large amounts of inoculum that can cause wide spread infection with in short period of time (Sen *et al.* 1999).

Spread

In the spring, spores of *Oidium* species that have over wintered in plant material are released from fruiting bodies and blown or splashed onto the foliage of susceptible hosts (EPPO 2002, Gupta & Ram 1999).

Symptoms

No information is available describing symptoms of *O. tenellum* in onion. However, *Olpitrichum* has been identified as one of the causal agents of grain mould, which also includes *Fusarium*, *Alternaria*, *Curvularia*, *Phoma* and *Colletotrichum*. Symptoms in this disease include the appearance of pink, orange, gray, white or black mycelium on the grain surface (Smith & Cartwright 2007).

Powdery mildews appear as spots or patches of a white to greyish, powdery, mildew growth on young plant tissue or entire leaves and other organs. Tiny, pinhead sized, spherical, at first white, later yellow brown, and finally black cleistothicea may be present singly or in groups on the white to greyish mildew in the older areas of infection. Powdery mildew is most common on the upper side of leaves, but it also affects the underside of green plant parts, such as leaves, young shoots and stems, buds, flowers and young fruits (Agrios 2005). There is no evidence to suggest that below ground plant tissue is susceptible to *O. tenellum* nor other powdery mildews.

Host range

Olpitrichum tenellum has been reported from temperate North America and Europe on *Allium*, *Gossypium*, *Pennisetum* and *Zea* (Farr *et al.* 2009). No records could be found of *Olpitrichum tenellum* on *Allium* in China but it has been recorded as a pathogen on maize in China (Chen *et al.* 2004).

5.6.1.4. Hazard identification conclusion

Based on the accepted absence of *O. tenellum* in New Zealand, the potential ability of this fungus to be imported on onion bulbs, and the potential ability of this fungus to cause disease symptoms on onion and a wide range of host plants in New Zealand, it is proposed that *O. tenellum* be considered a potential hazard requiring further assessment.

5.6.2. Risk assessment

Much of the information provided in the *Hazard Identification* section above relates to *Olpitrichum* (*Oidium*) species or powdery mildew fungi because there is no information specific to *O. tenellum* either on onion or other plant species. Despite this, overall mechanisms for pathogenicity are considered similar for *Olpitrichum* (*Oidium*) species or other powdery mildew fungi and *O. tenellum*; therefore, assumptions will be made on this basis in the following risk assessment.

5.6.2.1. Entry assessment

The likelihood of entry of *O. tenellum* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *O. tenellum* in China.

Several factors would influence the prevalence of *O. tenellum* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because powdery mildew can overwinter in plant/crop debris above the soil surface. Secondly, there is opportunity for the pathogen to infect onion plants via wind-dispersed conidia from, for example, infected maize plants. Thirdly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *O. tenellum*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and possibly associated humidity levels could be conducive for *O. tenellum* infection (10-30^{o}C). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the RH within the crop and therefore, increase the likelihood of infection within the crop.

Although onion leaves could become infected with *O. tenellum* in the field, there is no evidence in the literature to suggest that onion bulbs are susceptible to infection by this pathogen or other related powdery mildew – green plant tissue being the site of infection for these pathogens. If onion bulbs did become infected the pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild or not visible on examination. Storage conditions during shipment could allow for pathogen survival but would not be considered conducive for disease development (e.g., <5^{o}C). Under such conditions, it would be expected that *O. tenellum* would not be detected at the time of arrival into New Zealand.

The association of *O. tenellum* with onion bulbs unknown and as such is considered a possibility only. As such the likelihood of entry of *O. tenellum* into New Zealand on onion bulbs from China is considered negligible and *O. tenellum* does not require further assessment.

5.6.2.2. Assessment of uncertainty

There is a high level of uncertainty around the biology, distribution and epidemiology of *O. tenellum* on onion (i.e. most of the information is based on *Olpitrichum* species or other powdery mildew species) and the association of powdery mildew with onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

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5.7. *Phyllosticta* sp. and *Cochliobolus eragrostidis*

5.7.1. Hazard identification

5.7.1.1. Aetiologic agent

Phyllosticta sp.; Ascomycota: Botryosphaeriaceae.

Cochliobolus eragrostidis (Tsuda & Ueyama) Sivan. (1987); Ascomycota: Pleosporaceae. Other names include the anamorph *Curvularia eragrostidis* and synonym *Pseudocochliobolus eragrostidis* Tsuda & Ueyama.

5.7.1.2. New Zealand status

Cochliobolus eragrostidis is not recorded as present in New Zealand (NZFungi 2008, PPIN 2008).

There are a number of *Phyllosticta* species recorded in New Zealand but none have been recorded on onions (*Allium cepa*) or any species in the *Allium* genus (PPIN 2008). *Phyllosticta allii* has been recorded as a leaf spot or blight on onions (*Allium cepa*) in North America (Schwartz & Mohan 2008) but not New Zealand (NZFungi 2008, PPIN 2008).

5.7.1.3. Biology and epidemiology

For the purposes of this risk analysis, it will be assumed that the *Phyllosticta* species reported on onions in China (China 2008) is *Phyllosticta allii*.

As with many plant pathogenic fungi, in nature, the teleomorph stage is often rarer than the anamorph stage. As such, entry of the pathogen into New Zealand and the economic and environmental consequences of the pathogen to New Zealand will likely be more pertinent for the anamorphic stage, in this case *Curvularia eragrostidis* and *Phyllosticta allii*. It is noted that although the information provided in this risk assessment will be for *Curvularia eragrostidis*, it also pertains to *Cochliobolus eragrostidis*.

Biology and ecology

There is no information available for *C. eragrostidis* as a pathogen of onion. Therefore, information for this fungus on other plant hosts or *Curvularia* spp., where available, is provided.

Curvularia spp. cause leaf spots in host plants. They are widespread, airborne facultative pathogens of soil, plants and cereals in tropical or subtropical areas, while a few are found in temperate zones (Pitt *et al.* 1994, Kilambi 2005). A strain of *C. eragrostidis* (QZ-2000) has shown potential for biocontrol of the widespread weed, *Digitaria sanguinalis* (Jiang *et al.* 2008) through the production of a phytotoxic metabolite.

Conidia of *Curvularia* spp. have 3-4 cross walls, resulting in 4 and 5-celled spores. Macroscopically, colonies on agar media appear black, hairy and expanding (Sivanesan 1998, Kilambi 2005). Ascospores are hyaline, threadlike or whiplash in shape (Sivanesan 1998).

Phyllosticta allii produces small, ostiolate, dark pycnidial partially submerged in the host tissue in white lesions (Schwartz & Mohan 2008).

Epidemiology

Curvularia leaf spots in grasses are most prevalent under high temperatures (e.g. 30°C) and humid conditions. Rainfall and/or irrigation are important in the spread of spores through water splashes. Stressed or senescing leaf tissue is often prone to attack (York 1998).

In *Curvularia* leaf blight of pineapple, leaf injuries accelerated and increased infection, with symptoms appearing 4-5 days after inoculation and advancing upwards. Disease development was favoured by 48 or 72-hour incubation at relative humidity's of between 60-75% (Saikia & Roy 1981).

'Phyllostica leaf blight' was first reported from North America in 1925 during disease surveys. Some years later the disease was recorded as causing significant symptoms on yellow onions during periods of unusually high humidity (Schwartz & Mohan 2008). In China 'Phyllostica leaf blight' is recorded as a disease of summer and autumn months. Infection rates of 30-50% result in few infected leaves and little affect on onion production. When more serious outbreaks occur infection rates can reach 80% and production levels can be significantly affected (China 2008).

Conidia of *Curvularia* spp. are efficiently adapted for aerial dissemination as they are boomerang shaped to more-or-less spindle shaped and bent (Sivanesan 1998).

Symptoms

In maize, *Curvularia* species mainly cause small necrotic or chlorotic spots on leaves (Shamsi & Yasmin 2007). In grasses, *Curvularia* blight causes thinning and overall decline of the sward; irregular patches and streaks can also occur. Initially leaves are yellow and then become brown from the leaf tip down. Roots, stolons and rhizomes may also become infected. Infected tissues may become covered with a fine, grey layer of mycelia after which there is often an abundance of sporulation from infected and dead tissue. Spores are borne on the mycelia and no enclosed fruiting structures are formed (Wong *et al.* 2003).

Host range

Curvularia leaf spot affects many species of grasses (Huang *et al.* 2004), lemons (Mirza *et al.* 2004), yams (Michereff *et al.* 1999), *Acacia*, *Allium* spp., Camellia, Capsicum, *Citrus*, *Eucalyptus*, *Phaseolus*, *Pinus* and *Zea* (Sivanesan 1998).

As far as could be found *Phyllosticta allii* has only been reported on *Allium cepa*.

5.7.1.4. Hazard identification conclusion

Based on the accepted absence of *Phyllosticta* sp. and *Cochliobolus eragrostidis* in New Zealand, the potential ability of these fungi to be imported on onion bulbs, and the potential ability of these fungi to cause disease symptoms on onion and (in the case of *C. eragrostidis*) a wider range of host plants in New Zealand, it is proposed that *Phyllosticta* sp. and *Cochliobolus eragrostidis* be considered potential hazards requiring further assessment.

5.7.2. Risk assessment

Much of the information provided in the previous section relates to *Curvularia* spp. in general or *C. eragrostidis* as a pathogen of a wide variety of host species because there is no information specific to *C. eragrostidis* on onion. Although there may be some differences for the development of disease in different hosts, overall mechanisms for pathogenicity are likely to be similar for all hosts of *C. eragrostidis*; therefore, assumptions will be made on this basis in the following risk assessment.

5.7.2.1. Entry assessment

The likelihood of entry of *C. eragrostidis* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *C. eragrostidis* in China. The rate of infection of the *Phyllosticta* species causing 'Phyllostica leaf blight' in China is usually around 30-50% with few infected leaves (China 2008). Leaf infection rates increase when disease rates are higher (China 2008).

Several factors could influence the prevalence of *Phyllosticta* sp. and *C. eragrostidis* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there could be opportunity for infection because *Phyllosticta* sp. and *C. eragrostidis* are soilborne pathogens that can infect roots and stolons (albeit of grasses). Secondly, environmental conditions conducive for onion production in China could be conducive for infection of onions by *Phyllosticta* sp. and *C. eragrostidis*, although higher temperatures required by *C. eragrostidis* may not be reached. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), higher temperatures and precipitation levels may be conducive for *C. eragrostidis* infection (30^{o}C). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *Phyllosticta* sp. or *C. eragrostidis* in the field, these pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild or not visible, e.g., at temperatures below 20^{o}C for *C. eragrostidis* (CPC 2007). Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., $<5^{o}$C). Under such conditions, it would be expected that *Phyllosticta* sp. and *C. eragrostidis* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *Phyllosticta* sp. and *C. eragrostidis* into New Zealand on onion bulbs from China is considered low and is therefore non-negligible.

5.7.2.2. Assessment of exposure

Should onion bulbs infected with *Phyllosticta* sp. and *C. eragrostidis* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of these fungi in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying fungi destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *Phyllosticta* sp. and *C. eragrostidis* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Rainfall and/or irrigation are important in the spread of *Curvularia* spores through water splashes (York 1998). Conidia of *Curvularia* spp. are efficiently adapted for aerial dissemination (Sivanesan 1998). The potentially wide host range and easy of transfer of *C. eragrostidis* indicates the likelihood of exposure of *C. eragrostidis* in New Zealand from onion bulbs imported from China is low and is therefore non-negligible.

Infective life stages of *Phyllosticta* sp. are also likely to be easily disseminated however the potentially narrow host range of the species associated with onions (*Phyllosticta allii*) would limit exposure to gardens growing onion plants. The likelihood of exposure of *Phyllosticta* sp. in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.7.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *Phyllosticta* sp. and *C. eragrostidis* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26°C), and possibly winter daytime temperatures (12-17°C), that are conducive for onion growing could be conducive for disease development by *Phyllosticta* sp. and *C. eragrostidis*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

The host range of *C. eragrostidis* is large and offers considerable opportunities for establishment within the domestic environment. The host range of the *Phyllosticta* sp. recorded as being associated with onion in China (China 2008) is unknown. Assuming the species in question is *Phyllosticta allii*, the host range is restricted to onion (*Allium cepa*) and as such the opportunity for this pathogen to establish is significantly less.

The likelihood of *C. eragrostidis* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered low and is therefore non-negligible.

The likelihood of *Phyllosticta* sp. establishing in either home gardens or in garden waste areas is considered negligible. As such, the *Phyllosticta* sp. does not require further assessment.

5.7.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *C. eragrostidis* could spread within the private garden area via rain, heavy irrigation, or movement of infested crop debris or alternative hosts. The likelihood for *C. eragrostidis* to spread within these established areas, i.e., private gardens or garden waste areas is considered moderate and is therefore non-negligible.

C. eragrostidis may spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *C. eragrostidis* would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered unlikely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *C. eragrostidis* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore, non-negligible.

It is noted that *C. eragrostidis* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., citrus, yams, *Allium* spp., *Camellia* spp., *Capsicum* spp., *Eucalyptus* spp., *Pinus* spp. or corn. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic consequences

Specific information about the economic impact of *C. eragrostidis* on onion or its alternative hosts is not available. If the pathogen was to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *C. eragrostidis* would have economic consequences on private gardeners.

Significant economic consequences could result if *C. eragrostidis* was to spread from private gardens to commercial production areas. Infection rates of 30-50% result in few infected leaves and little affect on onion production. When more serious outbreaks occur infection rates can reach 80% and production levels can be significantly affected (China 2008).

Therefore, the likelihood is moderate that *C. eragrostidis* would have moderate economic consequences on the New Zealand onion industry. It is noted that both conventional and organic commercial growers of citrus, yams, *Allium*, *Camellia*, *Capsicum*, *Eucalyptus*, *Pinus* or corn could also be affected.

Environmental consequences

While there is no evidence of *C. eragrostidis* acting as a pathogen on New Zealand native flora, this pathogen has a wide host range that includes plant species that are either socially or culturally important within the urban environment or are from families that are closely related to native plants or important urban species (e.g. *Camellia*, *Eucalyptus*, *Pinus*, *Allium*, *Citrus* etc). As such, the likelihood is low that *C. eragrostidis* could establish on a native species or significant urban species and have an unwanted environmental impact within New Zealand.

Human health consequences

Infections in humans caused by *Curvularia* species are relatively uncommon despite the ubiquitous presence in the soil environment. However, some *Curvularia* spp. are thought to be causative agents of infections (e.g., wound infections, keratitis, allergic sinusitis, cerebral abscess, pneumonia, allergic bronchopulmonary disease, and endocarditis) in both immunocompromised patients or ones with intact immune systems (Hiromoto *et al.* 2008, Carter & Boudreaux 2004, Wilhelmus & Jones 2001, De Shazo & Swain 1995). *Curvularia eragrostidis* is not known to be of any significance to human health.

5.7.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *C. eragrostidis* spread from private gardens to commercial growing areas it could cause moderate economic and low environmental consequences to New Zealand.

5.7.2.6. Risk estimation

The likelihood estimate is low that *C. eragrostidis* would be associated with onion bulbs on entry into New Zealand; low that *C. eragrostidis* would be exposed to the environment; moderate that any *C. eragrostidis* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *C. eragrostidis* would spread from private garden areas to commercial onion production areas; moderate that spread to commercial production areas would result in moderate unwanted economic consequences; and low for environmental consequences to New Zealand.

As a result, the risk estimate for *C. eragrostidis* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

5.7.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also a high level of uncertainty in terms of epidemiology, spread and symptoms of infection caused by *C. eragrostidis* on onion, i.e., all of the information is based on *C. eragrostidis* on other host species or on *Curvularia* spp. in general. This analysis also assumes that the *Phyllosticta* species reported as being associated with onions in China is *Phyllosticta allii*. As such, the risk assessment should be reviewed once further relevant information becomes available that challenges the assumptions made in this analysis.

5.7.3. Risk management

5.7.3.1. Risk evaluation

Since the risk estimate for *C. eragrostidis* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.7.3.2. Option evaluation

There are a number of biosecurity risk management options available for *C. eragrostidis* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *C. eragrostidis*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *C. eragrostidis*;
- **c.** Inspection of onion plants or bulbs for *C. eragrostidis*;
- **d.** Treatment of onion bulbs for *C. eragrostidis* by a suitably efficacious method.

Pest free area (PFA)

Given the existence of *C. eragrostidis* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a

PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *C. eragrostidis* in the absence of human assistance is limited to relatively small distances, and symptoms of *C. eragrostidis* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *C. eragrostidis* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *C. eragrostidis*.

Inspection of onion plants or bulbs

C. eragrostidis can be detected when roots are severely infected. Inspecting onion roots or above-ground leaves during harvesting for symptoms of *C. eragrostidis*, and using standard testing techniques as conformation, should be considered an appropriate screening process. As the risk attributes leading to successful establishment of *C. eragrostidis* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated.

Under appropriate conditions, inspection and testing of onion roots during harvesting for symptoms of *C. eragrostidis* infection, and rejection of produce sourced from an infected field, should be considered an effective phytosanitary measure against *C. eragrostidis*.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *C. eragrostidis* without also negatively affecting the condition of the onion bulbs. Fungi would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *C. eragrostidis* in New Zealand requires bulb waste to be disposed into a suitable environment, treatments that reduce the level of bulb waste should be effective. A physical treatment that removes roots and the outer (hard) skin layers from bulbs and excludes bruised or decayed bulbs from export shipments should be considered an effective treatment for *C. eragrostidis*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

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5.8. *Phytophthora* species

Phytophthora is a member of the Oomycete family now considered part of the Stramenopiles and more closely related to the algae and dinoflagellates rather than fungi. The similarity in morphology to fungi is believed to be a result of convergent evolution (cited in Ormsby 2008). The majority of *Phytophthora* species are soil-borne micro-organisms causing crown and root rots in important agricultural crops (Erwin & Ribeiro 1996). Soil-borne *Phytophthora* infections are aggravated when the soil is saturated for prolonged periods (Duniway 1979).

The following analysis groups six *Phytophthora* species that are considered potential hazards on onion (*Allium cepa*) bulbs imported for consumption from China.

5.8.1. Hazard identification

5.8.1.1. Aetiologic agents

Phytophthora capsici Leonian.

Phytophthora cinnamomi Rands.

Phytophthora drechsleri (Tucker) Sarej.

Phytophthora meadii McRae.

Phytophthora palmivora (E.J. Butler) E.J. Butler 1919.

Phytophthora porri Foister.

5.8.1.2. New Zealand status

Phytophthora species *capsici*, *drechsleri*, *meadii*, *palmivora* and *porri* are not recorded as present in New Zealand (Beever *et al.* 2006, PPIN 2008, NZFungi 2008). The *Phytophthora* species *P. drechsleri* and *P. meadii* were once considered present in New Zealand based on morphological comparisons. More recent molecular analysis by Beever *et al.* (2006) determined that the only recorded detection of *P. drechsleri* from which an isolate was available indicated that the author had misidentified *P. cryptogea* as *P. drechsleri*. There were also no confirmed instances of *P. meadii* amongst the isolates of New Zealand *Phytophthora* tested.

Phytophthora cinnamomi is heterothallic with two known mating types, A1 and A2. The A2 mating type is the dominant strain world wide, while the A1 mating type has a limited distribution and host range (Zentmyer 1983). In New Zealand, 6 isolates sampled from diverse sites around NZ and sequenced in a study on *Phytophthora* diversity had identical ITS sequences. In contrast, authentic sequences from overseas showed modest variation, suggesting that the New Zealand isolates comprise a limited gene pool consistent with this species having being introduced (Beever *et al.* 2006).

5.8.1.3. Biology and epidemiology

With the exception of *P. porri*, very little information is available for the biology, ecology and epidemiology of these *Phytophthora* species on onion; therefore, much of the information provided for the risk assessment pertains to diseases caused by these *Phytophthora* species in other vegetable crops, such as solanaceous and cucurbit species, or on *Phytophthora* in general.

Biology and ecology

Phytophthora species that cause root rots over winter in the soil as mycelium, sporangia, zoospore cysts, chlamydospores and oospores, and survival can be extended in the presence of an organic substrate (Agrios 2005). Sexual reproduction in *Phytophthora* results in the production of oospores, which provide the means of long-term survival as the oospores are resistant structures (Elliott 1983). Laboratory research indicates that optimal temperature for growth of *P. cinnamomi* ranged between 20 and 32°C (Erwin 1983, page 150), with optimum temperatures for oospores production from heterothallic isolates is 15-24°C and from homothallic isolates is 18-24°C and optimum temperatures for chlamydospores germination is 20-30°C (Elliott 1983). Growth of *P. capsici* can occur between 7-37°C however optimum temperatures for zoospore production and infection occur between 27-32°C (Roberts *et al.* 2000, Gevens *et al.* 1994). The pathogen causes pre- and post-emergence damping-off in cucurbits in wet and warm (20 to 30°C) conditions (Pest Management 2007).

P. porri is capable of growing in the temperature range of 0-27°C, the optimum being in the range of 15-20°C (Kiichi *et al.* 1969). *P. palmivora* is a war-climate species capable of growing in the temperature range of 10-30°C, the optimum being in the range of 20-25°C (CPC 2007). *P. palmivora* has been imported into New Zealand on a regular basis on pawpaws from the Pacific Islands. Fruit are imported sound and clean but often develop the disease during later distribution with whole boxes of fruit occasionally covered in a felt of *P. palmivora* (Fullerton pers. com. 2009).

These *Phytophthora* species are soilborne pathogen and survive between crops as oospores (thick-walled sexual, resting spores) in and on seed and host plant debris in the soil (Babadoost 2004, Gevens *et al.* 1994). Because oospores are thick-walled, they are resistant to desiccation, cold temperatures, and other extreme environmental conditions, and can survive in the soil, in the absence of a host plant, for many years (Hausbeck & Lamour 2004).

Sporangia of *P. cinnamomi* germinate either by the formation of a germ tube(s) that eventually form a mycelium, or by release motile zoospores into water in the soil which swim to small roots (a chemotactic response to root exudates), encyst and within 20 to 30 minutes germinate on the root surface (Hardman 2005). Penetration occurs within 24 hours of germination (Ribeiro 1983) and sporangia may appear on the root surface within 2 to 3 days in susceptible plants (Hardman 2005). The pathogen then spreads in the young feeder roots causing a rot which may extend into the base of the stem. Propagules may also be splashed onto and infect aerial parts of the plant (Ribeiro 1983). The latent period (the time between pathogen penetration and sporulation) can be as short as 24 hours on eucalyptus seedlings (Weste 1983).

Phytophthora can also survive for long periods in dead plant material. The saprophytic phase can allow an increase in the population of the pathogen. Mycelium of *P. cinnamomi* can survive for at least 6 years in moist soil while zoospore cysts can survive for at least 6 weeks. Varying germination periods may help to maintain a low but continuing population. Chlamydospores can survive for at least 6 years if soil moisture exceeds 3% (Weste 1983).

Epidemiology

In the spring when soil moisture is at field capacity, *Phytophthora* oospores germinate and produce sporangia and zoospores. Abundant sporangia are produced on infected tissues, particularly on affected fruit, and dispersed via water or air. Sporangia can germinate and infect host tissues directly, or they can release zoospores. Zoospores are released in water and are dispersed by irrigation or surface water. Zoospores are able to swim for several hours and can directly infect plant tissues (Babadoost 2004, Lamour & Hausbeck 2003). A large amount of surface moisture is required for their movement (Gevens *et al.* 1994).

Chlamydospores form in soil, gravel or plant tissue during dry periods, germinate under favourable (moist) conditions and grow to form mycelia and sporangia or more chlamydospores. The latter may, in turn, remain dormant until conditions become suitable, then germinate to produce infective mycelia, sporangia and zoospores, or more chlamydospores. This cycle may continue for at least 5 years, provided there is a nutrient source (organic matter) and a non-competitive soil micro-flora (Weste 1983).

Since water is integral to the dispersal and infection of *Phytophthora*, maximum disease occurs during wet weather and in low, waterlogged parts of fields. Under ideal conditions of excessive rainfall and standing water the disease symptoms can occur 3-4 days after infection, resulting in epidemics caused by *Phytophthora*. As a result, *Phytophthora* species can rapidly affect entire fields (Gevens *et al.* 1994).

Spores are dispersed via water or air while zoospores are released in water and are dispersed by irrigation or surface water. *Phytophthora* are also spread as hyphae in infected transplants, through contaminated soil and equipment (Babadoost 2004, Gevens *et al.* 1994), and infected transplants and seeds (Pest Management 2007).

Symptoms

On *Allium*, *P. porri* causes leaf tip die back for several centimetres and the area becomes white. Infection results from direct contact between infested soil and leaf tips. Leaves may become distorted, twisted and water soaked but turn white and crisp (Holliday, 1996). Severely damaged leaves die off (Tichelaar & van Kesteren 1967). Infected areas develop in the middle or at the base of the leaf, with eventual collapse of the plant. Spots are surrounded by a green, transparent, water-soaked region. The lower parts of outer, wrapped leaves are desiccated and yellow or brown. A dark brown discolouration spreads from the base of the stem to the leaves (Holliday 1995).

Many infections start in the water basin that is usually present near the leaf axils. Lesions appear at some distance above this water basin because of leaf growth during the incubation period. Both young and old plants are affected, and severe infection results in rotting off of leaves at the soil level (CPC 2007). Root and bulb rot in the field and storage also occur (Kiichi *et al.* 1969).

For *Phytophthora* species in seedlings, a watery rot develops in the hypocotyls at or near the soil line, resulting in plant death. Seedling death is preceded by plant wilting. In pumpkin, after seedling emergence, *P. capsici* can infect both the petiole and leaf blade (Babadoost 2000). Dark brown, water-soaked lesions develop on petioles, resulting in a rapid collapse and death of leaves. Infection of the leaf blade results in development of leaf spots ranging from 5 mm to more than 5 cm in diameter. Infected areas are initially chlorotic and then become necrotic with chlorotic to olive-green borders within a few days (Babadoost 2004).

Mature cucurbit plants show symptoms of crown rot, with initial symptoms including a sudden, permanent wilt of infected plants without a change in colour (Zitter *et al.* 1996). Wilt in leaves progresses from the base to the extremities of the vines. The stem near the soil line turns light to dark brown and becomes soft and water-soaked. Infected stems collapse and die. Tap and lateral roots of infected pumpkin plants usually do not exhibit any symptoms. Following death of the foliage, roots may give rise to new vines if environmental conditions become less conducive for disease development. Phytophthora damping-off may result in partial to total loss of the crop (Babadoost 2004). Plants often die within a few days of the first appearance of symptoms or after the soil are saturated by excessive rain or irrigation.

Under wet and warm conditions, leaf spots expand rapidly, coalesce, and may cover the entire leaf. Under dry conditions, expansion of leaf spots may cease (Babadoost 2004).

P. cinnamomi causes a rot of fine feeder roots, leading to dieback and death of host plants. Larger roots are only occasionally attacked. Other symptoms include wilt, stem cankers (with sudden death of tree), decline in yield, decreased fruit size, gum exudation, collar rot (if infected through grafts near soil level) and heart rot (e.g. pineapple) (Zentmyer 1983).

Host range

Recorded hosts of *P. capsici* are solanaceous crops (pepper, eggplant, tomato) and cucurbits (cantaloupe, cucumber, summer squash, pumpkin, watermelon) (Gevens *et al.* 2004, Farr *et al.* 2009). *P. capsici* is recorded as a pathogen of *Allium cepa* in Taiwan (Ho 1990), and laboratory studies confirm that *A. cepa* has been found to be susceptible to *P. capsici* (Babadoost *et al.* 2008).

P. cinnamomi is currently considered the most widely distributed species of *Phytophthora*, with more than 1000 host species recorded in more than 90 different countries (cited in Ormsby 2008).

Japanese plum (*Prunus salicina*) is recorded as a major host of *P. drechsleri* while poinsettia (*Euphorbia pulcherrima*) is recorded as a minor host of the pathogen (CPC 2007). As part of the buckeye rot “complex”, hosts also include beans, corn, eggplant, melons, peppers, potato, pumpkin, rhubarb, squash, and turnip (Anon 1988).

P. meadii is recorded as a pathogen of *Leea* spp., Madagascar periwinkle (*Catharanthus roseus*), *Ficus* spp., *Piper* spp., and pineapple (Uchida 2008, Chowdappa *et al.* 2003).

Major hosts of *P. palmivora* are recorded as *Carica papaya* (papaw), *Cocos nucifera* (coconut), and *Durio zibethinus* (durian). Minor hosts are recorded as cashew nut (*Anacardium occidentale*), pineapple (*Ananas comosus*), *Citrus,* grapefruit (*Citrus* × *paradisi*), *Ficus carica* (fig) and black pepper (*Piper nigrum*) (CPC 2007).

P. porri appears to have a more limited spectrum of hosts, restricted to the alliums, white cabbage and carrots (Blancard *et al.* 2006).

5.8.1.4. Hazard identification conclusion

Based on the accepted absence of *Phytophthora* species *capsici*, *drechsleri*, *meadii*, *palmivora* and *porri* in New Zealand, the potential ability of these *Phytophthora* to infect onion plants and be imported on onion bulbs, and the potential ability of these *Phytophthora* to cause disease symptoms on onion and a wide range of host plants in New Zealand, it is proposed that of the *Phytophthora* species *capsici*, *drechsleri*, *meadii*, *palmivora* and *porri* be considered a potential hazard requiring further assessment.

Based on the epidemiological information provided above a strain or isolate of *P. cinnamomi* present in China but not in New Zealand could establish in New Zealand from imported onion bulbs and cause an unwanted impact. *P. cinnamomi* is therefore considered a potential hazard requiring further assessment.

5.8.2. Risk assessment

5.8.2.1. Entry assessment

Entry of *Phytophthora* species into New Zealand may occur through infected onion bulbs imported from China. The likelihood of entry into New Zealand is difficult to determine because there is no information available about (1) the *Phytophthora* prevalence in China and (2) the infection rate of onion by *Phytophthora* species in China.

Several factors would influence the prevalence of *Phytophthora* species in onions in the field and thus impact on the likelihood of entry into New Zealand. Firstly, there is opportunity for infection because *Phytophthora* species are able to survive between crops as oospores in and on host plant debris in the soil. Secondly, *Phytophthora* species are able germinate and infect host tissues directly, or it can release zoospores, which can then infect the plant. In China, environmental conditions are also favourable for infection by zoospores ranges between 27 and 32°C and damping off ranges between 20 and 30°C. Thirdly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *Phytophthora* species. For example, optimum temperatures for onion growth ranges between 13-30^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels are conducive for infection by *Phytophthora* species (27 and 32°C for infection by zoospores (Roberts *et al.* 2000; Gevens *et al.* 1994) and 20 to 30°C for damping off ranges (Pest Management 2007)).

Although onions may be infected with *Phytophthora* species in the field, this could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible, e.g., at temperatures below 20^{o}C. Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g. <5^{o}C). Under such conditions, it would be expected that infection by *Phytophthora* species would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii*, *palmivora* and *porri* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

5.8.2.2. Assessment of exposure

Should onion bulbs infected with *Phytophthora* species be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of these organisms in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying *Phytophthora* destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *Phytophthora* species would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Abundant sporangia are produced on infected tissues, particularly on affected fruit, and dispersed via water or air. Sporangia can germinate and infect host tissues directly, or they can release zoospores. Zoospores are released in water and are dispersed by irrigation or surface water. Zoospores are able to swim for several hours and can directly infect plant tissues (Babadoost 2004, Lamour & Hausbeck 2003). Alternatively chlamydospores can form in soil, gravel or plant tissue during dry periods, germinate under favourable (moist) conditions and grow to form mycelia and sporangia or more chlamydospores. The latter may, in turn, remain dormant until conditions become suitable, then germinate to produce infective mycelia, sporangia and zoospores, or more chlamydospores. This cycle may continue for at least 5 years, provided there is a nutrient source (organic matter) and a non-competitive soil micro-flora (Weste 1983).

The likelihood of exposure of *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii*, *palmivora* and *porri* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.8.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *Phytophthora* species would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *Phytophthora* species. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

P. palmivora is a warm-climate species currently restricted in distribution to tropical or sub-tropical regions. *P. palmivora* has also been observed entering New Zealand on shipments of other types of fresh produce but to date has failed to establish. The likelihood of *P. palmivora* establishing in New Zealand is considered negligible.

The risk of infection of alliums, white cabbage and carrot, common home garden crops, is likely to be quite high if contaminated bulbs are disposed of in the home garden. *Phytophthora* species in general have a significant capacity for rapid spread thus the likelihood of home garden infection foci eventually spreading to commercial sites is probably relatively high (Fullerton pers. com. 2009).

The likelihood of *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii* and *porri* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

5.8.2.4. Consequence Assessment

Spread

Once established in the environment of the home garden, *Phytophthora* species could spread via excessive rainfall, conditions in which there is standing water or movement of infested crop debris through common garden practices. Because such conditions could be considered common practice by home gardeners, the likelihood for *Phytophthora* species to spread within these established areas, i.e., private gardens or garden waste areas is considered moderate and is therefore, non-negligible.

Phytophthora species may spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *Phytophthora* species would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered likely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *P. capsici* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore, non-negligible.

It is noted that *Phytophthora* species could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., pepper, eggplant, tomato, cucumber, summer squash, pumpkin, or watermelon. The likelihood of this occurring is also considered low and is therefore non-negligible.

Economic and environmental consequences

Phytophthora species have had a range of economic and environmental impacts globally and in New Zealand. This family of organisms continues to demonstrate an ability to have significant economic and environmental impacts from both the spread of known or unknown species and through the hybridisation of existing species in an environment (cited in Ormsby 2008).

Human health consequences

Phytophthora species are not known to be of any direct significance to human health.

5.8.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *Phytophthora* species spread from private gardens to commercial growing areas it could cause high economic and environmental consequences to New Zealand.

5.8.2.6. Risk estimation

The likelihood estimate is moderate that *Phytophthora* species would be associated with onion bulbs on entry into New Zealand; low that *Phytophthora* species would be exposed to the environment; moderate that *Phytophthora* species (other than *P. palmivora*) that are exposed to the environment would successfully establish in private gardens in New Zealand; low that *Phytophthora* species would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in unwanted economic and environmental consequences to New Zealand.

As a result, the risk estimate for *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii* and *porri* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

The risk estimate for *Phytophthora palmivora* associated with imported onion bulbs for consumption is negligible and should not be considered a hazard

5.8.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also a high level of uncertainty around the biology, distribution and epidemiology of *Phytophthora* species on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

The further significant assumption underpinning this assessment is that the strains or isolates of *P. cinnamomi* being generated in China would represent greater level of risk to New Zealand than the strains or isolates being generated in New Zealand. The work completed by Beever *et al.* (2006), while indicating that New Zealand isolates had lower levels of genetic variation, looked at small representative sample only and as such could not be considered conclusive. Research should be undertaken to consider the potential for strain development within New Zealand environments based on the distribution of mating types and the significant environmental influences.

5.8.3. Risk management

5.8.3.1. Risk evaluation

Since the risk estimate for *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii* and *porri* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.8.3.2. Option evaluation

There are a number of biosecurity risk management options available for *Phytophthora* species *capsici*, *cinnamomi*, *drechsleri*, *meadii* and *porri* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of the hazard species of *Phytophthora*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of the hazard species of *Phytophthora*;
- **c.** Inspection of onion plants or bulbs for the hazard species of *Phytophthora*;
- **d.** Treatment of onion bulbs for the hazard species of *Phytophthora* by a suitably efficacious method;
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of the hazard species of *Phytophthora* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *Phytophthora* species in the absence of human assistance is limited to relatively small distances, and symptoms of *Phytophthora* species infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *Phytophthora* species in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against the hazard species of *Phytophthora*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *Phytophthora* species, inspection of healthy bulbs for the hazard species of *Phytophthora* would not be an effective phytosanitary measure.

Infections by the hazard species of *Phytophthora* will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *Phytophthora* symptoms and tested as appropriate. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *Phytophthora* species without also negatively affecting the condition of the onion bulbs. *Phytophthora* would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides or algaecides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *Phytophthora* species in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *Phytophthora* species. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for the hazard species of *Phytophthora* on onion (*Allium cepa*) bulbs imported from China for consumption:

a) Field surveys during suitably wet and warm periods to ensure the levels of disease caused by the hazard species of *Phytophthora* are very low (e.g. 0.01%)[8]; and

b) Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).

c) Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and

d) Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic infection of onion bulbs by the hazard species of *Phytophthora*, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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5.9. *Puccinia asparagi*

5.9.1. Hazard identification

5.9.1.1. Aetiologic agent

Puccinia asparagi DC; Urediniomycetes: Pucciniaceae.

5.9.1.2. New Zealand status

Puccinia asparagi is not recorded as present in New Zealand (NZFungi 2008, PPIN 2008).

5.9.1.3. Biology and epidemiology

Biology and ecology

Puccinia asparagi (asparagus rust) is a serious fungal disease of edible and ornamental asparagus (Koike *et al.* 1998). It is a rust fungus that can infect all aboveground plant parts except the berries, and is most damaging during prolonged dry periods. The disease weakens plants and reduces marketable yield of asparagus spears (Planck & Davis 2005). *P. asparagi* can infect onion (CPC 2007, Horst 1990), although this apparently is not commonly seen (Koike *et al.* 1998). As such, there is no information available for the biology, ecology and epidemiology of *P. asparagi* on onion; therefore, much of the information provided for the risk assessment pertains to *P. asparagi* infection in asparagus.

P. asparagi is autoecious (completes its lifecycle on one host or group of closely related collateral hosts) and macrocyclic (long-cycled) as it occurs in four stages (Smith *et al.* 1988, University of Illinois Extension 1990).

Epidemiology

The life cycle of *P. asparagi* is complex as it produces five different fruiting structures that appear in four different stages. The first stage of the disease cycle occurs in the spring when pycnia (fruiting structures) over-wintering on crop debris produce pycniospores, which then develop into spore-bearing aecia in concentric ring patterns. Air currents and splashing rains carry aeciospores to the small branches of asparagus, where they germinate and infect when free moisture (i.e. dew, fog or rain) is present (Koike *et al.* 1998).

Approximately two weeks after aeciospores infect the small branches, blister-like pustules, called uredia, are produced from which large numbers of spherical urediospores are produced. These spores are dispersed by the wind to produce numerous infections on other asparagus plants, which can be more than several hundred meters away. Successive generations of urediospores may be produced, germinate quickly under moist conditions and cause infections every 12 to 14 days until late summer (du Toit & Inglis 2001). The urediospore stage is often considered the most damaging stage (Koike *et al.* 1998).

During late summer or fall, urediospores production is replaced by teliospores, which are large, two-celled, thick-walled, black spores produced either in existing uredia or in newly formed pustules. Teliospores remain attached in the pustules on asparagus plant parts or plant debris for the remainder of the season and throughout the winter.

In the spring, over wintering teliospores germinate on the old stems or stubble of asparagus to produce basidiospores. This infection results in the development of pycnia, which produce pycniospores, shortly after which aecia and aeciospores develop, thus completing the disease cycle. No information could be found on whether all or only part of the *P. asparagi* life cycles occurs on onion (*Allium cepa*) plants.

Rust infection caused by *P. asparagi* is favoured by moderate temperature, high humidity and moisture. Pycniospores, aeciospores and urediospores germinate and infection takes place at temperatures between 10 and 30^{o}C with optimum temperatures ranging between 20 and 22^{o}C (RPD No. 934). *P. asparagi* is likely to be recurring and cannot be totally eradicated (Koike *et al.* 1998).

Spread

Basidiospores are dispersed through the air by wind and penetrate plant tissue, causing infection (Koike *et al.* 1998). Aeciospores are dispersed via air currents and splashing rains (Koike *et al.* 1998) while urediospores are then dispersed by the wind to other asparagus plants (du Toit & Inglis 2001).

Symptoms

On asparagus, spring infection by pycniospores are characterised by light green patches on new spears that mature into yellow or pale orange pustules in concentric ring patterns. The summer spore stage consists of pustules (uredia) which are brown and powdery. The autumn stage consists of black spore masses (telia). The winter stage consists of oval yellowish spots on stems, which contain the fruiting bodies (aecia and pycnia) of the fungus (Koike *et al.* 1998). On onion, light yellow to red pustules affect leaves and stalks (du Toit & Inglis 2001).

Host range

Asparagus (*Asparagus officinalis*) is listed as a major host of *P. asparagi* while onion (*Allium cepa*), Asparagus fern (*Asparagus setaceus*) and *Asparagus verticillatus* are listed as minor hosts of the pathogen (CPC 2007). Other hosts include a number of non-edible species of *Asparagus* and members of the *Allium* genus (Welsh onion, chives, shallot) (RPD No. 934).

5.9.1.4. Hazard identification conclusion

Based on the accepted absence of *P. asparagi* in New Zealand, the potential ability of this fungus to be infect onion plants and be imported with onion bulbs, the potential for widespread and long distant dispersal of spores, the potential ability of this fungus to cause disease symptoms on onion and a range of host plants in New Zealand, it is proposed that of *P. asparagi* be considered a potential hazard requiring further assessment.

5.9.2. Risk assessment

Much of the information provided in the previous section relates to *P. asparagi* infection on asparagus because there is no available information specific to the disease in onion. Although there may be some differences for the development of disease in different hosts, overall mechanisms for pathogenicity are considered similar for all hosts of *P. asparagi*. Therefore, assumptions will be made on this basis in terms of the following risk assessment.

5.9.2.1. Entry assessment

Entry of *P. asparagi* into New Zealand may occur through infected onion bulbs imported from China. The likelihood of entry into New Zealand is difficult to determine because there is no information available about (1) the pathogen's prevalence in China and (2) the infection rate of onion by *P. asparagi* in China, and (3) whether infection on onion will only occur if infected asparagus is within relatively close proximity.

Several factors would influence the prevalence of *P. asparagi* in onions in the field and thus impact on the likelihood of entry into New Zealand. Firstly, there is opportunity for infection because *P. asparagi* is able to overwinter as teliospores on crop debris. Secondly, the pathogen is able to spread very easily through air-borne spores and can go through several cycles in one growing season, as such, it is likely to recur and cannot be totally eradicated. Thirdly, environmental conditions conducive for onion production in China could also be conducive for infection of susceptable hosts by *P. asparagi*. For example, optimum temperatures for onion growth ranges between 13-24^{o}C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels are conducive for *P. asparagi* (20 and 22^{o}C, high humidity and moisture). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *P. asparagi* in the field, the pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible, e.g., at temperatures below 20^{o}C. Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., <5^{o}C). Under such conditions, it would be expected that *P. asparagi* would not be detected at the time of arrival into New Zealand.

Infection rates for *P. asparagi* on onion plants in the field are expected to be low as onion (*Allium cepa*) is only considered a minor host and this pathogen is not listed as a significant problem by China (China 2008). As infections are restricted to aboveground portions of host plants, only the upper neck or associated leaf material are likely to carry infectious life stages. Consignments of export-quality onions are not expected to contain large amounts of extraneous aboveground leaf material.

The likelihood of entry of *P. asparagi* into New Zealand on onion bulbs from China is considered low and is therefore non-negligible.

5.9.2.2. Assessment of exposure

Should onion bulbs infected with *P. asparagi* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of this fungus in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China. Infections in material that has been harvested at maturity and held in storage are likely to be at the teliospore stage, which must germinate to produce basidiospores for dispersal.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying fungi destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *P. asparagi* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

The compost disposal pathway is not considered significant for *P. asparagi*, as rust fungi are not considered strong saprophytes and as such are likely to be overwhelmed by saprophytic fungi and bacteria commonly found on vegetable material in compost bins.

An alternative exposure pathway is through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets. These sites are likely to generate considerable waste from which basidiospores could disperse to surrounding host plants. Basidiospores are dispersed through the air by wind and penetrate plant tissue, causing infection (Koike *et al.* 1998). Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (Martin pers. com. 2008).

The likelihood of exposure of *P. asparagi* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.9.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *P. asparagi* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *P. asparagi*. Pukekohe, the main onion producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

For *P. asparagi* to successfully establish a suitable alternative host for infection by basidiospores would be required in relatively close proximity. The level of available inoculate (basidiospores) would also be low as only associated leaf material is expected to carry the teliospores. Given the very narrow host range of *P. asparagi* the likelihood that a suitable alternative host would be available to this small volume of inoculate is considered very low.

The likelihood of *P. asparagi* establishing in commercial crops (adjacent to re-packaging plants) from onion bulbs imported from China is considered very low and is therefore likely to be negligible. However due to uncertainties around waste disposal patterns in New Zealand the likelihood will be considered non-negligible at this time.

5.9.2.4. Consequence Assessment

Spread

Once established in the environment *P. asparagi* would spread via airborne spore stages (basidiospores, aeciospores or urediospores). As suitable conditions are common in New Zealand, the likelihood for *P. asparagi* spreading from established areas into the wider environment including commercial production areas is high. As such, the likelihood for *P. capsici* spreading from a localised to commercial horticultural production area is considered high and is therefore non-negligible.

Economic consequences

P. asparagi is a serious fungal disease of edible asparagus. In the USA, serious rust damage has been reported on asparagus crops with many fields having 100% of the plants infected

(CPC 2007). The asparagus industry in New Zealand produces around $NZ 13 million annual, roughly half of which is exported (HortResearch 2007). Impacts to other horticultural crops (onions, chives etc) are not expected to be significant.

The likely economic consequences to New Zealand from *P. asparagi* are therefore moderate.

Environmental consequences

P. asparagi is a serious fungal disease of ornamental asparagus species. Several of these species in New Zealand are considered important weeds in need of biological control. As such the overall impact of *P. asparagi* on the New Zealand environment is likely to be positive.

Human health consequences

P. asparagi is not known to be of any direct significance to human health.

5.9.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *P. asparagi* spread into commercial growing areas it is likely to cause moderate economic consequences to New Zealand.

5.9.2.6. Risk estimation

The likelihood estimate is low that *P. asparagi* would be associated with onion bulbs on entry into New Zealand; low that *P. asparagi* would be exposed to the environment; very low that *P. asparagi* would successfully establish in New Zealand; high that *Phytophthora* species would spread into commercial onion production areas; and high that spread to commercial production areas would result in moderate unwanted economic consequences to New Zealand.

As a result, the risk estimate for *P. asparagi* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

5.9.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also a high level of uncertainty around the biology, distribution and epidemiology of *P. asparagi* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

5.9.3. Risk management

5.9.3.1. Risk evaluation

Since the risk estimate for *P. asparagi* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.9.3.2. Option evaluation

There are a number of biosecurity risk management options available for *P. asparagi* associated onion bulbs imported from China for consumption. The following risk management options are assessed:

a. Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *P. asparagi*;

b. Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *P. asparagi*;

c. Cleaning of onion bulbs to ensure no extraneous aboveground plant material (leaves) occur within the consignment;

d. Restricting the re-packaging of imported onions to plants that are a suitable distance away from commercial asparagus crops.

Pest free area (PFA)

Given the existence of *P. asparagi* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *P. asparagi* in the absence of human assistance can be over large distances, and symptoms of *P. asparagi* infestation may not be readily apparent at certain life stages, establishing a PFPP should not be feasible.

Cleaning of onion bulb consignments

As the pathway for establishment of *P. asparagi* in New Zealand requires significant volumes of infected material to be collected at a single location, such as waste at a re-packaging plant, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes any extraneous aboveground leaf material (the outer layer of the bulb skin) should be considered an effective treatment for *P. asparagi*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

Restricting re-packing plant locality

As the pathway for establishment of *P. asparagi* in New Zealand is through onion re-packaging plants and requires these re-packing plants to be in relatively close proximity to commercial asparagus crops, restricting re-packaging to sites suitably distant from commercial asparagus crops (e.g. metropolitan areas) should be considered an effective treatment for *P. asparagi*. Alternatively requiring imported bulbs to be packaged for retail sale before arriving in New Zealand would also be considered an effective phytosanitary measure for *P. asparagi*.

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5.10. *Pythium intermedium* and *Pythium vexans*

As with *Phytophthora* (see section 5.8), *Pythium* is a member of the Oomycete family now considered part of the Stramenopiles and more closely related to the algae and dinoflagellates rather than fungi.

5.10.1. Hazard identification

5.10.1.1. Aetiologic agents

Pythium intermedium de Bary 1881; Oomycete: Pythiaceae

Pythium vexans de Bary; Oomycete: Pythiaceae

5.10.1.2. New Zealand status

P. intermedium and *P. vexans* have been recorded as present in New Zealand (Robertson 1980) however the records were based on a personal communication of the author with H. C. Smith. The species was not studied in culture and no cultures could be found linking these species to plants in New Zealand. These records are not considered reliable and as such these fungi are currently considered absent from New Zealand (PPIN 2008, NZFungi 2008).

5.10.1.3. Biology and epidemiology

P. intermedium and *P. vexans* have been combined into a single risk assessment because overall, pathogenicity and disease development within hosts is similar for both pathogens. Differences in such aspects as host range, requirements for reproduction and mating type will be highlighted where appropriate.

Where possible, information specific to both pathogens on onion will be presented; however, where information is lacking, information will be provided for other *Pythium* spp. (Schwartz & Mohan 2008).

Biology and ecology

Worldwide, *Pythium* spp. are widely distributed in water and soil. They are saprophytes or low-grade parasites attacking fibrous roots of plants. Seeds or young plants emerging from seeds in wet soils heavily infested with *Pythium* spp. may be attacked by the pathogen (Agrios 2005).

Little has been documented concerning diseases caused by *P. vexans*. Probably, like other species of Pythium, *P. vexans* survives in soil by means of zoospores and sporangia for short and intermediate periods and by means of oospores for longer periods (Hendrix & Campbell 1973). The oospores germinate indirectly by releasing zoospores. The zoospores swim around in water and infect the roots of host plants. Mycelial growth occurs between 5 and 35°C (optimum 30°C). Peach stunting induced by *P. vexans* is more severe under high moisture conditions.

Pythium species are soilborne pathogens that in many cases overwinter as oospores in soil or in infected plant tissue within soil. Oospores survive adverse conditions (e.g., high/low temperatures, low moisture levels) better than vegetative mycelium, which in turn survive better than sporangia (Agrios 2005). When nutrients or exudates from plant roots become available under moist conditions, oospores germinate and infect roots of susceptible hosts.

Zoospores can initiate secondary infections, which preferentially attach to roots of Poaceous plants (Mitchell & Deacon 1986). Infection can occur within 2 hours of contact, with infection spreading inter- and intracellularly (McKeen 1977). Oospores and other survival structures are also produced in infected tissues (Schwartz & Mohan 2008). Dispersal of *Pythium* species is more usually by means of mycelium growth and movement of zoospores (CPC 2007).

Most *Pythium* species are homothallic and readily self with only a small number of species, one of which being *P. intermedium*, classified as heterothallic requiring the presence of an opposite mating type to sexually reproduce (Martin 1995, Hsu & Hendrix 1972). There is no evidence to suggest that *P. vexans* is heterothallic.

Epidemiology

The occurrence of *Pythium*-induced onion diseases in the field is predominantly a result of environmental conditions that favour disease rather than of spread of pathogens into uninfested fields (Schwartz & Mohan 2008). Depending on the moisture level and depth of planting, initial infection of roots and stems of young seedlings usually occurs at or slightly below the soil surface. Most severe infections occur when soil moisture is high and soil temperatures are below 18^{o}C. *Pythium* spp. that readily produce zoospores have been most commonly isolated from onion roots during periods of high rainfall, while species producing propagules that germinate directly appear more common during periods of moderate rainfall (Schwartz & Mohan 2008).

Spore dispersal can occur through movement of soil, e.g., on equipment and boots. Active zoospores can be dispersed through irrigation water, runoff from rain or water splashes (Schwartz & Mohan 2008). *P. vexans* is transmitted mainly through infested soil. Zoospores of this fungus can swim in open water for a short distance (CPC 2007).

Symptoms

Roots of infected onion seedlings initially exhibit a greyish, water-soaked appearance. Infected seedlings that become symptomatic after emergence quickly collapse and die. Plants infected after the seedling stage seldom die but they can become severely stunted. Leaves become yellow, which progresses from the leaf tip to the base; older leaves are most severely affected. Leaves may become wilted in the most severely affected plants (Schwartz & Mohan 2008).

Roots of affected plants initially appear water-soaked and as the disease progresses the cortex disintegrates but the epidermis and stele remain intact. Symptomatic roots appear collapsed with a white strand within. Older roots infected with *Pythium* spp. may become faintly yellow or brown, but marked colour changes are not typical. *Pythium* spp. can cause root decay of established onion plants under conditions of poor soil drainage; however, this type of infection is less common (Schwartz & Mohan 2008).

Epidermal and cortical cells of the stem of young seedlings are directly penetrated by mycelium, which breaks down cell walls and causes the collapse of cells and tissues. Seedlings infected in such a way will quickly die. If however, pathogen invasion is limited to the cortex of the belowground stem, the seedling may continue to live and grow for a short time until the lesion extends above the soil line. In time, the tissue collapses and the seedling will fall over and die (Agrios 2005).

For initial infections in older seedlings, the progression of the fungus is checked at or near the point of infection, as such, relatively small lesions develop. Well-developed, mature tissues are relatively resistant to the mechanical pressure and enzymatic activity of the pathogen (Agrios 2005). Rootlets of most plants can be attacked at almost any growth stage. Once the pathogen enters the root tips, it proliferates in the young cells quickly causing rootlet collapse and death. Fleshy or young roots are invaded to a much greater extent (Agrios 2005).

Infections of fleshy vegetable fruits and other organs can occur in the field, in storage, in transit and in the market. In the field, infections are initiated at the point of contact of the fruit and wet soil heavily infested with the pathogen. Enzymes secreted by the fungus cause tissue maceration, which then becomes soft and watery (Agrios 2005).

Host range

Hosts of *P. intermedium* are listed as including species in the following families: *Begoniaceae*, *Chenopodiaceae*, *Compositae*, *Coniferae*, *Cruciferae*, *Euphorbiaceae*, *Geraniaceae*, *Gramineae*, *Leguminosae*, *Liliaceae*, *Linaceae*, *Moraceae*, *Onagraceae*, *Ranunculaceae*, *Rosaceae*, *Solanaceae*, *Ulmaceae*, *Violaceae*, *Equisetales* and *Filicales* (Waterhouse & Waterstan 1964). *P. intermedium* is recorded as a disease-causing organism on a few of the species in these families. Along with onions examples include carrot (*Daucus carota*) (Hermansen *et al.* 2007, McDonald 2002), cucumber (*Cucumis sativus*) (Stanghellini *et al.* 1988), some species of conifers (Hocking 1970) and sugar beet (*Beta vulgaris* subsp. *vulgaris*) (Windels & Kuznia 1991).

Major hosts of *P. vexans* are listed as *Ananas comosus* (pineapple), *Annona*, *Anthurium*, *Brassica*, *Camellia*, *Carica*, *Carica papaya* (papaw), *Carya illinoinensis* (pecan), *Cinchona*, *Citrullus lanatus* (watermelon), *Citrus*, *Colocasia esculenta* (taro), *Dianthus* (carnation), *Elaeis guineensis* (African oil palm), *Elettaria*, *Eucalyptus* (Eucalyptus tree), *Gossypium* (cotton), *Hevea brasiliensis* (rubber), *Hydrangea* (hydrangeas), *Juniperus* (junipers), *Linum* (flax), *Lupinus* (lupins), *Lycopersicon esculentum* (tomato), *Medicago* (medic), *Nicotiana*, *Pelargonium* (pelargoniums), *Persea*, *Persea americana* (avocado), *Pinopsida* (conifers), *Piper* (pepper), *Poaceae* (grasses), *Prunus persica* (peach), *Pyrus* (pears), *Ricinus*, *Solanum tuberosum* (potato), *Spinacia oleracea* (spinach), *Strelitzia*, *Theobroma*, *Theobroma cacao* (cocoa), *Vicia* (vetch), *Vigna* (cowpea), *Vitis* (grape), and *Zingiber officinale* (ginger) (CPC 2007).

5.10.1.4. Hazard identification conclusion

Based on the accepted absence of *Pythium intermedium* and *P. vexans* in New Zealand, the potential ability of these fungi to be imported on onion bulbs, and the potential ability of these fungi to cause disease symptoms on onion and a number of host plants in New Zealand, it is proposed that *P. intermedium* and *P. vexans* be considered potential hazards requiring further assessment.

5.10.2. Risk assessment

Much of the information provided in the previous section relates to *Pythium* spp. as there is only a limited amount of information specific to *P. intermedium* and *P. vexans* as pathogens of onion. Although there may be some differences for the development of disease in different hosts, overall mechanisms for pathogenicity are considered similar for all hosts of *Pythium* spp.; therefore, assumptions will be made on this basis in terms of the following risk assessment.

5.10.2.1. Entry assessment

The likelihood of entry of *P. intermedium* and *P. vexans* into New Zealand is difficult to determine because there is no information available about (1) the pathogens prevalence and (2) the infection rate of onion by *P. intermedium* and *P. vexans* in China.

Several factors would influence the prevalence of *Pythium* in onions in the field and thus impact on the likelihood of entering New Zealand. Firstly, there is opportunity for infection because *Pythium* is a soilborne pathogen that can overwinter as oospores, or even as vegetative mycelium or sporangia on plant/crop debris. Secondly, there is opportunity for the pathogen to enter the onion plant through roots or the fleshy vegetative fruits in contact with the soil. Thirdly, environmental conditions conducive for onion production in China are also conducive for infection of onions by *Pythium*. For example, optimum temperatures for onion growth ranges between 13-24°C. Average climatic data for the onion producing areas indicates that the month prior to (May) and during harvest (June to September), average temperature ranges and precipitation levels are conducive for *Pythium* infection (soil temperatures around 18°C). In addition, for some commercial production systems, it is common practice for the crop to be watered three days prior to harvest (Appendix 3), which could increase the likelihood of infection within the crop.

Although onions may be infected with *Pythium* in the field, the pathogen could go undetected at the time of harvest or prior to export because disease symptoms may be very mild, or possibly not visible, e.g., at temperatures below 20°C. Storage conditions during shipment would allow for pathogen survival but would not be considered conducive for disease development (e.g., <5°C). Under such conditions, it would be expected that *Pythium* would not be detected at the time of arrival into New Zealand.

The likelihood of entry of *P. intermedium* and *P. vexans* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

5.10.2.2. Assessment of exposure

Should onion bulbs infected with *P. intermedium* or *P. vexans* be imported into New Zealand, discarded bulbs could act as a vehicle for exposure of these organisms in the environment, as the growing season for onions and other host plants in New Zealand (spring and early summer) would be expected to coincide with the most likely period of importing onion bulbs from China.

As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying *Pythium* species destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Onion bulbs showing disease symptoms such as those caused by *P. intermedium* or *P. vexans* would be more likely to be discarded. Therefore the proportion of waste containing infected material may be higher than in the imported consignment as a whole.

Pythium species survive in soil by means of zoospores and sporangia for short and intermediate periods and by means of oospores for longer periods (Hendrix & Campbell 1973). The oospores germinate indirectly by releasing zoospores. The zoospores swim around in water and infect the roots of host plants. *Pythium* species are therefore are soilborne pathogens that in many cases overwinter as oospores in soil or in infected plant tissue within soil. Oospores survive adverse conditions (e.g., high/low temperatures, low moisture levels) better than vegetative mycelium, which in turn survive better than sporangia (Agrios 2005). Oospores and other survival structures are also produced in infected tissues (Schwartz & Mohan 2008).

The likelihood of exposure of *P. intermedium* and *P. vexans* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

5.10.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *P. intermedium* and *P. vexans* would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing are also conducive for disease development by *P. intermedium* and *P. vexans*. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007).

The likelihood of *P. intermedium* and *P. vexans* establishing in either home gardens or in garden waste areas, especially those in which conditions are conducive for survival, is considered moderate and is therefore non-negligible.

5.10.2.4. Consequence assessment

Spread

Once established in the environment of the home garden, *P. intermedium* or *P. vexans* could spread within the private garden area via rain, heavy irrigation, or movement of infested crop debris or alternative hosts. The likelihood for *Pythium* sp. to spread within these established areas, i.e., private gardens or garden waste areas is considered moderate and is therefore, non-negligible.

Pythium sp. may spread from private gardens or garden waste areas to the wider environment, including commercial onion production areas. However, several factors in combination would be required for this to occur. For example, *Pythium* sp. would need to be in close proximity to a commercial growing area. Rainfall or irrigation levels sufficient to facilitate movement of the pathogen from a home garden to a planted site within a commercial production area would need to occur. For infested crop debris, physical transfer and incorporation of the material into a commercially planted field site would need to occur. It is considered unlikely that the above pathways would occur in combination in commercially planted field sites. As such, the likelihood for *P. intermedium* and *P. vexans* spreading from private gardens or garden waste areas to commercial onion production areas is considered low and is therefore, non-negligible.

It is noted that *P. intermedium* and *P. vexans* could also spread via the same pathways to other commercial crops that are alternative hosts of the pathogen, e.g., *Brassica*, *Camellia*, *Citrus*, *Dianthus* (carnation), *Eucalyptus* (Eucalyptus tree), *Hydrangea* (hydrangeas), *Linum* (flax), *Lupinus* (lupins), *Lycopersicon esculentum* (tomato), *Persea americana* (avocado), *Poaceae* (grasses), *Prunus persica* (peach), *Pyrus* (pears), *Solanum tuberosum* (potato), *Spinacia oleracea* (spinach), *Vitis* (grape), and *Zingiber officinale* (ginger). The likelihood of this occurring is also considered low and is therefore, non-negligible.

Economic consequences

Specific information about the economic impact of *Pythium* on onion or its alternative hosts is not available. If the pathogen was to spread within private gardens, the economic damage would not be considered significant because it would be limited to a confined area and the effect would be local. As such, the likelihood is negligible that *Pythium* would have economic consequences on private gardeners.

In contrast, significant economic consequences could result if *Pythium* was to spread from private gardens to commercial production areas. In onion growing areas of New York (which has a similar climate to that of New Zealand onion growing areas) yield losses due to *Pythium* spp. can be as high as 30% in severely affected areas (Stivers 1999). Infected seedlings that become symptomatic after emergence quickly collapse and die. Plants infected after the seedling stage seldom die but they can become severely stunted. Leaves become yellow, which progresses from the leaf tip to the base; older leaves are most severely affected. Leaves may become wilted in the most severely affected plants (Schwartz & Mohan 2008).

Based on the above information, the likelihood is high that *P. intermedium* and *P. vexans* would have moderate economic consequences in New Zealand. It is noted that both conventional and organic commercial growers of barley, onions, carrots, sugarbeet, *Brassica*, *Camellia*, *Citrus*, *Dianthus* (carnation), *Eucalyptus* (Eucalyptus tree), *Hydrangea* (hydrangeas), *Linum* (flax), *Lupinus* (lupins), *Lycopersicon esculentum* (tomato), *Persea americana* (avocado), *Poaceae* (grasses), *Prunus persica* (peach), *Pyrus* (pears), *Solanum tuberosum* (potato), *Spinacia oleracea* (spinach), *Vitis* (grape), and *Zingiber officinale* (ginger) could be affected.

Environmental consequences

While there is no evidence of *P. intermedium* or *P. vexans* acting as pathogens on New Zealand native flora, these pathogens have a wide host range that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species (e.g. *Daucus*, *Cucumis*, *Beta*, *Coniferae*, *Persea*, *Lycopersicon* etc). As such, the likelihood is low that *P. intermedium* and *P. vexans* could establish on a native species or significant urban species and have a low unwanted environmental impact within New Zealand.

Human health consequences

P. intermedium and *P. vexans* are not known to be of any significance to human health.

5.10.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that if *P. intermedium* and *P. vexans* spread from private gardens to commercial growing areas it could cause moderate economic and low environmental consequences to New Zealand.

5.10.2.6. Risk estimation

The likelihood estimate is moderate that *P. intermedium* and *P. vexans* would be associated with onion bulbs on entry into New Zealand; low that *P. intermedium* and *P. vexans* would be exposed to the environment; moderate that any *P. intermedium* and *P. vexans* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *P. intermedium* and *P. vexans* would spread from private garden areas to commercial onion production areas; high that spread to commercial production areas would result in moderate unwanted economic consequences and low environmental consequences to New Zealand.

As a result, the risk estimate for *P. intermedium* and *P. vexans* associated with imported onion bulbs for consumption is non-negligible and should be considered a hazard.

5.10.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *P. intermedium* and *P. vexans* on onion (i.e., much of the information is based on other *Pythium* spp.). As such, the risk assessment should be reviewed once further relevant information becomes available.

5.10.3. Risk management

5.10.3.1. Risk evaluation

Since the risk estimate for *P. intermedium* and *P. vexans* associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

5.10.3.2. Option evaluation

There are a number of biosecurity risk management options available for *P. intermedium* and *P. vexans* on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *P. intermedium* and *P. vexans*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *P. intermedium* and *P. vexans*;
- **c.** Inspection of onion plants or bulbs for *P. intermedium* and *P. vexans*;
- **d.** Treatment of onion bulbs for *P. intermedium* and *P. vexans* by a suitably efficacious method;
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *Phytophthora* species in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *P. intermedium* and *P. vexans* in the absence of human assistance is limited to relatively small distances, and symptoms of *P. intermedium* and *P. vexans* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *P. intermedium* and *P. vexans* in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *P. intermedium* and *P. vexans*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *P. intermedium* and *P. vexans*, inspection of healthy bulbs for *P. intermedium* and *P. vexans* would not be an effective phytosanitary measure.

P. intermedium and *P. vexans* infections will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for *P. intermedium* and *P. vexans* symptoms and tested as appropriate. This inspection could be used in with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *P. intermedium* or *P. vexans* without also negatively affecting the condition of the onion bulbs. Fungi would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Fungicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As the pathway for establishment of *P. intermedium* and *P. vexans* in New Zealand requires bulb waste to be disposed or planted into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *P. intermedium* and *P. vexans*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for *P. intermedium* and *P. vexans* on onion (*Allium cepa*) bulbs imported fromChina for consumption:

a) Field survey at the most susceptible stage of onion growth (seedlings) and in conditions suitable for disease expression (wet) to ensure *P. intermedium* and *P. vexans* disease levels are very low (e.g. 0.01%)[9]; and

b) Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8).

c) Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and

d) Onion bulbs showing disease symptoms (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic infection of *P. intermedium* or *P. vexans* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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5.11. *Thanatephorus cucumeris*

5.11.1. Hazard identification

5.11.1.1. Aetiologic agent

Thanatephorus cucumeris (A B Frank) Donk 1956 (anamorph *Rhizoctonia solani*); Basidiomycota: Ceratobasidiaceae.

5.11.1.2. New Zealand status

Thanatephorus cucumeris is recorded as present in New Zealand (PPIN 2008).

Rhizoctonia solani is a basidiomycete that occurs worldwide and is an important pathogen on seeds, roots, hypocotyls and stems of many vegetable and agronomic crops, including onion (Julián *et al.* 1996, Sumner 2008, McMillan 1995).

Rhizoctonia solani is a very complex species that is composed of anastamosis groups (AG) within which vegetatively compatible interactions take place (Ceresini 1999, Cubeta & Vilgalys 1997, Farr *et al.* 1989) and can be used to identify isolates. Twelve AGs (AG 1-12) have been described for *R. solani* (Ceresini 1999, Cubeta & Vilgalys 1997, Farr *et al.* 1989). AG groups appear to have different biological properties (in compatibility and sterility document) and therefore, differ in their ability to cause disease on crops (Cubeta & Vilgalys 1997, Windels *et al.* 1994). *Rhizoctonia solani* AG-4 causes seed rot and seedling disease in onions (Sumner 1996).

Rhizoctonia solani has been recorded in New Zealand on a number of different hosts, including potato, tomato, garlic, carrot, grape, pea, wheat, *Dianthus*, bean, strawberry, asparagus, and maize (PPIN 2008). The *Rhizoctonia solani* AG-4 has a recorded host range that includes tomato, pea, spinach, potato, slash and loblolly pine seedlings, stevia, snap bean, and onion (CPC 2007). Potato and tomato host a number of the *Rhizoctonia solani* groups and the cereals are restricted to AG-2 and AG-8. Unique to AG-4 are onions (*Allium*), pea (*Pisum*) and *Pinus*. The recorded hosts in New Zealand include garlic (*Allium sativum*) and pea (*Pisum sativum*), suggesting the *Rhizoctonia solani* isolate likely to be associated with onion bulbs imported from China, namely AG-4, is present in New Zealand.

5.11.1.3. Hazard identification conclusion

Based on the likely presence of *Rhizoctonia solani* AG-4 in New Zealand, it is proposed that *R. solani* not be considered a potential hazard and as such no further assessment is required.

5.11.1.4. Assessment of uncertainty

To date no record has been found of *Rhizoctonia solani* on *Pinus* species or onion (*Allium cepa*) in New Zealand, casting some doubt on the anastamosis groups present.

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6. Analysis of potential hazards - Insects

Thirty-eight insects are listed in Appendix 2 (see table 3.1 section 3.3) as being potential hazards associated with onion bulbs imported from China for consumption. One of these insects, *Gryllotalpa africana* Palisot de Beauvois (Orthoptera: Gryllotalpidae) or the 'Africna mole cricket', can feed on onion bulbs in the ground but is only likely to be associated with onions in international trade in the adult stage and as a hitchhiker. Normal commercial quality standards for onion produce would be expected to be adequate to ensure adult *Gryllotalpa africana* are unlikely to be associated with the fresh onion (*Allium cepa*) bulb pathway from China.

The remaining 37 insects are divided into 8 groups in the following sections: Diptera (leaf mining flies), Diptera (other phytophagous flies), Diptera (saprophagous flies), Coleoptera (beetles), Hempitera (bugs), Lepidoptera (leaf mining moths), Lepidoptera (other moths), and Thysanoptera (thrips).

6.1. Diptera (flies – leaf miners)

The Diptera are commonly known as (true) flies and include many familiar insects such as mosquitoes, black flies, midges, fruit flies, blowflies and houseflies. Flies are generally common and can be found all over the world except Antarctica. Many species are particularly important as vectors of disease in man, other animals, and plants. The major morphological feature which distinguishes flies from other insects is their reduced hind wings, termed halteres. The Diptera are divided into two suborders, the Nematocera and Brachycera. The Nematocera include generally small, delicate insects with long antennae such as mosquitoes, crane-flies, midges and their relatives. The Brachycera includes more compact, robust flies with short antennae (Wiegmann & Yeates 2007).

6.1.1. Hazard identification

6.1.1.1. Aetiologic agents

Liriomyza bryoniae (Kaltenbach, 1858); Diptera: Agromyzidae, commonly known as the 'Tomato leafminer'.

Liriomyza cepae (Hering, 1927) (synonym *Phytobia cepae*) Hering; Diptera: Agromyzidae, commonly known as the 'Stone Leek Leaf Miner'.

Liriomyza chinensis (Kato, 1949); Diptera: Agromyzidae, commonly known as the 'Stone Leek Leafminer'.

Liriomyza huidobrensis (Blanchard, 1926); Diptera: Agromyzidae, commonly known as the 'Serpentine leafminer'.

Liriomyza nietzkei (Spencer, 1973); Diptera: Agromyzidae, commonly known as the

Liriomyza sativae (Blanchard, 1938); Diptera: Agromyzidae, commonly known as the 'Vegetable leafminer'.

Liriomyza trifolii (Burgess in Comstock, 1880); Diptera: Agromyzidae, commonly known as the 'American serpentine leafminer'.

6.1.1.2. New Zealand status

The insect species listed above have not been recorded as being present in New Zealand (PPIN 2008, Scott & Emberson 1999).

6.1.1.3. Biology and epidemiology

Liriomyza species

Liriomyza species are small leaf mining flies, 1-3 mm in length. The adults have a characteristic yellow spot on the back (the scutellum) but laboratory analysis is required to confirm the identification of each species. They cause damage by puncturing the leaf surface to feed on the leaf tissue and to lay eggs. When the eggs hatch, the larvae tunnel within the leaf tissue forming damaging and disfiguring mines. Leaf mines and punctures reduce the quality of high value horticultural crops in addition to reducing the photosynthetic ability of the plant.

There are over 370 species of *Liriomyza* known worldwide, however, the majority are not considered pests as they each have a restricted host range that does not include economically important plant species (DEFRA 2007). *Liriomyza* are distributed widely but are most commonly found in temperate areas with relatively few species in the tropics (Parrella 1987). While *L. chinensis* and *L. nietzkei* have relative narrow host ranges limited to species within the genus *Allium*, the other *Liriomyza* species being considered here, namely *L. bryoniae*, *L. cepae*, *L. huidobrensis*, *L. sativae* and *L. trifolii*, are all considered polyphagous.

Soon after adult emergence, pairing occurs on the leaves and eggs are deposited singly in slits below the epidermis, predominantly at the centre or base of the leaf. The preoviposition period is 1 to 2 days and the oviposition period lasts 7 to 10 days (Neitzke 1953). Adult females live for 8 to 20 days and adult males for 3-15 days (Neitzke 1953, Parrella 1987). The females puncture the host leaves, usually near the tip, with the ovipositor and feed on the sap. Eggs are inserted into the plants and the larvae mine in the leaves, which causes white streaking in the leaves (Neitzke 1953). Egg-laying capacity varies considerably within the genus, with ranges from less than 100 to more than 600 eggs per female (Parrella 1987). The larvae hatch in approximately 2 to 8 days at 21^{o}C in the laboratory, reaching the base of the leave by the time they were fully fed (Neitzke 1953, Parrella 1987). The three larval instars last 2 to 5, 1 to 4 and 2 to 8 days, respectively (Neitzke 1953). Larvae are unable to leave one leaf and enter another (Parrella 1987).

When fully grown, larvae cut their way out of the leaf and fall to the ground after which time they burrow into the ground for pupation. Pupation occurs in the soil at a depth of 5 to 9 cm and total development time of the pupa is about 8-11 days. Pupae overwintered in diapause and can survive freezing temperatures (Neitzke 1953, Parrella 1987). Larvae overwinter in the soil from late November and activity is resumed from early March (spring) in southern districts and from early April in central and northern ones (Chou *et al.* 1970).

Adults are able to withstand freezing temperatures for short periods. Egg non-viability may be as high as 20% and is dependent on temperature (Parrella 1987). In agricultural fields the within-field spread of leafminers begins slowly at first, generally originating in weed hosts in borders adjacent to field crops. Prevailing winds influence the rate and direction of dispersal from the source of the infestation (Parrella 1987). The photosynthetic ability of the plants is often greatly reduced as the chlorophyll-containing cells are destroyed. Severely infested leaves may fall, exposing plant stems to wind action, and flower buds and developing fruit to scald. The presence of unsightly larval mines and adult punctures in the leaf palisade of ornamental plants can further reduce crop value. In young plants and seedlings, mining may cause considerable delay in plant development, leading to plant loss (CPC 2007).

Control with insecticides is usually complicated by the insect's biology, i.e. fast development time; smallness and high mobility of adults; relatively long pupal stage occurring in the soil; high reproductive capacity; and egg and larval stages in and protected by leaf tissue. *Liriomyza* species are also known to develop insecticide resistance relatively quickly (Parrella 1987).

Agrozymid leafminers are known to have over 40 insect parasitoids from the Pteromalidae and Hymenoptera families in their native and invaded ranges. The literature indicates that parasitoids attack the larval and pupal stages of the leafminers, i.e., when the larvae are feeding on the leaf tissue or the pupae are in the soil (Cikma *et al.* 2006, Tran & Takagi 2006, Giang & Ueno 2006, Bjorksten *et al.* 2004, Shepard *et al.* 1998, Parrella 1987).

The following species-specific information is also provided:

Liriomyza bryoniae

L. bryoniae is a highly polyphagous species and important primary hosts of economic importance include cabbages (*Brassica oleracea* var. *capitata*), cucumbers (*Cucumis sativus*), lettuces (*Lactuca sativa*), courgettes (*Cucurbita pepo*), melons (*Cucumis melo*), tomatoes (*Lycopersicon esculentum*) and watermelons (*Citrullus lanatus*) (Abul-Nasr & Assem 1961, Spencer 1972, Lee *et al*. 1990). In the pan-temperate region, *L. bryoniae* has been reported to complete its life cycle on plants from 16 families (EPPO/CABI 1996).

If a leaf is not sufficient for full development, then the larva can move up in the stem into a second leaf. The principal impact of the fly is through the larvae mining into leaves and petioles; the photosynthetic ability of the plant is reduced and growth is retarded. Young host plants are particularly susceptible to attack and frequently die (EPPO/CABI 1996). *L. bryoniae* is able to transmit tobacco mosaic tobamovirus (CPC 2007). Information on the mechanism of virus transmission has been difficult to come by. This analysis will assume the worst most likely case: that virus acquisition and transmission occur either through larval and adult life stages or alone by the adult.

Liriomyza cepae

Field and laboratory investigations of *L. cepae* in Germany showed that adult flight began early in May, reached its peak during the first half of June and virtually ceased in July, when the onions were harvested. The flies were present in greatest numbers under conditions of high temperatures and low relative humidity and least numerous under the reverse conditions. In Taiwan there are seven to ten generation a year of *L. cepae* (Neitzke 1953).

In vitro studies found that a single *L. cepae* female may deposit 27 eggs. The larvae of *L. cepae* mine not only in the leaves on onions but also the layers of the onion itself (Frankenhuyzen 1977). Some pupae collected in the field in August did not give rise to adults until September of the following year (Neitzke 1953). Pupae overwinter in the soil from late November and activity is resumed from early March in southern districts and from early April in central and northern ones (Chou *et al.* 1970, Neitzke 1953). The fly is parasitised to a considerable degree by *Halticoptera patellana* (Dalm) (Pteromalidae: Miscogasterinae) and by a Eulophid (Hymenoptera: Eulophidae) (Chou *et al.* 1970).

Liriomyza chinensis

In recent years, *L. chinensis* has become an important pest of *Allium* spp. in SE Asia (Tran *et al*. 2007) including Vietnam (Andersen *et al.* 2002) and Indonesia (Rauf *et al*. 2000). Although restricted to *Allium* spp., there is anecdotal evidence in Indonesia that pupae of this species can lodge in the skins of the onion bulbs and so could be transported between regions relatively easily (Malipatil & Ridland 2008).

Liriomyza huidobrensis

L. huidobrensis is highly polyphagous and is considered a serious pest of potato, vegetables and ornamental plants in the field and glasshouses in many parts of the world. Sixteen families of plants have been recorded as hosts, without a clear preference for any particular family (CPC 2007). *L. huidobrensis* pupates within the leaf, whereas other species usually pupate externally, either on the foliage or in the soil just beneath the surface. Pupation is adversely affected by high humidity and drought (EPPO/CABI 1996). As *L. huidobrensis* pupates in leaves, pupae could be present in onion bulbs at the time of harvest (Martin pers. com. 2008)

All stages of *L. huidobrensis* are killed within a few weeks by cold storage at 0°C. Newly laid eggs are, however, the most resistant stage and can be maintained under normal conditions for 3-4 days to allow eggs to hatch. Subsequent storage of infested material at 0°C for 2 weeks should then kill off the larvae of *L. huidobrensis* (EPPO/CABI 1996, Webb & Smith 1970[10]).

It is primarily a tropical and warm temperate species, but in some parts of Europe it has shown an ability to become a major pest of a wide variety of ornamental or vegetable crops grown under glass (CPC 2007). Pupae can survive outdoors in Northern Europe (van der Linden 1993). The ability of *L. bryoniae* and *L. huidobrensis* to overwinter was investigated during 1990-92 in the Netherlands. Although mortality of over wintering pupae was high, some pupae of both species survived a winter with 30 frost days and a minimum temperature of -11.5°C.

Liriomyza nietzkei

If *L. nietzkei* can occur in large numbers on host species (onion (*Allium cepa*), leek (*Allium porrum*) and possibly other *Allium* species), has the potential to cause severe damage, and is treated as a serious pest by most authors. However, outbreaks seem to be rather intermittal and local (Dempewolf 2008). *L. nietzkei*, *Liriomyza cepae*, and *Liriomyza chinensis* are often mis-diagnosed and publications referring to *Liriomyza* biology prior to 1973 should be considered with care (Dempewolf 2008).

As with the other *Liriomyza* miners on *Allium* the larvae dwell in the leaves and the stem layers of the plant (Dempewolf 2008). In the Alessandria district of Italy, the adults of *L. nietzkei* emerge at the beginning of May, 90% being females; pairing occurs 2-3 days later and oviposition after a further 2-3 days, in the young leaves of onion. Leaves are normally occupied by numerous larvae, which make thread-like mines; leaves containing many mines rapidly wither and die. Larval development takes about 20 days, after which the larvae pupate in the soil. New adults emerge from mid-June to early July and oviposit on leek and

10 The leaf miner on which Webb & Smith (1970) worked was identified as *Liriomyza munda* which has been synonymised with *L. sativae*, which is not normally regarded as a pest of Chrysanthemums. However, it is likely that the species used by Webb & Smith (1970) was *Liriomyza trifoloii*, the leaf miner that was the first to be a major problem on Chrysanthemums (Martin pers. com. 2008) onion, but since the plants are then older and stronger, the damage is usually less severe than in the earlier infestations. In 1968, whole beds of onion plants were destroyed, but in subsequent years attacks were much lighter. *L. nietzkei* has not been found on leek or onion near Milan or Bergano or in other parts of northern Italy, and it is concluded that infestation remains restricted to a small area (Suss 1975). Nietzke (1954) reported only one generation for Germany, the flies emerge in May (spring) and remain abundant until July (mid summer).

Liriomyza sativae

This species prefers hosts within the Solanaceae and Fabaceae, but has also been recorded on seven other families. As well as onion, *L. sativae* has been recorded on lucerne, *Amaranthus* spp., *Aster* spp., aubergines, *Capsicum annuum*, celery, clovers, cucumbers, *Cucurbita pepo*, *Dahlia* spp., faba beans, *Lathyrus* spp., maize, melons, peas, *Phaseolus lunatus*, *P. vulgaris*, potatoes, tomatoes, *Tropaeolum* spp. and *Igna* spp (CPC 2007, EPPO/CABI 1996).

L. sativae has been recorded as causing 30% defoliation in an 80-ha field of tomatoes in the USA. Cucurbit crops severely attacked in the seedling stage by *L. sativae* can be destroyed. Young plants are particularly susceptible to damage and consequent reduced efficiency or death, whilst older plants may also be seriously damaged through leaf loss due to many mines occurring in each leaf. Damage is caused by larvae mining into leaves and petioles. *L. sativae* usually pupates externally, either on the foliage or in the soil just beneath the surface. *L. sativae* is reported to inefficiently transmit celery mosaic potyvirus and papaya ringspot potyvirus, neither of which are found infecting onions (*Allium* spp.). All in-plantae lifestages of *L. sativae* (eggs and larvae) are killed within a few weeks by cold storage at 0°C (CPC 2007, EPPO/CABI 1996, Webb & Smith 1970[11]) whereas about 5% of larvae survived 8 weeks of storage at 4.5°C (Zitter *et al*. 1980).

L. sativae will spread in any suitable habitat with a warm summer temperature, especially in temperature-controlled glasshouses where reproduction can become almost continuous. Particularly suitable are monocultures of primary hosts (such as Solanaceae, Leguminosae and Asteraceae) which can give rise to very large fluctuations in populations, particularly in glasshouse conditions where natural migration of hymenopterous parasites is difficult. At harvest, when the primary host is removed, there are usually enough suitable wild hosts locally to act as a reservoir and ensure continuation of *L. sativae* until the fields, or glasshouses, are again planted with preferred hosts (CPC 2007).

The likelihood of *L. sativae* acting as a vector for potyviruses is considered remote under natural conditions, although viruses were vectored under laboratory conditions (Zitter *et al*. 1980). Information on the mechanism of virus transmission has been difficult to come by. This analysis will assume the worst most likely case: that virus acquisition and transmission occur either through larval and adult life stages or alone by the adult.

Liriomyza trifolii

L. trifolii has been recorded from 25 families with preference shown for the Asteraceae, including the following important crops: *Aster* spp., beetroots, *Bidens* spp., *Brassica chinensis*, *Capsicum annuum*, celery, Chinese cabbages, chrysanthemums, cotton, cucumbers, *Dahlia* spp., *Dianthus* spp., garlic, *Gerbera* spp., *Gypsophila* spp., *Lathyrus* spp.,

11 The leaf miner on which Webb & Smith (1970) worked was identified as *Liriomyza munda* which has been synonymised with *L. sativae*, which is not normally regarded as a pest of chrysanthemums. However, it is likely that the species used by Webb & Smith (1970) was *Liriomyza trifolii*, the leaf miner that was the first to be a major problem on chrysanthemums (Martin pers. com. 2008) leeks, lettuces, lucerne, marrows, melons, onions, peas, *Phaseolus coccineus*, *P. lunatus*, *P. vulgaris*, potatoes, spinach, tomatoes, *Tropaeolum* spp., *Vigna* spp., watermelons and *Zinnia* species (EPPO/CABI 1996).

In chrysanthemum cuttings, *L. trifolii* survives cold storage at 1.7°C for at least 10 days. Newly laid eggs of *L. trifolii* in chrysanthemums survived for up to 3 weeks in cold storage at 0°C (Webb & Smith 1970[12]). Eggs incubated for 36-48 h were killed after 1 week under the same conditions (Webb & Smith 1970). All stages of larvae were killed after 1-2 weeks at 0°C (Webb & Smith 1970). Sixteen days at 1.1°C is required to cause 100% mortality of *L. trifolii* eggs in celery (Parrella 1987). Webb & Smith (1970) proposed that chrysanthemum cuttings should be maintained under normal glasshouse conditions for 3-4 days after lifting to allow eggs to hatch. Subsequent storage of the plants at 0°C for 1-2 weeks should then kill off the larvae.

> Webb & Smith (1970) looked at egg hatching and larval pupation on a relatively small sample of infested chrysanthemum cuttings. In the control samples (no cold treatment) the combined number of hatching eggs in the two tests undertaken was 560 with 190 of the resulting larvae pupating. Incubating eggs for more than two days prior to treatment resulted in no survivors after one week in storage at 0ºC. These results provide a treatment efficacy of 99.4643% (or one survivor in 187) at the 95% level of confidence (Couey & Chew 1986).

L. trifolii is now the major pest of chrysanthemums in North America. Vegetable losses in the USA are also considerable, for example losses for celery were estimated at US$ 9 million in 1980. It was noted, however, that damage to celery during the first 2 months of the 3-month growing season was insignificant and largely cosmetic, whereas considerable yield loss resulted from pest presence during the final month. 1.5 million larval mines per hectare were recorded from onion in Iowa. *L. trifolii* is also known to be a vector of plant viruses (EPPO/CABI 1996). The occurrence of leaf punctures from *L. trifolii* significantly increased the incidence of *Alternaria* leaf blight lesions (*Alternaria cucumerina*) on muskmelon leaves (*Cucumis melo*) (CPC 2007) by providing wound sites for infection.

Liriomyza parasitoids

As stated earlier, agrozymid leafminers are known to have over 40 insect parasitoids from the Pteromalidae and Hymenoptera families in their native and invaded ranges. Parasitoids of agrozymid species are usually polyphagous and therefore pose a risk to native fauna in areas they are introduced (Larios 2007).

There are two main types of parasitoids known to science: *Idiobiont* and *Koinobiont*. Idiobiont parasitoids are those which prevent any further development of the host after initial parasitization, which typically involves a host life stage which is immobile (e.g., an egg or pupa), and idiobiont parasitoids usually live outside the host. Koinobiont parasitoids allow the host to continue its development and often do not kill or consume the host until the host is about to either pupate or become an adult. As such koinobiont parasitoids typically live within or on an active, mobile host. Koinobiont parasitoids are more host specific than idiobiont parasitoids (Althoff 2003).

12 The leaf miner on which Webb & Smith (1970) worked was identified as *Liriomyza munda* which has been synonymised with *L. sativae*, which is not normally regarded as a pest of chrysanthemums. However, it is likely that the species used by Webb & Smith (1970) was *Liriomyza trifolii*, the leaf miner that was the first to be a major problem on chrysanthemums (Martin pers. com. 2008)

6.1.1.4. Hazard identification conclusion

Based on the accepted absence of the *Liriomyza* species (*L. bryoniae*, *L. cepae*, *L. chinensis*, *L. huidobrensis*, *L. nietzkei*, *L. sativae*, *L. trifolii*) in New Zealand, the potential ability of larvae and pupae and any associated hymenopterous parasitoids to be imported on/in onion bulbs, and the potential ability of these insects to cause damage to crops or native insects in New Zealand, it is proposed that they be considered potential hazards requiring further assessment.

6.1.2. Risk assessment

Because the overall biology is similar for all seven species in the *Liriomyza* genus, these species will be considered together as *Liriomyza* sp. in the following risk assessment with significant differences in biology noted as appropriate

6.1.2.1. Entry assessment

The likelihood of larvae entering New Zealand is difficult to determine, as there is little information available about the prevalence of these insects in China and their likely association with onion bulbs in international trade.

The likely association of a given *Liriomyza* species with imported bulbs would depend on in-field infestation levels and life cycle characterises. For the Liriomyza species *bryoniae*, *cepae*, *nietzkei* and *sativae*; pupation only usually occurs in the soil and as such only larvae still within the leaves could potentially be associated with onion bulbs that have had the aboveground leaf material removed. For the remaining species (*chinensis*, *huidobrensis* and *trifolii*), pupation may occur within the leaf allowing both larvae and pupae to potentially be associated with the bulb. Leaf minor larvae and/or pupae would only become associated with onions bulbs in the field prior to harvest.

The *Liriomyza* species would be less apparent than saprophagous species as they could be hidden under the outer layer of the onion bulb. Larvae complete development in around 10 to 20 days under favourable temperatures. As the larvae found in bulbs would be close to the end of their development, a period of cooling would be required to ensure the development rate was significantly slowed to prevent pupation. However pupation could occur within the onion bulb allowing entry of a viable lifestage into New Zealand.

It should also be noted that the entry pathways for infesting insects are also relevant to any associated insect parasitoids. In the case of idiobiont parasitoids, as the larvae would be parasitised within the aboveground foliage of the onion plant in the field, the larvae would remain in these discarded portions of the plant at harvest. As such there is a negligible likelihood that idiobiont parasitoids would be associated with onion bulbs in international trade. As koinobiont parasitoids allow the host larvae to remain mobile and continue development, the likelihood of these parasitoids entering New Zealand on onion bulbs from China is directly linked to the likelihood of the entry of the larvae themselves. The preditation rate of *Liriomyza* larvae by parasitoids is recorded as being less than 10% under agricultural conditions at the time of harvest (Tran *et al.* 2007). Therefore the likelihood of the entry of koinobiont parasitoids is expected to be at least 10 times lower than the host larvae themselves. Once in the bulb the larvae would not be exposed to preditation by parasitoids.

The likelihood of entry of *Liriomyza* sp. low and are therefore considered non-negligible. The entry of koinobiont parasitoids, which must enter on *Liriomyza* larvae infesting the imported bulbs, is considered highly unlikely and as such is negligible.

6.1.2.2. Assessment of exposure

Exposure could occur through the disposal of infested onions into composts or other garbage waste material. As imported onion bulbs are primarily destined for consumption, it is expected that most will be consumed or otherwise processed. It is estimated that only around 1% of the bulbs will be discarded into household composting systems (see section 3.2.1.1). When fully grown, larvae cut their way out of the leaf, fall to the ground and burrow into the ground for pupation. Pupation occurs in the soil at a depth of 5 to 9 cm and total development time of the pupa is about 8-11 days. Pupae overwintered in diapause and can survive freezing temperatures (Neitzke 1953, Parrella 1987). Alternatively adult flies may emerge from pupae carried within the waste bulbs.

An alternative exposure pathway is through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets and considerable onion waste is generated from which adults could disperse to surrounding host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (pers. com. Martin 2008). Flies would need to emerge from pupae carried within the waste bulbs.

The likelihood for the exposure of *Liriomyza* spp. is considered low and is therefore non-negligible.

Flies emerging from pupae may vector viruses from the onion to surrounding host plants. As there are no known viruses of concern likely to be associated with onions in China, the likelihood of *Liriomyza* spp. vectoring any viruses of concern into New Zealand is considered negligible.

6.1.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of any of the species of insects listed would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing could also be conducive for the development of larvae into pupae and for pupae to develop into adults. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007). Many of the *Liriomyza* spp. would find suitable conditions for establishment in most parts of New Zealand.

Although environmental conditions may be conducive for larval survival, pupal development; overwintering and adult development; and emergence, several factors would need to occur in combination in order for a population to establish. Firstly, each species requires males and females for mating. As such, both sexes need to develop from pupae in waste areas and both sexes need to emerge and locate each other under conditions suitable for mating (environmental and chemical cues). For the *Liriomyza* spp. with host ranges restricted to *Allium*, this would further be influenced by the vicinity of onions and other *Allium* spp. to the site of emergence, as volatiles emitted from *Allium* spp. are important chemical cues for successful mating in these species.

Secondly, a sufficient number of males and females would need to be produced and emerge in order to establish a population in the first, and subsequent, seasons. The numbers of male and female adults initially emerging in the New Zealand environment would be influenced by (1) the numbers of larvae originally infesting onion bulbs in the field in China and (2) the numbers of infested bulbs discarded in New Zealand. It is difficult to estimate the number of larvae that could be present in infested onion bulbs in the field in China.

Due to the low likelihood of *Liriomyza* life stages entering on imported onions, the numbers of emerging male and female adults of *Liriomyza* spp. is expected to be insignificant and therefore negligible and as such no further assessment is required.

6.1.2.4. Risk estimation

The likelihood estimate is low that *Liriomyza* spp. would be associated with onion bulbs on entry into New Zealand; low that these insects would be exposed to the environment; and negligible that any *Liriomyza* spp. life stages that are exposed to the environment would successfully establish in private gardens in New Zealand.

As a result, the risk estimate for *Liriomyza* spp., and any accompanying parasitoids, associated with onion (*Allium cepa*) bulbs imported from China for consumption is negligible and should not be considered a hazard on this pathway.

6.1.2.5. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also considerable uncertainty in terms of the epidemiology of these insects on onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

6.1.3. References

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6.2. Diptera (flies – other phytophagous)

6.2.1. Hazard identification

6.2.1.1. Aetiologic agents

Bradysia odoriphaga (Yang & Zhang 1985); Diptera: Sciaridae, commonly known as the 'Chinese chive maggot'.

Delia antiqua (Meigen 1826); Diptera: Anthomyiidae, otherwise known as *Hylemya antiqua* or *Phorbia antiqua*, and commonly known as the 'Onion fly' or 'Onion maggot'.

Delia floralis (Fallén 1824); Diptera: Anthomyiidae, commonly known as the 'Turnip maggot'.

6.2.1.2. New Zealand status

The insect species listed above have not been recorded as being present in New Zealand (PPIN 2008, Scott & Emberson 1999).

6.2.1.3. Biology and epidemiology

Bradysia odoriphaga

Adult fungus gnats (*Bradysia* spp., Sciaridae) are small (~2.5 mm long), dark, mosquito-like flies, with delicate long legs and antennae and one pair of wings (Atkinson 2000). Adults are weak fliers, typically found drifting around nursery plants, under benches, or running over the pot or media surface (Atkinson 2000).

Mated adult females deposit up to 200 eggs singly or in clusters in crevices or cracks on the surface of the growing media. Adult females prefer to lay eggs where fungus is growing. The offspring of a given female will either be all males or all females. At 70-75°F (21-24°C), these whitish-yellow eggs hatch in 3-6 days. The four larval instars then feed for about 2 weeks and usually pupate near the soil surface within a thread chamber. After 3-7 days in the pupal stage, adults emerge and live for up to 8 days. They can develop from egg to adult in 3-4 weeks. This life cycle is dependent on temperature and as temperatures decrease, the length of their developmental time increases (Sanderson 2009).

In temperate areas, fungus gnats are major insect pests in greenhouses (Cloyd *et al*. 2007) all year round and in field crops during warmer months (Yuan *et al*. 2006). The most suitable temperature range for *B. odoriphaga* was reported as being from 20 to 25°C (Mei *et al*. 2004). Fungus gnat larvae are the damaging stage of this insect. They are usually concentrated in the top 1-2 inches of the growing media (Sanderson 2009), but may be found throughout the pot media profile or burrowing into the plant stem near the soil line (Atkinson 2000). The larvae are translucent, legless, and worm-like, with a distinctive black head capsule, and are about ¼ inch long just prior to pupation (Sanderson 2009). Larvae prefer to feed on fungi rather than healthy plant tissue. Although fungus gnat larvae can eat plant material, they need fungi in their diet for optimal survival, development, and reproduction (Sanderson 2009).

Adults and larvae have been implicated in the transmission of plant fungal diseases, including *Thielaviopsis*, *Pythium*, *Verticillium*, and *Fusarium*. Larvae may transmit fungal plant diseases via their excretion. Adults may transmit these diseases via excretion or by carrying spores of disease organisms on their bodies (Sanderson 2009).

B. odoriphaga can be widely found in China, where the larvae are reported to damage the roots and bulbs of onions affecting normal growth (China 2008). *B. odoriphaga* is also recorded as a serious pest of garlic (*Allium tuberosum*), bunching or spring onion (*Allium fistulosum*) (Xue *et al.* 2005), and chives (*Allium schoenoprasum*).

Delia antiqua and *Delia floralis*

Because onion is listed as a major host of *D. antiqua*, information about the biology, life history and reproduction is provided for this *Delia* species and is assumed similar to that of *D. floralis*. *D. antiqua* (onion maggot) is one of many flies generally known as "root maggots" (*Delia* spp.) but the only species that is restricted to onion and other *Allium* species (Cranshaw 2004).

Studies investigating *D. antiqua* dispersal found that adult flies were captured in large numbers in onion plots in a 740-ha site at locations up to 1.5 km from overwintering sites during the first flight. Damage by onion flies were also observed in the same plots at locations varying from 0.4 to 1.5 km distant from overwintering sites (Straub & Eckenrode 2000, Martinson *et al.* 1988). Though they can disperse over large areas, many remain within a few hundred meters of their emergence sites. Once an onion field is located, they typically remain in or near the borders of the field. Second and third generations emerging from onion fields do not disperse very far (Final IPM Plan 1998).

Host finding by *D. antiqua*, in terms of food and oviposition resources, involves long-range sensory inputs that are both visual and olfactory. The adult flies fly upwind (anemotaxis) toward onion plants, which have volatile attractants, e.g., propyl disulfide and n-dipropyl disulfide (Metcalf 1999). Flies will enter the plume of volatiles from damaged onions several meters downwind of the source, alight on the soil, turn into the wind, and then move upwind toward the source in a series of short flights interspersed with landing and walking (Dinodonis & Miller 1980). This upwind response to host odour has been found to be independent of female ovarian development or mated status, and serves to draw females to their oviposition sites and may assist males in locating sites where females are likely to arrive (McDonald & Borden 1997).

Delia antiqua overwinters in the soil as pupae (Wilsey *et al.* 2007). In most temperate regions, three overlapping generations of larvae occur while three to four generations a year occur in Japan (Wilsey *et al.* 2007, Straub & Eckenrode 2000). In the spring, the first adult flies emerge from pupae with peak flights occurring approximately two weeks later (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000). Adults live between two and four weeks (Cranshaw 2004). As the adults mature (i.e. 7 to 10 days after emergence), they become sensitive to the onion odour and mating typically occurs in or near onion plantings (University of Manitoba 2009). Females lay eggs in soil cracks near the plants or occasionally on the young leaves or plant necks. Each female is capable of laying between 150 and 200 eggs (Straub & Eckenrode 2000). The eggs hatch into larvae 2 to 3 days after they are laid (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000). The optimum temperature for egg laying, survival and development is 20^{o}C (Keller & Miller 1990).

Most newly hatched *D. antiqua* larvae crawl below the soil surface and feed on the roots or burrow into the basal plant of the bulbs. The larvae use their hooked mouthparts to feed on the onion tissue. More than one larva may infest a single plant and if plants are killed before larvae complete their development, larvae immigrate to nearby intact plants in search of additional food (Straub & Ekenrode 2000). Larvae lifespan depends on the temperature, e.g., larvae can live for 45 days at 15°C and 17 days at 25-30°C. Any injury site on the bulb facilitates entry of the larvae (Andaloro & Eckenrode 1983).

When fully developed, the larvae leave the bulb and enter the soil to pupate at a depth of 2.5 to 10 cm. Pupae remain in the soil for two to four weeks before second generation adult emergence occurs in early/mid summer with peak flights taking place in mid summer (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000). Summer diapausing of pupae is induced by high temperatures and long day-lengths (≥23^{o}C under 16 h light/8 h dark days) (Ishikawa *et al.* 2000). The life cycle of the second-generation adult fly continues as described for the first generation.

Emergence of the final flight begins in early autumn when the ground temperature is below 15°C and may continue into late autumn. Winter diapause is induced by low temperatures and short day-lengths (≤15^{o}C under 12 h light/12 h dark days) (Ishikawa *et al.* 1987). Flies that emerge from these pupae the following spring constitute the spring flight (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000).

The larvae cause damage by using their hooked mouthparts to enter the base of the plant. First generation larvae cause very noticeable damage to the seedlings, which first wilt and then become flaccid. Frequently, attacked seedlings die before the larvae are fully-grown; forcing the larvae to move to adjacent plants (Wilsey *et al.* 2007). At the site of damage, bacterial pathogens can invade wounded tissue and the larvae then feed on decomposing tissues (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000).

Second generation larvae feed on developing bulbs, resulting in distorted growth accompanied by rotting tissue, and further feeding by third generation larvae on late season onion bulbs also results in an unmarketable product. Since the majority of commercial onions are stored, infected and rotting onions present a potential for reducing quality of adjacent onions in storage (Wilsey *et al.* 2007). Healthy, undamaged bulbs become increasingly resistant to attack as they begin to mature (FWS 1998).

Onion and leek are recorded as major hosts of *D. antiqua* while shallot (*Allium cepa* var. *aggregatum*), Welsh onion, garlic (*Allium sativum*), and chives (*Allium schoenoprasum*) are recorded as minor hosts (CPC 2007). Turnip rape (*Brassica rapa* subsp. *oleifera*) and cruciferous (Brassicaceae) crops are listed as major hosts of *D. floralis* while onion, leek, rape *(Brassica napus* var. *napus*), collards (*Brassica oleracea* var. *viridis*), radish (*Raphanus sativus*) and white mustard (*Sinapis alba*) are recorded as minor hosts (CPC 2007).

6.2.1.4. Hazard identification conclusion

Based on the accepted absence of *Bradysia odoriphaga*, *Delia antiqua* and *Delia floralis* in New Zealand, the potential ability of larvae and pupae and any associated hymenopterous parasitoids to be imported on/in onion bulbs, and the potential ability of these insects to cause damage to crops or native insects in New Zealand, it is proposed that they be considered potential hazards requiring further assessment.

6.2.2. Risk assessment

Because the overall biology is similar for both species of the *Delia* genus, these species will be considered together as *Delia* sp. in the following risk assessment with significant differences in biology noted as appropriate

6.2.2.1. Entry assessment

The likelihood of larvae entering New Zealand is difficult to determine, as there is little information available about the prevalence of these insects in China and their likely association with onion bulbs in international trade.

Most newly hatched *D. antiqua* larvae crawl below the soil surface and feed on the roots or burrow into the basal plant of the bulbs. The larvae use their hooked mouthparts to feed on the onion tissue. More than one larva may infest a single plant and if plants are killed before larvae complete their development, larvae immigrate to nearby intact plants in search of additional food. Larvae lifespan depends on the temperature, e.g., larvae can live for 45 days at 15°C and 17 days at 25-30°C. Any injury site on the bulb facilitates entry of the larvae.

While being phytophagous, the fungus gnat (*B. odoriphaga*) also requires rotting plant material infected by fungal saprophytes. However, infestation by eggs or larvae of *B. odoriphaga* would only occur in the field prior to or during harvest.

The likelihood of entry of *B. odoriphaga* and *Delia* sp. into New Zealand on onion bulbs from China is moderate and is therefore considered non-negligible.

6.2.2.2. Assessment of exposure

Exposure could occur through the disposal of infested onions into composts or gardens. As imported onion bulbs are intended for consumption, it is expected that most will be consumed and any accompanying insects destroyed. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). In the case of *B. odoriphaga* and the *Delia* sp. the injury of the onion prior to consumption would increase the likelihood that the bulbs would be discarded into compost, allowing the infesting insects the opportunity to complete their life cycle.

Exposure could also occur through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets and considerable onion waste is generated from which larvae could disperse to surrounding soil or host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (pers. com. Martin 2008).

When fully developed, the larvae of *B. odoriphaga* and the *Delia* sp. leave the infested bulb and enter soil to pupate. *B. odoriphaga* larvae feed primarily on fungi and as such can complete their life cycle in soil. Larvae of *Delia* sp. will move to healthy plants in a field when the infested bulb becomes less suitable for larval growth.

The likelihood for the exposure of *B. odoriphaga* and the *Delia* sp. is considered low and is therefore, non-negligible.

6.2.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of any of the species of insects listed would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing could also be conducive for the development of larvae into pupae and for pupae to develop into adults. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007). Many of these Diptera species would find suitable conditions for establishment in most parts of New Zealand.

Although environmental conditions may be conducive for larval survival, pupal development/overwintering and adult development/emergence, several factors would need to occur in combination in order for a population to establish. Firstly, each species requires males and females for mating. As such, both sexes need to develop from pupae in waste areas and both sexes need to emerge and locate each other. For the Diptera species with host ranges restricted to *Allium*, this would further be influenced by the vicinity of onions and other *Allium* spp. to the site of emergence, as volatiles emitted from *Allium* spp. are important chemical cues for successful mating in these species.

Secondly, a sufficient number of males and females would need to be produced and emerge in order to establish a population in the first, and subsequent, seasons. The numbers of male and female adults initially emerging in the New Zealand environment would be influenced by (1) the numbers of larvae originally infesting onion bulbs in the field in China and (2) the numbers of infested bulbs discarded in New Zealand. It is difficult to estimate the number of larvae that could be present in infested onion bulbs in the field in China.

Taking into consideration the very low number of onion bulbs that are predicted to be discarded into the New Zealand environment, the numbers of emerging male and female adults of *B. odoriphaga* or *Delia* sp. is expected to be low. Given the likely abundance of suitable host material for these insects, the successful development of a population from these surviving pupae or adults should be considered moderate and therefore non-negligible.

6.2.2.4. Consequence assessment

Spread

Once successfully established in New Zealand, *B. odoriphaga* and the *Delia* sp. would be expected to spread relatively quickly through the many hosts available. The likelihood of spread is considered high and is therefore non-negligible.

Economic consequences

In temperate areas *B. odoriphaga* are major insect pests of commercial *Allium* species in greenhouses all year round (Cloyd *et al*. 2007) and in field crops during warmer months (Yuan *et al*. 2006). Adults and larvae have been implicated in the transmission of plant fungal diseases, including *Thielaviopsis*, *Pythium*, *Verticillium*, and *Fusarium* (Sanderson 2009).

The larvae of *Delia* sp. cause damage by using their hooked mouthparts to enter the base of the plant. First generation larvae cause very noticeable damage to the seedlings, which first wilt and then become flaccid. Frequently, attacked seedlings die before the larvae are fully-grown; forcing the larvae to move to adjacent plants (Wilsey *et al.* 2007). Second generation larvae feed on developing bulbs, resulting in distorted growth accompanied by rotting tissue, and further feeding by third generation larvae on late season onion bulbs also results in an unmarketable product. At the site of damage, bacterial pathogens can invade wounded tissue and the larvae then feed on decomposing tissues (Wilsey *et al.* 2007, Nault 2007, Li *et al.* 2001, Klass & Snover 2000). Since the majority of commercial onions are stored, infected and rotting onions present a potential for reducing quality of adjacent onions in storage (Wilsey *et al.* 2007). Onion (*Allium cepa*) and leek (*Allium porrum*) are recorded as major hosts of *D. antiqua* (CPC 2007). Turnip rape (*Brassica rapa* subsp. *oleifera*) and cruciferous (Brassicaceae) crops are listed as major hosts of *D. floralis* (CPC 2007).

The most significant economic impacts of *B. odoriphaga* and the *Delia* spp. are likely to be restricted to the warmer areas of New Zealand. These areas are also the major growing areas for the host crops. The likelihood is high that *B. odoriphaga* and the *Delia* spp. would have moderate economic consequences on commercial production of host crops.

Environmental consequences

While there is no evidence of *B. odoriphaga* or the *Delia* spp. infesting on native New Zealand flora, these pests have host ranges that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species (e.g. *Allium*, *Brassica* etc). As such, the likelihood is low that *B. odoriphaga* and the *Delia* spp. could establish on a native species or significant urban species and have a low environmental impact within New Zealand.

Human health consequences

B. odoriphaga and the *Delia* spp. are not known to be of any significance to human health.

6.2.2.5. Conclusion of consequence assessment

Based on the above assessment it is concluded that if any of the *B. odoriphaga* and the *Delia* spp. spread from private gardens to commercial growing areas or the wider environment, they could cause moderate to high economic and low environmental consequences to New Zealand.

6.2.2.6. Risk estimation

The likelihood estimate is moderate that *B. odoriphaga* and the *Delia* spp. would be associated with onion bulbs on entry into New Zealand; low that *B. odoriphaga* and the *Delia* spp. would be exposed to the environment; low that any *B. odoriphaga* and the *Delia* spp. that is exposed to the environment would successfully establish in private gardens in New Zealand; high that *B. odoriphaga* and the *Delia* spp. would spread from private garden areas to commercial onion production areas; and high that spread to commercial production areas would result in moderate unwanted economic and low environmental consequences to New Zealand.

As a result, the risk estimate for *B. odoriphaga* and the *Delia* spp. associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible and should be considered a hazard.

6.2.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns in New Zealand. There is also considerable uncertainty in terms of the epidemiology of these insects on onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

6.2.3. Risk management

6.2.3.1. Risk evaluation

Since the risk estimate for *B. odoriphaga* and the *Delia* spp. associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

6.2.3.2. Option evaluation

There are a number of biosecurity risk management options available for *B. odoriphaga* and the *Delia* spp. on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *B. odoriphaga* and the *Delia* spp.;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *B. odoriphaga* and the *Delia* spp.;
- **c.** Inspection of onion plants or bulbs for saprophagous insects or evidence of infestation by *B. odoriphaga* and the *Delia* spp.;
- **d.** Treatment of onion bulbs for *B. odoriphaga* and the *Delia* spp. by a suitably efficacious method.

Pest free area (PFA)

Given the existence of *B. odoriphaga* and the *Delia* sp. in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

Given the existence of *B. odoriphaga* and the *Delia* sp. in China on crops and weed plant species, it is unlikely that a PFPP could successfully be established for all of the plant species of concern. As the risk attributes leading to successful establishment of saprophagous insects in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *B. odoriphaga* and the *Delia* sp.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *B. odoriphaga* and the *Delia* spp. infestations, inspection of healthy bulbs for *B. odoriphaga* and the *Delia* spp. would not be an effective phytosanitary measure.

Infestations of *B. odoriphaga* and the *Delia* spp. should be readily apparent on bulbs when they are showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for infestations of saprophagous insects. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. No efficacy information has been provided for the following methyl bromide treatment schedule. Given the relatively low likelihood of successful establishment of *B. odoriphaga* and the *Delia* spp. in New Zealand from imported onion bulbs, the following treatment schedule is likely to be more than 99.95% effective against *B. odoriphaga* and the *Delia* spp. and therefore provide an adequate level of efficacy.

Methyl bromide fumigation schedule for internal feeders (and leafminers) in onion bulbs.

Temperature (ºC)	Rate (g/m³)	Minimum Concentration Readings (g/m³) at:					C/T Value (g h/m³)
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	
33 ºC or above	32	26	19	—	—	—	51
26-32 ºC	40	32	24	—	—	—	64
21-25 ºC	48	38	29	—	—	—	77
16-20 ºC	48	38	26	26	—	—	92
11-15 ºC	48	38	26	—	26	—	104
4-10 ºC	48	38	26	—	—	26	117

As the pathway for establishment of *B. odoriphaga* and the *Delia* sp. in New Zealand requires bulb waste to be disposed into a suitable environment, treatments that reduce the level of bulb waste should also be considered. A physical treatment that removes roots and the outer (hard) skin layers from bulbs and excludes bruised or decayed bulbs from export shipments should be considered an effective treatment for *B. odoriphaga* and the *Delia* spp. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

6.2.4. References

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6.3. Diptera (flies – saprophagous)

6.3.1. Hazard identification

6.3.1.1. Aetiologic agents

Atherigona orientalis (Schiner 1868); Diptera: Muscidae, commonly known as the 'Pepper fruit fly'.

Calliphora vomitoria (Linnaeus 1758); Diptera: Calliphridae, commonly known as the 'Bluebottle fly'.

Euxesta notata (Wiedemann 1830); Diptera: Otitidae, commonly known as the 'Cherry worm'.

6.3.1.2. New Zealand status

The insect species listed above have not been recorded as being present in New Zealand (PPIN 2008, Scott & Emberson 1999).

6.3.1.3. Biology and epidemiology

Atherigona orientalis

Larvae of *A. orientalis* are typically found in damaged plant material, including fruits, and it may develop in dung and dead insects. However, when an insect is found in damaged plant material, it can be very difficult to determine whether the pest has caused the damage (phytophagous) or whether it simply entered an already damaged plant part and acted as a saprophagous species (CPC 2007). As such onion bulb contamination may occur directly to exposed (above-ground) surfaces of the onion bulbs in the field or through damaged parts of the onion bulbs during harvest, transport or storage before processing.

A. orientalis has a pantropical distribution and is considered unlikely to become established in temperate areas (Cahill 1992). The application, by Cahill (1992), of CLIMEX (a climate matching computer model) to *A. orientalis* distribution data found that this fly was only likely to establish in the warmer northern parts of New Zealand, and may not be able to persist during the colder months in natural environments.

Major hosts of *A. orientalis* include cabbages and cauliflowers (*Brassica oleracea*), bell pepper (*Capsicum annuum*), navel orange (*Citrus sinensis*), melon (*Cucumis melo*), tomato (*Lycopersicon esculentum*), beans (*Phaseolus*), and sorghum (*Sorghum bicolor*) (CPC 2007). Minor hosts include onion (*Allium cepa*), cucumber (*Cucumis sativus*), carrot (*Daucus carota*), peach (*Prunus persica*), aubergine (*Solanum melongena*), wheat (*Triticum aestivum*), and maize (*Zea mays*) (CPC 2007). While *A. orientalis* is primarily a saprophage, it is of some importance as a major vector of faecal and other filth-born diseases (CPC 2007).

Calliphora vomitoria

The adult fly of *C. vomitoria* eats from and lays eggs in decaying matter. Larvae feed in decaying organic matter then move to soil to pupate.

Female *C. vomitoria* flies lay eggs on or near suitable habitats. Tiny maggots hatch from eggs in 6 to 48 hours. Maggots develop through three stages (instars) on carrion for 3 to 9 days before leaving the food source to pupate in soil. After 2 to 7 days in a prepupal stage, they form a puparium from their last larval stage skin. A fourth larval stage occurs within the puparium before pupation. Adult flies emerge 10 to 17 days after the formation of the puparium. Development from egg to adult occurs in 16 to 35 days, depending on temperature and environmental conditions (Drees & Jackman 1999).

Euxesta notata

The genus *Euxesta* includes more than 70 species, most of which are distributed in tropical and subtropical areas (Steyskal 1968). *Euxesta notata* has been recovered from cull onions (Everts *et al.* 1985), imported onions (Aihara *et al.* 1985) and as a secondary pest in rotting or damaged onions (Merrill & Hutson 1953). Walnuts (Boyce 1929), oranges, pineapples, melons and apples (see Allen & Foote 1967) are also listed as host species. Nearly all of the reared species of this genus have saprophagous larvae, and very few of the North American species are phytophagous (Oldroyd 1964).

Laboratory tests with *E. notata* indicated that there was no sign of pupal diapause but only 5-10% of larvae pupated within 30 days at 20^{o}C when the daily photoperiod was 8-10 hours compared to 90% when daily photoperiod was 12-16 hours. When larvae that failed to pupate were kept at 5^{o}C and removed to various conditions of temperature and photoperiod at weekly intervals, chilling by itself appeared to have little influence, photoperiod also seemed unimportant, but a temperature of 25^{o}C induced rapid pupation (McLeod 1964). No other information could be found on the biology, life history or reproduction of *E. notata*.

6.3.1.4. Hazard identification conclusion

Based on the accepted absence of *Atherigona orientalis*, *Calliphora vomitoria* and *Euxesta notata* in New Zealand, the potential ability of larvae and pupae and any associated hymenopterous parasitoids to be imported on/in onion bulbs, and the potential ability of these insects to cause damage to crops or native insects in New Zealand, it is proposed that they be considered potential hazards requiring further assessment.

6.3.2. Risk assessment

6.3.2.1. Entry assessment

The likelihood of larvae entering New Zealand is difficult to determine, as there is little information available about the prevalence of these insects in China and their likely association with onion bulbs in international trade.

A. orientalis, *C. vomitoria* and *E. notata* eggs and larvae could potentially infest onion bulbs damaged in the field, during harvest or while in storage and have begun to rot. Infestation rates would therefore reflect the availability of adult (female) flies in the field and around processing and storage areas, and the proportion of damage bulbs in the harvest. At the time of processing the saprophagous insects would be conspicuous through their association with the rotting plant material on the infected bulbs.

The likelihood of entry of *A. orientalis*, *C. vomitoria* and *E. notata* into New Zealand on onion bulbs from China is considered moderate and is therefore non-negligible.

6.3.2.2. Assessment of exposure

Exposure could occur through the disposal of infested onions into composts or other garbage waste material. . It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). In the case of the saprophagous insects the development of rotting in the onion prior to consumption would increase the likelihood that the bulbs would be discarded into compost, allowing the infesting insects the opportunity to complete their life cycle.

An alternative exposure pathway is through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets and considerable onion waste is generated from which adults could disperse to surrounding host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (pers. com. Martin 2008). Maggots leaving the food source to pupate in soil would not successfully complete there lifecycle via this exposure pathway. Only saprophagous insects that pupate in the host material would be of concern on this exposure pathway.

The likelihood for the exposure of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) through these two pathways is considered low and is therefore, non-negligible.

6.3.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of any of the species of insects listed would be in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing could also be conducive for the development of larvae into pupae and for pupae to develop into adults. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007). Many of these Diptera species would find suitable conditions for establishment in most parts of New Zealand.

Although environmental conditions may be conducive for larval survival, pupal development/overwintering and adult development/emergence, several factors would need to occur in combination in order for a population to establish. Firstly, each species requires males and females for mating. As such, both sexes need to develop from pupae in waste areas and both sexes need to emerge and locate each other under conducive conditions (environmental and chemical cues). For the Diptera species with host ranges restricted to *Allium*, this would further be influenced by the vicinity of onions and other *Allium* spp. to the site of emergence, as volatiles emitted from *Allium* spp. are important chemical cues for successful mating in these species.

Secondly, a sufficient number of males and females would need to be produced and emerge in order to establish a population in the first, and subsequent, seasons. The numbers of male and female adults initially emerging in the New Zealand environment would be influenced by (1) the numbers of larvae originally infesting onion bulbs in the field in China and (2) the numbers of infested bulbs discarded in New Zealand. It is difficult to estimate the number of larvae that could be present in infested onion bulbs in the field in China.

Taking into consideration the very low number of onion bulbs that are predicted to be discarded into the New Zealand environment, the numbers of emerging male and female adults of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) is expected to be low. Given the likely abundance of suitable host material for these insects in a garbage environment the successful development of a population from these surviving adults should be considered high and therefore non-negligible.

6.3.2.4. Consequence assessment

Spread

Once successfully established in New Zealand, saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) would be expected to spread relatively quickly through the many hosts available. The likelihood of spread is considered high and is therefore non-negligible.

Economic consequences

Economic consequences of saprophagous insects (*A. orientalis*, *B. odoriphaga*, *C. vomitoria*, *Delia* sp. and *E. notata*) are likely to be restricted to increased spoilage of stored products and fungal infected produce in the field. Although saprophagous insects are only rarely considered primary plant pests, they are occasionally responsible for serious losses; the slightest injury to fruit will allow saprophagous insects to lay eggs. Once inside the fruit, they rapidly turn them into rotten pulp. A number of these saprophagous insects will also feed on carrion and act as vectors for plant and animal diseases. Therefore these saprophagous insects are considered to have a moderate likelihood of causing moderate to high impacts on economically important host species in New Zealand.

Environmental consequences

Given the saprophagous nature of these insects, and in some cases their ability to vector plant and animal diseases, the likelihood is moderate that these saprophagous insects could impact native plant and in some cases animal species and have an environmental impact within New Zealand.

Human health consequences

A. orientalis is of some importance as a major vector of faecal and other filth-born diseases (CPC 2007). *C. vomitoria* is also capable of vectoring diseases to humans and as such should be considered to have a moderate likelihood of causing low to moderate impacts on human health.

6.3.2.5. Conclusion of consequence assessment

Based on the above assessment it is concluded that if any of the saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) spread from private gardens to commercial growing areas or the wider environment, they could cause moderate to high economic, low to moderate health, and environmental consequences to New Zealand.

6.3.2.6. Risk estimation

The likelihood estimate is moderate that saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) would be associated with onion bulbs on entry into New Zealand; low that saprophagous insects would be exposed to the environment; low that any saprophagous insects exposed to the environment would successfully establish in private gardens in

New Zealand; high that saprophagous insects would spread from private garden areas to commercial onion production areas; and moderate that spread to commercial production areas would result in moderate to high unwanted economic, low to moderate health and environmental consequences to New Zealand.

As a result, the risk estimate for saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible and should be considered a hazard.

6.3.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also considerable uncertainty in terms of the epidemiology of these insects on onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

6.3.3. Risk management

6.3.3.1. Risk evaluation

Since the risk estimate for saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) associated with onion bulbs imported from China is non-negligible, options for phytosanitary measures are provided for consideration.

6.3.3.2. Option evaluation

There are a number of biosecurity risk management options available for saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) on onion bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of saprophagous insects;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of saprophagous insects;
- **c.** Inspection of onion plants or bulbs for saprophagous insects or evidence of infestation by saprophagous insects;
- **d.** Treatment of onion bulbs for saprophagous insects by a suitably efficacious method;

Pest free area (PFA)

Given the existence of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

Given the existence of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) in China on crops and weed plant species, it is unlikely that a PFPP could successfully be established for all of the plant species of concern. As the risk attributes leading to successful establishment of saprophagous insects in New Zealand are relatively restricted (a low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*).

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear saprophagous insect (*A. orientalis*, *C. vomitoria* and *E. notata*) infestations, inspection of healthy bulbs for saprophagous insects would not be an effective phytosanitary measure.

Infestations of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) should be readily apparent on bulbs when they are showing bruising or decay. During harvesting onion bulbs showing decay or bruising could be inspected for infestations of saprophagous insects. This inspection could be used in with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. No efficacy information has been provided for the following methyl bromide treatment schedule. Given the relatively low likelihood of successful establishment of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) in New Zealand from imported onion bulbs, the following treatment schedule is likely to be more than 99.95% effective against these hazards and therefore provide an adequate level of efficacy.

Methyl bromide fumigation schedule for internal feeders (and leafminers) in onion bulbs.

Temperature (ºC)	Rate (g/m^3)	Minimum Concentration Readings (g/m^3) at:					C/T Value ($g\ h/m^3$)
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	
33 ºC or above	32	26	19	—	—	—	51
26-32 ºC	40	32	24	—	—	—	64
21-25 ºC	48	38	29	—	—	—	77
16-20 ºC	48	38	26	26	—	—	92
11-15 ºC	48	38	26	—	26	—	104
4-10 ºC	48	38	26	—	—	26	117

As the pathway for establishment of saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*) in New Zealand requires bulb waste to be disposed into a suitable environment, treatments that reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers from bulbs and excludes bruised or decayed bulbs from export shipments should be considered an effective treatment for saprophagous insects (*A. orientalis*, *C. vomitoria* and *E. notata*). A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

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6.4. Coleoptera (beetles)

6.4.1. Hazard identification

6.4.1.1. Aetiologic agents

Alphitobius laevigatus (Fabricius 1758); Coleoptera: Tenebrionidae, commonly known as the 'Black fungus beetle'.

Exomala orientalis (Waterhouse 1875) synonym *Blitopertha orientalis*; Coleoptera: Scarabaeidae, commonly known as the 'Oriental beetle'.

Leptinotarsa decemlineata (Say 1824); Coleoptera: Chrysomelidae, commonly known as the 'Colorado potato beetle'.

Luperomorpha suturalis (Chen 1938); Coleoptera: Chrysomelidae, commonly known as the 'Flea beetle'.

Phaedon brassicae (Baly 1874); Coleoptera: Chrysomelidae, commonly known as the 'Daikon leaf beetle'.

6.4.1.2. New Zealand status

The insect species listed above have not been recorded as being present in New Zealand (Leschen *et al*. 2003, PPIN 2008, Scott & Emberson 1999).

6.4.1.3. Biology and epidemiology

Alphitobius laevigatus

A. laevigatus is considered to have a cosmopolitan distribution and is found in temperate, sub-tropical and tropical regions around the world, although it appears to be more commonly encountered in the tropics. This beetle is associated with a wide range of stored commodities, especially if they have suffered some mould damage. *A. laevigatus* can complete its life cycle in about 30 days at 35°C and 70% RH. In good storage conditions *A. laevigatus* is considered a minor pest. The presence of *A. laevigatus* usually indicates moisture problems within the commodity or a general lack of attention to the disposal of damp residues (CPC 2007). High moisture levels and poor hygiene can be a practical problem in some NZ onion stores (Martin pers. com. 2008). For control, the removal of infested residues from the previous harvest is essential, as is general hygiene in stores, such as ensuring that all spillage is removed and cracks and crevices are filled (CPC 2007).

Exomala orientalis

E. orientalis is a polyphagous pest, whose larvae feed on the roots of most grasses, ornamental plants and many vegetable crops, and has been recorded in particular damaging maize (*Zea mays*), pineapples (*Ananas comosus*) and sugarcane (*Saccharum officinarum*). Movement in international trade is considered to occur either as adults that may remain hidden in flowers, or larvae that may be present in the soil accompanying consignments (CPC 2007).

E. orientalis has a 1-year life cycle in Korea and New York, USA. The adults begin to emerge from late June, with peak emergence in mid-July in New York and a few may still be around into August, whereas they emerge from late May and peak in mid-June in Korea. The adults are weak fliers, but they may fly short distances during the day. Oviposition occurs both during the day and night for up to 20 days after mating. The females deposit their eggs singly, 2.5-23 cm deep in damp soil. The females lay an average of 25 eggs, but some may deposit as many as 63 in June in Korea, but in July and early October in New York, USA. The egg stage lasts for approximately 17 to 25 days, depending upon temperature and moisture. First-instars may feed up to 30 days before moulting. The grub population consists mainly of first-instars in August, second-instars by early September and third-instars by early October in New York, USA whereas in Korea first-instars were observed in July (CPC 2007).

The grubs feed by severing plant roots close to the soil surface. Their depth in the soil depends on the soil texture and moisture. The larvae burrow deeper into the soil as the surface layer dries out during the summer. The damage usually appears by early September and third-instars by early October. *E. orientalis* responds rapidly to shifting temperature. As soil temperatures drop to about 9.9°C in October, the larvae move downward for hibernation. They hibernate in an earthen cell, 20-40 cm underground. In spring, as soil temperatures warm to 6.1°C during late March or early April, the grubs start to move upward. Feeding continues until early June, when the grubs again burrow down 8-23 cm to pupate. The prepupal and pupal periods last approximately 1 and 2 weeks, respectively. The beetles begin emerging in late June, completing the annual cycle (CPC 2007).

Leptinotarsa decemlineata

L. decemlineata attacks potatoes and various other cultivated crops including tomatoes and aubergines. It also attacks wild solanaceous plants, which occur widely and can act as a reservoir for infestation. The adults feed on the tubers of host plants in addition to the leaves, stems and growing points. Larvae are voracious foliage feeders. By the final or fourth instar, they may feed on petioles and stems, if the plants have become severely defoliated (CPC 2007).

The beetles overwinter as diapausing adults in the soil, typically at depths of 7.6 to 12.7 cm. Overwintered adult beetles emerge from the ground over a period of several weeks in spring or early summer, depending on the climate and their physiological condition. Following emergence in the spring overwintered adults disperse to find suitable host plants by walking and by flight. Beetles typically mate before entering hibernal diapause and mate repeatedly in the spring, often within 24 h of emergence from the soil. Oviposition begins 5-10 days after emergence at 15-30°C. Eggs are laid in masses, containing 10-30 eggs, on the lower surface of the leaf. Egg laying usually continues over several weeks, with each female laying up to 2000 eggs. The larvae hatch using egg bursters or oviruptors situated on the meso- and metathorax and abdominal segment 1. They hatch in 4-14 days. After freeing themselves from the chorion, the larvae partly or entirely consume the chorion before feeding on leaf tissue. Larvae moult four times, the last of which is the larval/pupal moult. Larval development requires as little as 8 days or as long as 28 days at average temperatures of 29 and 14°C, respectively. Mature fourth-instar larvae burrow into the soil where they pupate. The pupal stage typically lasts 8 to 18 days, depending on temperature. Developmental thresholds, which range from 8 to 12°C, vary among populations and life stages. At constant temperatures, development is most rapid between 25 and 33°C; at higher temperatures larval growth is slowed and mortality increases (CPC 2007).

Adults and larvae can readily be transported on potato plants and tubers, and in all forms of packaging and transport. Fresh vegetables (of non-host crops) grown on land harbouring overwintered beetles are a common means of transport in international trade (CPC 2007).

Luperomorpha suturalis

L. suturalis is one of the two major pests of garlic chives (*Allium ramosum*) in China, and has been reported as a pest of onions by P. R. China (China 2008). It is distributed in the provinces of Jilin, Hebei, Shanxi, Shandong, Jiangsu and Anhui. There are few reports about the biology of the flea beetle. The beetle has two generations each year in the north and overwinter as larvae or pupae in 5–10cm deep soil. Emergence of the overwintering adults occurs in early April and lasts till September because of generation overlapping (Yang *et al.* 2003). Adult beetles eat leaves causing wormholes and notches while the larva damage fibrous roots and bulbs and cause rotting, poor growth and withering and wilting of the leaves (China 2008). After feeding on chive leaves, adults lay eggs in the soil. Young larvae tunnel into roots and feed causing damage to host plants resulting in leaf yellowing or death and as much as 30–50% yield loss. As larvae begin to bore into and feed on roots when soil temperature is above 15ºC, they can affect the entire chive growing-season in greenhouses (Yang *et al.* 2003).

Phaedon brassicae

P. brassicae is considered a polyphagous insect having been reported on the following cultivated plants: *Allium cepa, Beta vulgaris, Brassica chinensis, Chrysanthemum coronarium, Daucus carota, Lactuca sativa, Raphanus sativum*, or weeds such as *Capsella bursa-pastoris and Rorippa atrovirens*. In Southern China, it is reported as an important pest of Brassicaceae, such as *Brassica alboglabra, B. juncea* var. *foliosa, B. chinensis, Brassica pekinensis, Nasturium officinale,* and *Raphanus sativus* (EPPO RS 2006).

P. brassicae is a multivoltine species that oversummers and overwinters as an adult (Wang *et al.* 2007). Adults and larvae feed on leaves, perforating them. They are light-avoiding and remain still on the lower leaf surface during the day. Eggs are laid on the lower leaf surface. In experiments completed in China the larval stage lasted 10 days at 25°C. Mature larvae live close to the ground on the upper leaf surface, and they feed more intensively in the dark. Pupae are 5 mm long and bright yellow. From the literature, it is not clear whether pupation takes place in the soil or on lower leaf surface. Details are lacking on the biology of the insect and its damage (EPPO RS 2006). This species has now been found in Italy indicating an ability to move in international trade (Limonta & Colombo 2004).

6.4.1.4. Hazard identification conclusion

Alphitobius laevigatus, *Exomala orientalis*, *Leptinotarsa decemlineata*, *Luperomorpha suturalis* and *Phaedon brassicae* are not known to be in New Zealand. These beetles are only likely to be associated with onions as:

- eggs in soil deposits (*Luperomorpha suturalis*);
- larvae feeding on roots (*Exomala orientalis*, *Luperomorpha suturalis*, *Phaedon brassicae*);
- adults feeding on leaf material (*Luperomorpha suturalis*, *Phaedon brassicae*);
- adults feeding on fungi associated with onion bulbs (*Alphitobius laevigatus*); or
- adult stowaways (hitchhikers) associated with onion bulbs or the packaging they are contained in (*Leptinotarsa decemlineata*).

Standard commercial cleaning and hygiene practices should be sufficient to ensure these organisms would not be associated with onion bulbs in international trade.

Subject to the standard commercial treatments that remove most roots, soil and loose skin layers from bulbs, and excludes bruised or decayed bulbs from export shipments, it is proposed that these beetles not be considered potential hazards and as such do not require further assessment. A more detailed commodity description for commercially produced bulbs is provided in section 2.1.9.

6.4.1.5. Assessment of uncertainty

There is considerable uncertainty in terms of the epidemiology of these insects on onions and their potential association with bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

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6.5. Homoptera (bugs)

6.5.1. Hazard identification

6.5.1.1. Aetiologic agents

Bemisia tabaci (Gennadius 1889); Homoptera: Aleyrodidae, commonly known as the 'Tobacco whitefly'.

Icerya seychellarum (Westwood 1855) synonym *Dorthesia seychellarum*; Homoptera: Margarodidae, commonly known as the 'Seychelles scale'.

6.5.1.2. New Zealand status

Although *Icerya seychellarum* has been recorded as occurring in New Zealand, it is not known to have established, but has been intercepted many times in quarantine on produce from other countries (Morales 1991, PPIN 2008, Scott & Emberson 1999).

Bemisia tabaci has been recorded in New Zealand (PPIN 2008, Scott & Emberson 1999) however only the Q and B biotypes have been found to date (Scott *et al.* 2007). More than 20 races or biotypes have been identified (CPC 2007, Scott *et al.* 2007) and most biotypes can vector over 60 plant viruses (CPC 2007).

6.5.1.3. Biology and epidemiology

Bemisia tabaci

B. tabaci has been known as a minor pest of cotton and other tropical or semi-tropical crops in the warmer parts of the world and, until recently, has been easily controlled by insecticides. In the southern states of the USA in 1991, however, it was estimated to have caused combined losses of $USD 500 million to the winter vegetable crops through feeding damage and plant virus transmission. *B. tabaci* is also a serious pest in glasshouses in North America and Europe (EPPO/CABI 1996).

The feeding of adults and nymphs causes chlorotic spots to appear on the surface of the leaves. Depending on the level of infestation, these spots may coalesce until the whole of the leaf is yellow, apart from the area immediately around the veins. Such leaves are later shed. The honeydew produced by the feeding of the nymphs covers the surface of the leaves and can cause a reduction in photosynthetic potential when colonized by moulds. Honeydew can also disfigure flowers and, in the case of cotton, can cause problems in processing the lint. With heavy infestations, plant height, number of internodes and quality and quantity of yield can be affected (e.g. in cotton). The larvae of the B biotype of *B. tabaci* are unique in their ability to cause phytotoxic responses to many plant and crop species. These include a severe silvering of courgette leaves, white stems in pumpkin, white streaking in leafy brassica crops, uneven ripening of tomato fruits, reduced growth, yellowing and stem blanching in lettuce and kai choy (*Brassica campestris*) and yellow veining in carrots and *Lonicera* (EPPO/CABI 1996).

B. tabaci is the vector of over 110 plant viruses (DEFRA 2006) in the genera *Geminivirus*, *Closterovirus*, *Nepovirus*, *Carlavirus*, *Potyvirus* and a rod-shaped DNA virus (EPPO/CABI 1996). The emergence of the B biotype of *B. tabaci*, with its ability to feed on many different host plants has given whitefly-transmitted viruses the potential to infect new plant species. This has already been shown to have occurred in the Americas (EPPO/CABI 1996).

Adults of *B. tabaci* do not fly very efficiently but once airborne, they can be transported quite large distances by the wind. All stages of the pest are liable to be carried on planting material and cut flowers of host species (EPPO/CABI 1996).

Eggs are laid usually in circular groups, on the underside of leaves, with the broad end touching the surface and the long axis perpendicular to the leaf. They are anchored by a pedicel which is inserted into a fine slit made by the female in the tissues, and not into stomata, as in the case of many other aleyrodids. Eggs are whitish when first laid but gradually turn brown. Hatching occurs after 5-9 days at 30°C but, like many other developmental rates, this depends very much on host species, temperature and humidity (EPPO/CABI 1996).

On hatching, the first instar, or "crawler", is flat, oval and scale-like. This first instar is the only larval stage of this insect which is mobile. It moves from the egg site to a suitable feeding location on the lower surface of the leaf where its legs are lost in the ensuing moult and the larva becomes sessile. It does not therefore move again throughout the remaining nymphal stages. The first three nymphal stages last 2-4 days each (this could however vary with temperature). The fourth nymphal stage is called the 'puparium', and is about 0.7 mm long and lasts about 6 days; it is within the latter period of this stage that the metamorphosis to adult occurs (EPPO/CABI 1996).

The adult emerges through a "T"-shaped rupture in the skin of the puparium and spreads its wings for several minutes before beginning to powder itself with a waxy secretion from glands on the abdomen. Copulation begins 12-20 h after emergence and takes place several times throughout the life of the adult. The life span of the female could extend to 60 days. The life of the male is generally much shorter, being between 9 and 17 days. Each female lays up to 160 eggs during her lifetime, although the B biotype has been shown to lay twice as many, and each group of eggs is laid in an arc around the female. Eleven to fifteen generations can occur within one year (EPPO/CABI 1996).

Until recently, *B. tabaci* was mainly known as a pest of field crops in tropical and sub-tropical countries: cassava (*Manihot esculenta*), cotton (*Gossypium*), sweet potatoes (*Ipomoea batatas*), tobacco (*Nicotiana*) and tomatoes (*Lycopersicon esculentum*). Its host plant range within any particular region was small, yet *B. tabaci* had a composite range of around 300 plant species within 63 families (EPPO/CABI 1996). With the evolution of the highly polyphagous B biotype, *B. tabaci* has now become a pest of glasshouse crops in many parts of the world, especially *Capsicum*, courgettes (*Cucurbita pepo*), cucumbers (*Cucumis sativus*), *Hibiscus*, *Gerbera*, *Gloxinia,* lettuces (*Lactuca sativa*), poinsettia *(Euphorbia pulcherrima*) and tomatoes (*Lycopersicon esculentum*). *B. tabaci* moves readily from one host species to another and is estimated as having a host range of around 600 species (Asteraceae, Brassicaceae, Convolvulaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Malvaceae, Solanaceae, etc.) (EPPO/CABI 1996).

Because of the difficulty of detecting low levels of infestation in consignments, it is best to ensure that the place of production is free from the pest (EPPO/CABI 1996). Particular attention is needed for consignments from countries where certain *B. tabaci*-listed viruses are present (EPPO/CABI 1996).

Icerya seychellarum

I. seychellarum can be recognized by its large size (up to 10 mm long) and granular white or pale-yellow wax, which contains silky tubular threads and forms tufts on the dorsum and along the margins of the body (CPC 2007).

Icerya species have three immature stages. Development from egg to adult usually takes about 3 months. As with all scale insects, the females are wingless and look similar to the immature stages. Males are rare and are not required for reproduction. The female begins laying eggs 5 or 6 days after the beginning of the production of the ovisac, and continues for 6-17 days. The first-instar nymphs usually hatch within a few hours, at most, 24 hours. The crawlers remain in the egg sac for 2-3 days, then emerge and crawl actively over the leaves. The majority of crawlers eventually settle on the undersides of the leaves and on the young twigs and begin to secrete their distinctive yellow wax body covering. The females remain on the leaves and twigs throughout their lives, eventually producing ovisacs. Unlike some of the related species of *Icerya*, *I. seychellarum* does not congregate in masses, but is rather generally distributed over the tree along major veins on the lower surfaces of the leaves (CPC 2007).

I. seychellarum is a pest of guava, citrus, breadfruit, avocado, jackfruit, palms and roses in a number of Pacific Islands, where it has been recorded killing trees, and in the Seychelles, the Mascarene Islands and Japan. Heavy infestations have been recorded on Australian chestnut trees (*Castanospermum australe*) dropping copious amounts of honeydew onto cars parked beneath, but causing no apparent damage to the trees (CPC 2007).

6.5.1.4. Hazard identification conclusion

While *Icerya seychellarum* and stains of *Bemisia tabaci* are not known in New Zealand, their association with aerial parts of host plants suggests that they are unlikely to be associated with onion bulbs in international trade. As such these organisms are not considered potential hazards and as such do not require further assessment.

6.5.1.5. Assessment of uncertainty

There is considerable uncertainty in terms of the epidemiology of these insects on onions and their potential association with bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

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6.6. Lepidoptera (moths – leaf miners)

6.6.1. Hazard identification

6.6.1.1. Aetiologic agents

Acrolepia manganeutis (Meyrick 1913); Lepidoptera: Acrolepiidae, commonly known as the 'Stone leek miner'.

Acrolepiopsis sapporensis (Matsumura 1931) (synonym *Acrolepia sapporensis*); Lepidoptera: Acrolepiidae, commonly known as the 'Stone leek miner'. This species was misidentified in Hawaii as *Acrolepia assectella*.

6.6.1.2. New Zealand status

Acrolepia manganeutis and *Acrolepiopsis sapporensis* have not been recorded as being present in New Zealand (Dugdale 1988, Hoare 2001, PPIN 2008, Scott & Emberson 1999).

6.6.1.3. Biology and epidemiology

Acrolepiidae are a small family of microlepidoptera in the superfamily Yponomeutoidea. The family comprises three genera, *Acrolepia* Curtis, *Acrolepiopsis* Gaedike, and *Digitivalva* Gaedike, with 95 species recorded worldwide. Seven species of *Acrolepiopsis*, one species of *Digitivalva*, and no species of *Acrolepia* are known from the Nearctic region. Larvae of *Acrolepiopsis* feed on Liliaceae and Dioscoreaceae, those of *Acrolepia* feed on Asteraceae, and those of *Digitivalva* feed on Solanaceae (Landry 2007).

Limited information is available for *A. sapporensis* as a pest of onion bulbs while there is no information available for *A. manganeutis*. Because *A. sapporensis* has been described to be similar to *Acrolepia assectella* (Landry 2007), information is provided for *A. assectella* where it is lacking for *A. sapporensis* and *A. manganeutis*.

Biology and ecology

A. assectella overwinters as adults or pupae in host plants or plant debris (Ellis 2004). In northern countries *A. assectella* has two or three generations per year and five or six generations per year in southern countries (Carter 1984). The first generation adults occur in the winter with activity ceasing under cold conditions. In spring, when temperatures increase to approximately 9.5^{o}C, adults emerge at dusk in search of mates (Ellis 2004).

The female, which mates within 24 hours after emergence, indicates her availability and readiness to mate by emitting a sex pheromone. In response, the male emits its pheromone that attracts the female and stops her calls (Thibout 1972). To locate an appropriate egg-laying site, females use a long-range scent cue from leek. Once it is near the host, egg laying is stimulated by a non-volatile, non-sulphurous scent cue (Auger & Thibout 1979). It is possible that surface leaf waxes contain weakly volatile substances that are responsible for short-range attraction and host recognition (Ellis 2004). Host recognition is particularly important to females when selecting egg-laying sites.

During the first stage of egg laying the female sweeps the most sensitive areas of her antennae over the leaf surface and the sensillae of her ovipositor moves back and forth touching the leaf surface. This activity may aid the female in receiving chemical cues from the plant tissue that cause her to begin egg laying. The amino acid Propyl (Propyl CSO), which is characteristic of *Allium* spp., appears to have a positive affect in stimulating oviposition (Thibout & Auger 1996). Once prompted, the female begins to lay eggs singly on the lower surfaces of the leaf tissue (Ellis 2004).

Each female moth produces an average of 100 eggs in her lifetime, which is approximately 6 weeks. Eggs are deposited on the centre of inflorescences or on leaves. Where three generations per year occur, in the spring, the eggs of the second generation take between 4 and 6 days to hatch. Eggs of the last generation that are laid in the autumn hatch in approx 8 to 11 days. Egg laying lasts for approximately 20 days (Ellis 2004, HYPP 2009).

Larvae develop in 15 days at 25^{o}C and there are 5 instar stages. The numbers of first generation derived from overwintering adults is small; it is the summer generations that are much more harmful. Larvae mine the leaf and 2 to 5 days later it exits the mine and burrows in between the central leaves. Second generation adults appear at the beginning of July and oviposition occurs during July and August (Ellis 2004, HYPP 2009). Mature larvae make a mesh cocoon, which they attach externally to foliage of the host plant. They can also pupate on the soil or near the plant. Pupae develop in 10 days at 25^{o}C (Ellis 2004, HYPP 2009). In climates that support a second generation, adult moths emerge from the cocoon and usually are the most destructive. In climates that do not support a second generation, some adults will emerge and seek shelter in plant debris (Ellis 2004). Remaining pupae will overwinter and adult moths will emerge the next season (Ellis 2004, HYPP 2009). *Acrolepia assectella* adults are capable of flying short distances between fields and may fly *en masse* to new locations (Jenner & Mason 2005).

Epidemiology

In onions, *A. assectella* larvae mine tunnels in the epidermis of the leaves and after approximately 5 days move toward the heart of the plant, eventually boring through the inner leaves. *Acrolepia manganeutis* larva are recorded as eating leaf chlorenchyma and causing anomalous radial white tunnels that lower yield and onion quality (China 2008). In onions, the *Acrolepia assectella* larvae remain in the leaf cone and cause partial desiccation. The damage in itself is of minor importance; however, under unfavorable conditions, the onions may age too quickly and the larvae may bore downward into the more turgescent bulbs and form galleries (Carter 1984, HYPP 2009). Damage may not be visible in storage (HYPP 2009). Harvested crops containing damaged bulbs should be rejected as hidden damage may cause serious losses in storage (INRA 2000).

Host range

Hosts of *A. sapporensis* (stone leek miner) are listed as *Allium* spp., e.g., leek, garlic, onions, shallot, Welsh onion (CPC 2007), scallion (Landry 2007) and chive (Landry 2007, CFIA 2001). There is no information about host associations for *A. manganeutis* other than that of onion (China 2008) and stored yams (Fletcher 1919), and the general statement by Landry (2007) that species of the *Acrolepia* feed on plants within the Asteraceae. The latter statement suggests that *A. manganeutis* may be a species within the genus *Acrolepiopsis*.

6.6.1.4. Hazard identification conclusion

The ‘Stone leek miner’ moths, *Acrolepia manganeutis* and *Acrolepiopsis sapporensis*, have been recorded as feeding on onion plants under certain conditions and could conceivably be associated with onion bulbs in international trade. Based on the accepted absence of *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* in New Zealand, the potential ability of larvae to be imported on or in onion bulbs, and the potential ability of these insects to cause damage to onion in New Zealand, it is proposed that they be considered potential hazards requiring further assessment.

6.6.2. Risk assessment

Because biological information on *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* is limited, this analysis will use information on *Acrolepia assectella* where it is lacking for *A. sapporensis* and *A. manganeutis*.

6.6.2.1. Entry assessment

The likelihood of larvae entering New Zealand is difficult to determine, as there is little information available about the prevalence of these insects in China and their likely association with onion bulbs in international trade.

INRA (2000) state that under unfavorable conditions (to the larvae), the larvae may reach the more turgescent bulbs (larger bulbs protruding from the earth) and form galleries. They go on to say that harvested crops containing bulbs damaged in this way should be rejected as hidden damage may cause serious losses in storage, presumably from rot-causing fungi and bacteria. . Larvae would only become associated with onion bulbs in the field prior to harvest. As damage may not be visible in storage, larvae within bulbs would not be visible on inspection. However damage to the bulbs, caused by bacteria or fungi rotting damaged tissue, is more likely to be visible.

Larvae of *Acrolepia assectella* complete development in around 15 days under favourable temperatures. As the larvae found in bulbs would be close to the end of their development a period of cooling would be required to ensure the development rate was significantly slowed to prevent pupation (and separation from the bulb). However pupation could occur within or attached to the onion bulb allowing entry of viable lifestage into New Zealand.

The likelihood of entry of *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* into New Zealand on onion bulbs from China is considered low and is therefore non-negligible.

It should also be noted that the entry pathways for infesting insects are also relevant to any associated insect parasitoids. The likelihood that parasitoids would be associated with 'Stone leek miner' larvae infesting bulbs is considered very small and therefore negligible, as the larvae would need to be healthy to move down the leaf and into the onion bulb. Once in the bulb the larvae would not be exposed to preditation by parasitoids. As the likelihood of entry of these insect parasitoids is negligible, no further assessment is required.

6.6.2.2. Assessment of exposure

Exposure could occur through the disposal of infested onions into composts or other garbage waste material. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). The development of rotting in the onion prior to consumption would increase the likelihood that the bulbs would be discarded into compost, allowing the infesting insects the opportunity to complete their life cycle.

An alternative exposure pathway is through re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets and considerable onion waste is generated from which adults could disperse to surrounding host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (pers. com. Martin 2008).

Larvae may form galleries in mature bulbs (Carter 1984, HYPP 2009) and develop to adulthood within the bulbs. Long term overwintering may occur as adults or pupae (Ellis 2004). Adults could therefore emerge and disperse from bulbs at any time. The likelihood for the exposure of *Acrolepia manganeutis* or *Acrolepiopsis sapporensis* through the disposal pathway is considered low and is therefore non-negligible.

6.6.2.3. Assessment of establishment

Environmental conditions most suitable for the establishment of *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* would be anywhere onions are grown commercially but would be most suitable in the northern regions of New Zealand (Kaitaia, Kerikeri, Whangarei, Auckland and Tauranga). For example, in Kerikeri, average summer daytime temperatures (22-26^{o}C), and possibly winter daytime temperatures (12-17^{o}C), that are conducive for onion growing could also be conducive for the rapid development of larvae into pupae and for pupae to develop into adults. Pukekohe, the main onion-producing region in New Zealand, has similar climatic conditions to that of Kerikeri and other northern regions (Douglas *et al.* 2007). As such *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* would find suitable conditions for establishment in most parts of New Zealand.

Although environmental conditions may be conducive for larval survival, pupal development/overwintering and adult development/emergence, several factors would need to occur in combination in order for a population to establish. Firstly, both species require males and females for mating. As such, both sexes need to develop from pupae in waste areas and both sexes need to emerge and locate each other under suitable conditions for mating (environmental and chemical cues). As the host ranges of *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* are likely to be restricted to *Allium*, this would further be influenced by the vicinity of onions and other *Allium* spp. to the site of emergence, as volatiles emitted from *Allium* spp. are important chemical cues for successful mating in these species.

Secondly, a sufficient number of males and females would need to be produced and emerge in order to establish a population in the first, and subsequent, seasons. The numbers of male and female adults initially emerging in the New Zealand environment would be influenced by (1) the numbers of larvae originally infesting onion bulbs in the field in China and (2) the numbers of infested bulbs discarded in New Zealand. It is difficult to estimate the number of larvae that could be present in infested onion bulbs in the field in China.

Due to the low likelihood of larvae of *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* entering on imported onions, the numbers of emerging male and female adults of *Liriomyza* sp. is expected to be insignificant and therefore negligible and as such no further assessment is required.

6.6.2.4. Risk estimation

The likelihood estimate is low that *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* would be associated with onion bulbs on entry into New Zealand; low that these insects would be exposed to the environment; and negligible that any *Acrolepia manganeutis* or *Acrolepiopsis sapporensis* life stages that are exposed to the environment would successfully establish in private gardens in New Zealand.

As a result, the risk estimate for *Acrolepia manganeutis* and *Acrolepiopsis sapporensis* associated with onion (*Allium cepa*) bulbs imported from China for consumption is negligible and should not be considered a hazard on this pathway.

6.6.2.5. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also considerable uncertainty in terms of the epidemiology of these insects on onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

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6.7. Lepidoptera (moths – others)

6.7.1. Hazard identification

6.7.1.1. Aetiologic agents

Autographa gamma (Linnaeus 1758); Lepidoptera: Noctuidae, commonly known as the 'Silvery moth'.

Hadula trifolii (Hufnagel 1766); Lepidoptera: Noctuidae, commonly known as the 'Clover cutworm'.

Helicoverpa armigera (Hübner 1809); Lepidoptera: Noctuidae, commonly known as the 'Cotton bollworm'. Otherwise known as the synonym *Heliothis armigera* (Hübner).

Loxostege sticticalis (Linnaeus 1761); Lepidoptera: Crambidae, commonly known as the 'Beet webworm'.

Mamestra brassicae (Linnaeus 1758); Lepidoptera: Noctuidae, commonly known as the 'Cabbage moth'.

Peridroma saucia (Hübner 1808); Lepidoptera: Noctuidae, commonly known as the 'Pearly underwing moth'.

Sarcopolia illoba (Butler 1878); Lepidoptera: Noctuidae, commonly known as the 'Mulberry caterpillar'.

Spodoptera exigua (Hübner 1808); Lepidoptera: Noctuidae, commonly known as the 'Beet armyworm'.

Trichoplusia ni (Hübner 1802); Lepidoptera: Noctuidae, commonly known as the 'Cabbage looper'.

Xestia c-nigrum (Linnaeus 1758); Lepidoptera: Noctuidae, commonly known as the 'Spotted cutworm'.

6.7.1.2. New Zealand status

Of the insect species listed above all but *Helicoverpa armigera* have not been recorded as being present in New Zealand (Dugdale 1988, Hoare 2001, PPIN 2008, Scott & Emberson 1999).

While *Helicoverpa armigera* is widely established in New Zealand (PPIN 2008), pesticide-resistant strains exist in China (Liang *et al.* 1998) that are not believed to be present in New Zealand (Cameron & Walker 2004).

6.7.1.3. Biology and epidemiology

Autographa gamma

This polyphagous pest is found on cereals, grasses, fibre crops, brassicas and other vegetables including legumes. *A. gamma* can feed on at least 224 plant species, including 100 weeds, from 51 families. *A. gamma* is a migratory species and adults undertake seasonal migrations to areas where they are unable to breed continuously. In areas where it is unable to overwinter, severe infestations occur sporadically. In the UK, *A. gamma* may complete two generations during the summer, depending on when the immigrants arrive, and on weather conditions (CPC 2007).

The young caterpillars feed on the foliage of their host plants and tend to occur singly, rather than in groups. When they are young, they skeletonize the leaves, but older caterpillars eat the whole leaf. Larval development takes from 51 days at 13°C to 15-16 days at 25°C and the pupal stage from 32 days at 13°C to 6-8 days at 25°C. When the larvae are disturbed, they drop off the plant (CPC 2007).

In areas where *A. gamma* is able to survive the winter, it overwinters in the third to fourth larval instars or the pupal stage. There is no true diapause (CPC 2007). *A. gamma* s host to a number of recorded parasites and hyperparasites (CPC 2007).

Apart from damaging the foliage of their host plants, larvae can scrape the skin from grapes and feed on the contents of the fruits. Damage becomes economical significant when 25% of the leaf area of a plant is destroyed (CPC 2007).

Hadula trifolii

The host range of *H. trifolii* is very wide, affecting mostly herbaceous dicotyledons (Chenopodiaceae, Cruciferae, Polygonaceae, Malvaceae, Papilionaceae [Fabaceae] and Solanaceae). However, some monocotyledon hosts have also been reported, such as onion (on young leaves) and, in Hungary, maize. *H. trifolii* very rarely affects trees, though it is recorded as a pest of young conifers in forest nurseries and some deciduous trees in North America (CPC 2007).

H. trifolii is present, with very few exceptions, throughout the Holarctic region. It occurs all over continental USA, except for Alaska. Most of its distribution area falls between 60°N and 20°N, plus a little further north in Fennoscandia and further south to include a wider band of northern Africa and the whole Arabic peninsula. It appears well-adapted to the different climatic conditions present across this area, so it can be found as much in the colds of northern Quebec (Canada), Tibet (China) and Fennoscandia (Europe) as in the heat of northern Africa and the Arabic peninsula, though becoming increasingly more localized or rare towards the extreme cold or hot boundaries of this biogeographical region (CPC 2007).

In northern areas, where *H. trifolii* is univoltine, the single generation of moths flies from late June to July. In southern areas, where it is bivoltine, the first generation normally flies from late May to late July and the second one from mid-August to early October. The adult moths are mainly nocturnal and come to flowers, sugar and artificial light (mercury vapour and ultraviolet), hiding and remaining still during the day. Females release a sex pheromone to attract males and mate on the night of emergence or on the second to third night of adult life. For adult females obtained from larvae reared in laboratory conditions on an artificial diet, the mean life span was 14 days and mean fecundity 694 eggs. In laboratory conditions egg laying took place 4-5 days after mating. In the wild, eggs are laid singly on stems and leaves of the foodplant and, in general terms, hatch within a week, sometimes in only 5 days. The larvae are very intolerant of light and feed by night, hiding on the ground at the base of the foodplant by day. They are terrestrial larvae, i.e. always feed on foliage above the soil surface. Pupation takes place subterraneanly, at depths of 3-5 cm, in a frail cocoon. In the Ukraine, non-overwintering pupae take from 7 to 19 days to complete their metamorphosis to moths. Pupae represent the overwintering stage (CPC 2007).

H. trifolii larvae can cause damage to a wide variety of plants, including many vegetables, field crops and some deciduous trees. *H. trifolii* caused crop losses in Manitoba in 1980, when damage was found in sunflowers, oilseed rape, onions and flax. *H. trifolii* has also been recorded as a minor pest of other crops, including cabbage in Romania and Bulgaria, lucerne in Turkmenistan and Bulgaria, clover in Bulgaria, and maize in Hungary (CPC 2007).

Helicoverpa armigera

H. armigera also overwinters as the pupal stage, under the soil surface. At the beginning of May, adults emerge and mate promptly. The females lay eggs on weeds and host plants of economic importance, but normally the first generation feeds on weeds. The oviposition period lasts for about 20 days, during which time each female lays 500-2700 eggs. The incubation period takes 3-4 days in summer and about a week during spring and autumn. The larval period lasts 14-18 days in summer and 17-21 days in autumn. During the growing season, *H. armigera* produces two to six generations according to the climatic conditions (CPC 2007). Caterpillars damage flowers, fruit and leaves of host plants (Cameron & Walker 2005).

Overseas, resistance to synthetic pyrethroids has been of particular concern and control failures in Australia have led to the development of a strategy to limit resistance in crops in which *H. armigera* is a key pest. Resistance to SPs also occurs in Thailand and India, and *Heliothis virescens* has become resistant in the USA. *Helicoverpa armigera* has a history of resistance to DDT and has also developed resistance to endosulfan, carbamates and organophosphates. Control failures resulting from resistance have not been reported in New Zealand (Cameron & Walker 2005).

The most important crop hosts of which *H. armigera* is a major pest are cotton, pigeonpea, chickpea, tomato, sorghum and cowpea; other hosts include groundnut, okra, peas, field beans (*Lablab* spp.), soyabeans, lucerne, *Phaseolus* spp., other Leguminosae, tobacco, potatoes, maize, flax, a number of fruits (*Prunus*, *Citrus*), forest trees and a range of vegetable crops. A wide range of wild plant species support larval development (CPC 2007).

Loxostege sticticalis

L. sticticalis is a polyphagous insect, and hundreds of plant species are its hosts. Hosts are mainly in the families Fabaceae, Solanaceae, Asteraceae, Convolvulaceae, Polygonaceae, Poaceae, Chenopodiaceae, Brassicaceae, Liliaceae, Malvaceae, Apiaceae, Cyperaceae, Rosaceae, Papaveracae, Plantaginaceae, Cucurbitaceae and Cannabaceae. The larvae prefer to feed on leaves of growing plants. When populations are of high density and short of food, the larvae can feed on almost all tender parts of growing plants, even the bark of some trees (CPC 2007).

Populations of *L. sticticalis* inhabit the northern part of the Northern Hemisphere, usually to the north of 30°N. This species occurs widely on the continents of Asia and Europe; Italy and the Netherlands may be the southern and western limits, respectively, and the Far East of Russia the eastern limit. The southern limit of *L. sticticalis* in China as recorded as 37°N (CPC 2007).

Larvae of *L. sticticalis* have silk spinning and collection features. The first three larval instars develop quickly. Eggs or first-instar larvae can be found on the lower surface of leaves. Second and third instars hide in webs and can be found on the upper surface of leaves. The fourth and fifth instars are voracious feeding stages; they can move quickly and often congregate and move from one field to another for feeding as host plants are depleted (CPC 2007).

The mature larva makes a silk cocoon, hides itself in the cocoon as it stops feeding, and begins to enter a prepupal diapause stage. Cocoons are buried in soil 2-4 cm deep near the habitat of the late-instar larvae. Diapause, regulated by photoperiod and temperature, makes this species resistant to unsuitable environments and assists *L. sticticalis* in developing large populations Adults migrate long distances after emergence. Moths emigrate from the habitat of the prepupae and become an immigrant population in the habitat of the next generation In China and the former USSR, this species showed intermittent abundance with population cycles of about 20 years periodicity in the twentieth century. In China; populations increased during the intermittent period in the main overwintering areas which led to outbreak years of *L. sticticalis* in northern and north-eastern China (CPC 2007).

L. sticticalis is attacked by a large assemblage of polyphagous natural enemies, which probably vary in importance in different parts of its range (CPC 2007).

Mamestra brassicae

M. brassicae larvae are extremely polyphagous: although they prefer *Brassica* crops, beetroots, legumes, lettuces, onions and potatoes are also frequently reported to be infested. The species is also found on a wide range of other vegetable crops and ornamental flowers in glasshouses and in the open, and on a wide range of deciduous tree species (CPC 2007).

M. brassicae is present throughout the Palaearctic region from Europe to Japan and subtropical Asia mainly between 30°N and 70°N. The species is not present in America or Oceania (CPC 2007).

The adult moths emerge from pupae in the soil. Shortly after emergence the moths mate, and the females deposit their eggs in regular batches of up to 70-80 eggs, mainly on the undersides of leaves. Mean batch size is in the range 14-37 eggs with the mean and maximum number of eggs per female reported to be about 500-1500 and 2000-3000, respectively. The eggs normally hatch in 6-14 days, and the larvae immediately start to feed on the leaves. Young larvae feed gregariously mostly during dark periods. In field experiments with white cabbage it was found that the larvae started to spread all over the host plant within a few hours after hatching. After 1-2 days they were found on the nearest neighbouring plants and rows, and they continued to disperse radially from the original infested plant throughout the larval stage. In the first three or four instars, the larvae feed mainly on the external leaves. From the fifth instar they display a negative phototaxis and move into the heart of the plants. Nearly full-grown larvae are often concealed in the soil during daytime and enter the plants to feed at night. Larval development normally takes 4-7 weeks. Mature larvae leave the plants to pupate in thin cocoons in the soil at a depth of about 3-5 cm. Hibernation and aestivation take place in the pupal stage (CPC 2007).

Depending on the climate, *M. brassicae* develops one to three generations per year. In central Europe and most parts of southern Europe two or three generations occur, whereas in the northern parts of the distribution area *M. brassicae* is univoltine or partially bivoltine. In central parts of the distribution area *M. brassicae* is a serious pest, mainly on Brassica crops, beetroots and legumes, but also on other vegetable crops (CPC 2007). In laboratory experiments, larval mortality increased with decreasing temperature within the range 18.0-10.5°C. Eggs and larvae did not survive at 8.5°C (Johansen 1997). *M. brassicae* is attacked by a large assemblage of parasites (CPC 2007).

Peridroma saucia

The larvae of *P. saucia* have been recorded on a wide range of more than 130 angiosperms, preferring primarily herbaceous dicotyledonous plants, then woody shrubs and low-growing fruit trees, and thirdly monocotyledonous plants, mainly grasses. As a result, the species primarily inhabits open, disturbed areas where a wide range of host plants is available. Damage to crop species is more severe in areas where weedy plants grow adjacent to or among the crop plants. The migratory habits of the moths result in the species occurring in many remote areas that have been opened for agriculture (CPC 2007).

The species does not survive cold winter temperatures and is a permanent resident only as far north as southern Europe and the southern USA (CPC 2007). *P. saucia* is considered to be a minor agricultural pest in most of Europe and eastern Asia, but is a more significant pest in southern Europe (for example, Italy) and in greenhouses on such crops as peppers and globe artichoke. It is a major pest in most of the USA, especially on potato, tomato, tobacco and lucerne, but estimates of financial loss are rarely reported. An exception was a major outbreak of the variegated cutworm on potato in the early 1900s where losses were estimated at 2.5 million dollars. Damage to lucerne crops is most severe in terms of time delay between harvesting a crop and growth of the next crop (CPC 2007).

Variegated cutworms overwinter as pupae with a high percent mortality occurring during this life stage. Female moths emerging from surviving pupae compensate by laying over 2000 eggs during their short life span. Clusters of 60 or more eggs are deposited on stems or leaves of slow-growing plants as well as on fences and buildings. During the summer, eggs usually hatch in 5 days. The active larvae feed at night and on cloudy days for about 3½ weeks before burrowing into the soil to pupate. The non-overwintering pupal stage lasts 2 weeks to a month before second generation moths emerge. Requiring 48 days to complete a life cycle, variegated cutworms produce two to four generations each year depending on weather conditions and latitude (Sorensen & Baker 2008). A wide variety of parasitoids have been reared from *P. saucia* (CPC 2007).

Sarcopolia illoba

Little information is available on the biology of *S. illoba*. A general search of the internet reveals that *S. illoba* is polyphagous having been recorded on many hosts including eggplant, carrots, betts, strawberries, chrysanthemum, beans, peas, alfalfa, soybean, cowpea, mulberry, and blackberry to name a few. Larvae feed mainly at night on young leaves, flower buds and young fruit. It is assumed for the purposes on this analysis that the biological characteristics of *S. illoba* that are important in the context of phytosanitary risk are similar to those of *Mamestra brassicae*.

Spodoptera exigua

S. exigua is a polyphagous pest which attacks most kinds of field crops. It is most commonly recorded from grasses and from maize, rice, sorghum, cotton, tobacco, groundnut, broad bean, sesame, jute, *Citrus*, sugarbeet, lucerne, various vegetables, and weed species (CPC 2007). *S. exigua* originated in Southeast Asia and has now been recorded from Europe, Africa, Australia and North America (CPC 2007, Capinera 2006). It is a sub-tropical and tropical species adapted for life in the warmer regions of each continent; temperature optimum for larval development is reported to be 28°C, but is lower for both oviposition and pupation. In the tropics, breeding can be continuous with four to six generations per year, but in northern regions only one or two generations develop; at lower temperatures, activity and development cease, and when freezing occurs all stages are usually killed. *S. exigua* overwinter in the warmer regions of the Mediterranean, North America and Africa and invade the cooler northern regions as temperatures permit (CPC 2007).

S. exigua eggs are laid at night on the leaves of the host and are generally stuck to the lower surface of the lower leaves. Egg masses consist of tight clusters of 50-150 eggs, usually covered with a protective layer of abdominal bristles. On onions, eggs are deposited in clusters from as few as 20 to over 100 eggs. Hatching usually requires 2-5 days. The first two instars feed gregariously on the underside of the young leaves causing a characteristic skeletonizing or 'windowing' effect. Larger larvae become cannibalistic and thus one or two larvae per plant are usual (CPC 2007). Larvae feed on both foliage and fruit. They also burrow into the crown or centre of the head on lettuce, or on the buds of cole crops (Capinera 2006). Rate of larval development through the six instars is controlled by a combination of diet and temperature conditions. Development usually takes 10-12 days at 28°C but can last as long as 35 days at 16°C. Larger larvae are nocturnal unless they enter the armyworm phase when they swarm and disperse, seeking other food sources. Pupation takes place inside a loose cocoon in an earthen cell, and 6-9 days are required for development. Adults emerge at night, and typically use their natural pre-oviposition period (1-3 days) to fly for considerable distances before they settle to oviposit. On average, adults live for 8-11 days. Given the short generation time of approximately 25 days, several generations can be completed in a cropping cycle under favourable conditions (24-28°C). *S. exigua* is attacked by a large assemblage of parasites (CPC 2007).

Trichoplusia ni

T. ni is widely distributed but is usually considered to have a tropical or subtropical origin. It does not overwinter in many areas where it commonly occurs, but rather migrates there annually. T. ni adults are strong fliers and can migrate considerable distances. *T. ni* is a sporadic migrant only in the UK and northern Europe (CPC 2007).

Adults are strong fliers and are primarily nocturnal. During the day the adults can be found resting in foliage or in crop debris. Moths feed on various wild and cultivated hosts where they obtain water and dissolved nutrients. Adults emerge in spring. There is a pre-ovipositional period of ca. 4 days after which mating begins and most mating occurs after 3-4 days and can continue up to 16 days. Oviposition of viable eggs reaches a peak at 3-6 days and the number of eggs laid can vary over the range ca. 300-1600. The eggs are laid singly on plants (CPC 2007).

There are five larval stages and the total development time of the larval period can vary widely depending on temperature; the normal duration of the larval stage is 2-4 weeks and the pupal stage lasts about 2 weeks (CPC 2007). Gaikwad *et al.* (1983) recorded that at 25°C, *T. ni* eggs hatched in 3-4 days, the 5 instar larval period ranged from 9 to 17 days, and pupation lasted for 6 to 9 days and generally occurred on the underside of leaves or litter or in a folded webbed leaf or between two webbed leaves. With adults surviving 6 to 9 days the total life cycle of *T. ni* in laboratory conditions was estimated on average to be 24 days (Gaikwad *et al.* 1983). There are 3-4 generations per year and *T. ni* can overwinter as a pupa in a cocoon attached to the foliage of its host plants. Many parasitoids are associated with *T. ni* larvae or eggs (CPC 2007).

T. ni populations can cause both severe yield and quality losses, especially under dry conditions. Under severe infestations in cabbage, no heads may be marketable at the end of the season (CPC 2007).

T. ni larvae are considered polyphagous with many recorded hosts being important vegetables. Major hosts include *Brassica juncea* var. *juncea* (Indian mustard), *Brassica napus* var. *napobrassica* (swede), *Brassica napus* var. *napus* (rape), *Brassica oleracea* (cabbages, cauliflowers), *Brassica oleracea* var. *botrytis* (cauliflower), *Brassica oleracea* var. *capitata* (cabbage), *Brassica oleracea* var. *gemmifera* (Brussels sprouts), *Brassica oleracea* var. *gongylodes* (kohlrabi), *Brassica oleracea* var. *italica* (broccoli), *Brassica oleracea* var. *viridis* (collards), *Brassica rapa* subsp. *oleifera* (turnip rape), *Brassica rapa* subsp. *chinensis* (Chinese cabbage), *Brassica rapa* subsp. *pekinensis* (Pe-tsai), *Brassica rapa* subsp. *rapa* (turnip), *Cucurbitaceae* (cucurbits), *Gossypium* (cotton), *Lycopersicon esculentum* (tomato), *Spinacia oleracea* (spinach) (CPC 2007). *Allium cepa* (onion) is listed as one of many minor hosts (CPC 2007)

Xestia c-nigrum

The larvae of *X. c-nigrum* feed on a wide range of herbaceous plants, both weedy and agriculturally important species. The species primarily inhabits open areas where wide ranges of host plants are available. Damage to crop species is more severe in areas where weedy plants grow adjacent to or among the crop plants (CPC 2007).

In most of its range there are two generations of adults each year, one in the late spring and the other in late summer and autumn. There is only one generation per year in northern Europe and at higher elevations in Japan; three generations are reported for southern Europe. Eggs are laid in a single layer singly or in groups of up to 100. A female may lay from 800 to 1500 eggs in her lifetime. Eggs are usually laid on suitable host plants but may also be scattered on the soil under plants. The egg stage lasts for about 6-9 days in the spring and summer when the temperature averages about 20°C, but up to 12 days in the autumn when the mean temperatures average about 15°C (CPC 2007).

During the summer the larva normally passes through six (occasionally seven) stages (instars) before pupating. In the summer the larvae from the spring generation take about a month to reach maturity, but larvae from the autumn generation pass the winter in the larval stage and the number of instars is more variable. Larvae enter the winter in the early-to-middle instars but are usually in the fourth or fifth instar in the spring, suggesting that they continue to feed and grow under the snow during the winter. The larvae can be particularly damaging in the spring because they are large and feed on developing shoots and plant buds. The mature larva has a prepupal resting phase that lasts from 2 to 11 days (depending on mean temperature). The larva buries itself in the soil and pupates in a silk-lined chamber. The pupal stage lasts for 3 weeks in warm weather, and for up to 5 weeks in early spring. After adults emerge from the pupal case they have a pre-oviposition period of 3 or 4 days in spring and summer and 4-6 days in the fall. Adults are nocturnal and generally live for 2-3 weeks. They are attracted to light, and their presence and abundance can be monitored with light traps and pheromone traps to attract males (CPC 2007).

X. c-nigrum is considered a minor agricultural pest in most of its range, but can develop into a major local infestation on a wide variety of crops. For example, it is reported to cause extensive damage to the buds of grapevine in the spring, resulting in reduced yield in parts of the USA (California, Michigan and Washington) but not elsewhere. Usually most feeding activity is on foliage, so damage is in reduced yield rather than crop losses. Wide varieties of parasitoids have been reared from *X. c-nigrum* (CPC 2007).

Lepidopteron parasitoids

There are two main types of parasitoids known to science: *Idiobiont* and *Koinobiont*. Idiobiont parasitoids are those which prevent any further development of the host after initial parasitization, which typically involves a host life stage which is immobile (e.g., an egg or pupa), and idiobiont parasitoids usually live outside the host. Koinobiont parasitoids allow the host to continue its development and often do not kill or consume the host until the host is about to either pupate or become an adult. As such koinobiont parasitoids typically live within or on an active, mobile host. Koinobiont parasitoids are more host specific than idiobiont parasitoids (Althoff 2003).

6.7.1.4. Hazard identification conclusion

Based on the biological descriptions of the Lepidoptera species provided above, *Autographa gamma*, *Hadula trifolii*, *Helicoverpa armigera*, *Loxostege sticticalis*, *Mamestra brassicae*, *Peridroma saucia*, *Sarcopolia illoba*, *Spodoptera exigua*, *Trichoplusia ni*, and *Xestia c-nigrum* complete their life cycles in association with plants as either eggs or larvae on above-ground leaves of host plants or as pupae in the soil. These moth species are therefore unlikely to be associated with commercially-produced onion bulbs in international trade and as such are not considered potential hazards and do not require further analysis.

Any parasitoids associated with these Lepidoptera species are therefore also unlikely to be associated with onion bulbs in international trade and as such are not considered potential hazards and do not require further analysis.

6.7.1.5. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also considerable uncertainty in terms of the epidemiology of these insects on onion bulbs. As such, the risk assessment should be reviewed once further relevant information becomes available.

6.7.2. References

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6.8. Thysanoptera (thrips)

6.8.1. Hazard identification

6.8.1.1. Aetiologic agents

Frankliniella occidentalis (Pergande 1895); Thysanoptera: Thripidae, commonly known as the 'Western flower thrips'.

Scirtothrips dorsalis (Hood 1919); Thysanoptera: Thripidae, commonly known as the 'Chilli thrips'.

Thrips palmi (Karny 1925); Thysanoptera: Thripidae, commonly known as the 'Melon thrips'.

Thrips parvispinus (Karny 1925); Thysanoptera: Thripidae, commonly known as the 'Melon thrips'.

Thrips tabaci (Lindeman 1889); Thysanoptera: Thripidae, commonly known as the 'Onion thrips'.

6.8.1.2. New Zealand status

Scirtothrips dorsalis, *Thrips palmi*, and *Thrips parvispinus* have not been recorded as being present in New Zealand (PPIN 2008, Scott & Emberson 1999).

Frankliniella occidentalis and *Thrips tabaci* are considered established in New Zealand (PPIN 2008) however strains exhibiting varied or greater pesticide resistance, virus vectoring capability, and/or host range or preference, exist in populations of these thrips in other countries (CPC 2007). At the time of publishing this draft analysis, published evidence of resistance in *Thrips* on onions in China to the pesticides applied to onions in New Zealand was not available. Methods of pesticide application in China reportedly increase the likelihood of resistance developing in treated populations (Talekar 1991). The conclusions drawn in this analysis on the risks of pesticide resistant *Thrips* on onions in China will be reviewed once further information becomes available.

6.8.1.3. Biology and epidemiology

The most advanced thrips species are the flower thrips, primarily species of *Thrips* and *Frankliniella*. Pollen provides nutrients for greater egg production, and the adults of most species feed in the flowers of a wide range of the available plant species, including those that are not suitable reproductive hosts. Young leaves are exploited by adults when flowers are scarce. The highly vagile nature of thrips and their other population attributes suggested an ability to outstrip regulatory capacities of natural enemies (Funderburk 2001).

Feeding by thrips, and its by-products, and fouling of plant surfaces, are the main problems associated with crop losses (CPC 2007).

Frankliniella occidentalis

F. occidentalis is remarkably versatile and opportunistic. Natural populations of the species breed vigorously on a wide range of plant species in many different habitats, from lowland to sub-alpine and from humid to arid. This natural versatility pre-adapts the species as a pest. *F. occidentalis* has the basis for fast development of resistance. It has a short generation time and a high fecundity. Furthermore, the haplodiploid breeding system of ***F.*** *occidentalis* can accelerate the development of resistance (Jensen 2000). Development of resistance in *F. occidentalis* and many other arthropod pests is an international problem. The expanding international trade with plant material not only spreads the pests but also spreads resistance genes associated with pests (Jensen 2000).

Even the pest strains, which are presumably inbred, reproduce successfully in a wide range of temperatures and humidities under experimental conditions. However, they cannot survive cold winters outdoors in northern Europe (CPC 2007). At least 250 plant species from more than 65 families being listed as 'hosts'. Unfortunately, the term 'host-plant' is poorly defined in the literature on thrips, plant species sometimes being listed as 'hosts' simply because one or more adult thrips have been collected from them. For many of the 250 plants from which *F. occidentalis* has been recorded there is little or no evidence of breeding (CPC 2007).

As a pest it is found both outdoors and in glasshouses, and it attacks the flowers and leaves of a wide range of cultivated plants. These include onions, apricots, peaches, nectarines and plums; roses, chrysanthemums, carnations, sweet peas, *Gladiolus*, *Impatiens*, *Gerbera* and *Ranunculus*; peas, tomatoes, *Capsicum*, cucumbers, melons, strawberries, lucerne, grapes and cotton (CPC 2007).

Under favourable conditions, *F. occidentalis* will reproduce almost continuously, with up to 15 generations in a year being recorded under glass. The total life cycle from egg to egg has been recorded as 44.1, 22.4, 18.2 and 15 days at 15, 20, 25 and 30°C. Each female lays typically between 20 and 40 eggs during its life. The highest reproductive rate was recorded at 20°C (95.5 hatched eggs/female). Adult thrips sometimes enter closed buds, and eggs are laid concealed within such buds in the parenchymatous tissues; they are also laid in similar tissues of leaves, flower parts and young fruits (CPC 2007).

There are two active larval stages and two non-feeding pupal stages. Second-instar larvae are very active, often seeking concealed sites for feeding. At the end of the second instar, larvae normally drop to the ground and seek somewhere to pupate. The pupation site varies; most commonly it is in the surface layer of dead leaves beneath a plant or even on the plant itself, rather than in the soil. The pupal stage usually takes more than a week before the adult is ready to emerge. Adults and larvae of this species can survive sub-zero temperatures and still reproduce effectively afterwards at higher temperatures (CPC 2007).

Adults can be carried long distances on the wind and thrips breeding outdoors on wild plants can be carried on the wind and then drawn in through the vents of glasshouses. *F. occidentalis* is hard to detect on plant material and is easily missed in plant quarantine (CPC 2007). *F. occidentalis* has been recorded on onion bulbs imported into New Zealand (see Appendix 1).

Scirtothrips dorsalis

S. dorsalis is highly polyphagous and has been recorded from more than 100 plant species spread across 40 different families (Collins *et al.* 2006). Native host plants are probably various Fabaceae, such as *Acacia*, *Brownea*, *Mimosa* and *Saraca*, but *S. dorsalis* is known as a pest on many crops including *Actinidia chinensis*, *Arachis*, *Capsicum*, *Citrus*, cotton (*Gossypium hirsutum*), *Fragaria*, grapevine (*Vitis vinifera*), *Hevea brasiliensis*, *Hydrangea*, *Mangifera*, *Nelumbo*, onions (*Allium cepa*), *Ricinus*, *Rosa*, tamarinds (*Tamarindus indica*) and tea (*Camellia sinensis*). It is only cited as a significant pest of *Citrus* in Japan and Taiwan (EPPO/CABI 1996).

S. dorsalis is mainly a tropical species, but its occurrence in citrus-growing areas with a subtropical climate suggests that it could possibly establish on citrus in southern Europe and the Mediterranean area. On the basis of its natural geographical and host range, *S. dorsalis* seems less likely to establish on citrus under Mediterranean conditions than *S. aurantii* or *S. citri*. On the other hand, its host range includes a number of vegetable crops, and the possibility of introduction onto glasshouse crops in Europe merits consideration (EPPO/CABI 1996). In recent years *S. dorsalis* has started to spread rapidly around the world, associated with the movement of people and plants. Most recently, it has arrived in Florida where it is reported to be present on roses and peppers. The incidence of interceptions of *S. dorsalis* made by the England and Wales Plant Health Service suddenly increased during 2005, with interceptions on produce from India, Kenya, St. Lucia and Thailand (Collins *et al.* 2006).

While *S. dorsalis* is capable of producing continual generations per year, *S. dorsalis* typically undergo 4-8 generations per year. The number, frequency, and duration of generation times are dependant on temperature and moisture. Life cycles are the slowest at the upper and lower temperature extremes, and *S. dorsalis* is capable of over wintering in the soil or protected in plant parts in the adult stage (NPAG 2006). The adult females lay the eggs in the leaves, and the thrips pass through two active feeding larval stages and two quiescent pupal stages before reaching adulthood. Reproduction is both sexual and parthenogenetic (Collins *et al.* 2006).

Unlike many Thysanoptera, *Scirtothrips* spp. seem to require access to soft green tissues, except when pupating in leaf litter and soil. So only seedlings or cuttings with young growing leaf buds are liable to carry these pests. Only young fruits are attacked, so the risk of these thrips being carried on harvested fruits is small (EPPO/CABI 1996). With distortion of young leaves and scarring of fruit, leading both to crop yield reduction and loss of crop quality.

The occurrence of *S. dorsalis* typically coincides with the flowering of host plants, although *S. dorsalis* feeds on shoots, leaves, and young fruit in addition to flowers (NPAG 2006). Like other members of the genus, *S. dorsalis* breeds on young leaves and on the apex of young fruit, particularly under the calyx. It does not feed on mature leaves; adults may at times be found in flowers. Pupae may be found in the axils of the leaves, in leaf curls and under the calyces of flower and fruits, as well as in the soil. The highest risk of transportation therefore is on seedlings or cuttings, or other plants with active growing points (Collins *et al.* 2006). Damage is most severe at growing tips, on young leaves and shoots, or on flowers and young fruits (Collins *et al.* 2006). *S. dorsalis* is recorded as a pest of flowers of onions in India (EPPO/CABI 1996).

S. dorsalis has been known to transmit several plant diseases including Tomato Spotted Wilt Virus which causes Bud Necrosis Disease in peanuts, Yellow Spot Virus on groundnut, non viral Chilli Leaf Curl disease, Peanut Chlorotic Fan Virus, Peanut Yellow Spot Virus (NPAG 2006), Groundnut chlorotic fan-spot virus and Tobacco streak virus (Collins *et al.* 2006).

S. dorsalis has been discovered (intercepted) on the leaves, fruit, and flowers of 30 different plant species. *S. dorsalis* are small thrips (adults are barely more than 1 mm long) (Collins *et al.* 2006) and are difficult to detect without the aid of stereoscopes. As such, *S. dorsalis* infested commodities may go undetected in commercial fruit and vegetable shipments as well as flowers and propagative materials from infested regions (NPAG 2006).

Thrips palmi

T. palmi is a polyphagous pest, especially of Cucurbitaceae and Solanaceae. It has been reported as an outdoor pest of aubergines (Solanum melongena), *Benincasa hispida*, *Capsicum annuum*, cotton (*Gossypium* spp.), cowpeas (*Vigna unguiculata*), cucumbers (*Cucumis sativus*), *Cucurbita* spp., melons (*Cucumis melo*), peas (*Pisum sativum*), *Phaseolus vulgaris*, potatoes (*S. tuberosum*), sesame (*Sesamum indicum*), soyabeans (Glycine *max*), sunflowers (*Helianthus annuus*), tobacco (*Nicotiana tabacum*) and watermelons (*Citrullus lanatus*). It can infest flowers, for example of citrus in Florida (USA) or mango in India. It can also infest weeds (e.g. in unheated glasshouses in Japan: *Vicia sativa*, *Cerastium glomeratum* and *Capsella bursa-pastoris*) (EPPO/CABI 1996).

The geographical distribution of *T. palmi* continues to expand year by year, and the species can be expected to become pantropical in due course (CPC 2007). However, establishment of this species is presumably limited by climatic conditions (McDonald *et al.* 1999). The threshold temperature for development of *T. palmi* and the thermal constant for pre-adult stages were estimated to be 11.6°C and 189.1 day-degrees, respectively (CPC 2007). For example, although outdoor overwintering normally occurs in Okinawa (26°N), in the southern part of Kyushu (about 32°N) and further north on mainland Japan, there is no overwintering out of doors, and greenhouses serve as foci for summer populations. However, a recent study reported no reduction of adult populations at temperatures as low as -3 to -7°C in an unheated glasshouse in Japan (EPPO/CABI 1996). In Australia, infestations are localised, and their extent is probably limited by the prevailing aridity (CPC 2007). Dentener *et al.* (2002) concluded that *T. palmi* should be expected to survive in the warmer parts of New Zealand (the upper North Island).

Adults usually emerge from pupae in the soil or leaf litter, and move to the young leaves and flowers of the host plant, where they lay their eggs in the green tissue in an incision made with the ovipositor. There are two active larval instars and two relatively inactive ‘pupal’ instars. At 25°C, the life cycle from egg to egg lasts only 17.5 days (CPC 2007).

The life cycle differs little from that of most phytophagous Thripidae: the adults emerge from the pupa in the soil and go to the leaves or flowers of the plant, where they lay their eggs. The second-stage larva goes into the soil, develops there and pupates, thus completing the cycle. The specialized mouthparts are adapted for sucking. Therefore the type of plant injury caused by feeding is always sucking damage. The life cycle and population dynamics of *T. palmi* in Japan has been reviewed by Kawai (1990a) (EPPO/CABI 1996).

The pre-oviposition period was 1-3 days for virgin females and 1-5 days for mated ones. Virgin females laid 1.0-7.9 eggs per day, with 3-164 eggs laid during their lifespan. Mated females laid 0.8-7.3 eggs per day and laid 3-204 eggs during their lifespan (CPC 2007).

Both adults and larvae of *T. palmi* feed gregariously on leaves, firstly along the midribs and veins. Stems are attacked, particularly at or near the growing tip, and they are found amongst the petals and developing ovaries in flowers and on the surface of fruit. They leave numerous scars and deformities, and finally kill the entire plant (CPC 2007).

T. palmi, a polyphagous feeder, quickly builds up heavy infestations causing severe injuries. Both larvae and adults feed gregariously on leaves (first along the midribs and the veins), stems (particularly at or near the growing tips), flowers (among the petals and developing ovary) and fruits (on the surface), leaving numerous scars and deformities, and finally killing the entire plant (EPPO/CABI 1996).

T. palmi has only moderate dispersal potential by itself, but is liable to be carried on fruits, or plants for planting of host species, or in packing material (EPPO/CABI 1996). *T. palmi* can be found in pockets, cracks or crevices on host plants. At inspection, silvery feeding scars on the leaf surface, especially alongside the midrib and veins, can be seen (EPPO/CABI 1996). *T. palmi* itself is not easily detectable because of its small size, so quarantine procedures are difficult to manage and this pest has probably slipped through the net with increased traffic in plant produce around the world (CPC 2007). Because *T. palmi* is difficult to detect at low density in consignments, inspections should be made during the growing season at the place of production (EPPO/CABI 1996).

In India, *T. palmi* is the vector of groundnut bud necrosis tospovirus, in Japan and Taiwan of watermelon silvery mottle tospovirus (EPPO/CABI 1996).

Thrips parvispinus

Very little information is available on the biology of *T. parvispinus*. In Malaysia, feeding damage by *T. parvispinus* on papaya is associated with secondary attacks by the saprophytic fungus *Cladosporium oxysporum* (causing bunchy and malformed top of papaya). Extensive leaf damage was observed on *Gardenia* plants in Greece. *T. parvispinus* is recorded as a vector of tobacco streak ilarvirus in transmission studies from infected tomato pollen to seedlings of *Chenopodium amaranticolor* (Mound & Collins 2000). As a tropical and polyphagous species, *T. parvispinus* could present a risk to protected ornamental and vegetable crops.

For the purposes of this risk analysis, *T. parvispinus* and *T. palmi* will be considered together using the biological description of *T. palmi*.

Thrips tabaci

T. tabaci is polyphagous and very easy to overlook when it infests plants, which means it is frequently and easily transported by man. As well as plant leaves and pollen, *T. tabaci* larvae are also predatory on small arthropods, mite eggs and small mites (CPC 2007). In general there is much less known about pesticide resistance in *T. tabaci* than in the closely related and highly polyphagous *Frankliniella occidentalis* (Collins *et al.* 2006). Resistance has been confirmed to deltamethrin in New Zealand (Martin *et al.* 2003), to lambda-cyhalothrin in the USA (Shelton *et al.* 2003) and to cypermethrin in Nicaragua (Rueda & Shelton 2003). In South-East Asia, numerous combinations of these and other insecticides are often used, with the likelihood of increasing resistance developing in treated populations (Talekar 1991).

Over most of its geographic range *T. tabaci* is usually parthenogenic. *T. tabaci* has an estimated net reproductive rate of 26-80 eggs per female, with a peak rate of 5.5-10 eggs per day at 25°C, with eggs being embedded into plant tissue. Egg production is influenced by the species of food plant and nutritional status of the tissues. When fully fed, second instar larvae generally drop to the ground, although some may move to the lower surface of the leaves or into leaf axils for metamorphosis. Unlike some other species, *T. tabaci* larvae that enter the soil do not form a cell but lie in a matrix of loose soil where they quickly transform into a non-feeding prepupa. This instar is capable of limited crawling if disturbed, but normally remains immobile. The pupal stage, which is also non-feeding, soon follows the prepupal stage. Both the prepupal and pupal stages of *T. tabaci* are extremely brief. The duration of development from egg laying to emergence of adult ranges from 11 days at 30°C to 23 days at a mean of 22.4°C (CPC 2007).

Adult *T. tabaci* overwinter in sheltered positions in various crop plants, such as lucerne, red clover, cereals and a wide range of weeds, especially members of the Asteraceae including Achillea, Senecio, Emilia, and the Brassicaceae. *T. tabaci* does not overwinter in debris, nor does any life history stage overwinter in the soil. There is no true diapause, merely cold quiescence. Although adults can live for many months over winter, they are short-lived at higher temperatures (CPC 2007).

T. tabaci adults can fly short distances (tens of metres) with direct flight, but they can also be transported very long distance on air currents. Heavy infestations of about 20 thrips per plant will kill seedling onions whereas similar numbers on mature plants are harmless, or even beneficial, killing the leaves and thereby encouraging curing of the onion bulb (CPC 2007).

6.8.1.4. Hazard identification conclusion

While *Thrips tabaci* is found in onion bulbs (China 2008) and both *Frankliniella occidentalis* and *Thrips tabaci* have been intercepted on onion bulbs in international trade (see Appendix 1), there is no information supporting the association of *Scirtothrips dorsalis*, *Thrips palmi* or *Thrips parvispinus* with onion bulbs. Further to this the nature of their association with the aerial parts of host plants also suggests that they are unlikely to be associated with onion bulbs in international trade. As such these organisms are not considered potential hazards and do not require further assessment.

Frankliniella occidentalis and *Thrips tabaci* have been intercepted on onion bulbs imported into New Zealand and thus are considered potential hazards requiring further assessment.

6.8.2. Risk assessment

6.8.2.1. Entry assessment

Frankliniella occidentalis and *Thrips tabaci* are more likely to enter New Zealand as pupae in the outer layers of the bulb or as adults recently emerged from pupae or infesting bulbs as hitchhikers. Adults of both species can live for many months in cold conditions, with *F. occidentalis* able to survive sub-zero temperatures.

Populations of both thrips species can reach very high levels in short periods of time when conditions are suitable. Plant infestations of *Thrips tabaci* may be considered beneficial just prior to harvesting as they aid in killing the leaves and thereby encouraging curing of the onion bulb. Both *Frankliniella occidentalis* and *Thrips tabaci* have been intercepted on onion bulbs entering New Zealand.

The likelihood of entry of *F. occidentalis* and *T. tabaci* into New Zealand on onion bulbs from China is considered moderate and is therefore, non-negligible.

6.8.2.2. Assessment of exposure

For *F. occidentalis* and *T. tabaci*, any infested bulb material that ends up on a compost heap represents potential exposure pathway as any contaminating adults could disperse to surrounding host plants. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1).

Waste generated at re-packaging plants in New Zealand, where imported bulbs are re-packaged for retail outlets, is likely to generate considerable waste from which adults could disperse to surrounding host plants. Repackaging plants are currently located in areas close to where commercial crops are grown, increasing the likelihood that associated organisms may transfer to crops established in New Zealand (Martin pers. com. 2008).

If *F. occidentalis* and *T. tabaci* adults are present on bulbs or bulb waste deposited outdoors, adults can fly short distances (tens of metres) with direct flight, but they can also be transported very long distance on air currents. Both *F. occidentalis* and *T. tabaci* are highly polyphagous and likely to find suitable hosts in garden or agricultural settings.

The likelihood of exposure of *F. occidentalis* and *T. tabaci* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

6.8.2.3. Assessment of establishment

Environmental conditions in most parts of New Zealand would not restrict the ability of these thrips to establish under normal conditions, as natural populations of these species breed vigorously on a wide range of plant species in many different habitats. Both *T. tabaci* and the pest strains of *F. occidentalis* are likely to be parthenogenic, therefore requiring only one adult to establish a population. As populations of both *F. occidentalis* and *T. tabaci* already exist in New Zealand, parthenogenesis may not necessarily be required.

The likelihood of establishment of *F. occidentalis* and *T. tabaci* from onion (*Allium cepa*) bulbs imported from China is considered moderate and is therefore non-negligible.

6.8.2.4. Consequence assessment

Spread

Once successfully established in warmer areas on New Zealand, both *F. occidentalis* and *T. tabaci* would be expected to spread relatively quickly through the many hosts available as weeds in disturbed ecosystems and into available garden or commercial crops. The likelihood of spread is considered high and is therefore non-negligible.

Economic consequences

As both *F. occidentalis* and *T. tabaci* are already established and widespread in New Zealand, economic consequences of their re-establishment are restricted to the introduction into the local population of new biotypes exhibiting one of the following biological characteristics:

- Resistance to a pesticide in or potentially in use against thrips in New Zealand. There would need to be an expectation that the pesticide resistance would not develop naturally in New Zealand within the timeframe of the likely establishment of the pesticide-resistant biotype.
- Host preference or association not existing in New Zealand. Once again there would need to be an expectation that such host preferences or associations would not develop normally in New Zealand or are not due to some environmental effect within New Zealand (e.g. climate restrictions on pest prevalence and potential host growing areas).

- Biotypes exist overseas that cause greater damage to economically or environmentally important host plants than biotypes in New Zealand. An increase in damage could occur either directly from thrips feeding on leaves or pollen, or indirectly through more efficient vectoring of virus diseases on susceptible hosts.

Prior to around 1992 the biotype of *F. occidentalis* existing in New Zealand, the 'lupin strain' first recorded in 1934, is considered to have low resistance to pesticides (Kirk 2001, Martin & Workman 1994). In 1992 a new biotype of *F. occidentalis*, latterly named the 'greenhouse strain', became apparent on glasshouse-grown crops in Auckland due to its greater level of pesticide resistance (Martin & Workman 1994). It was considered at the time that quarantine procedures in place for the international trade in glasshouse ornamentals would not be effective at preventing the establishment of new thrips species or biotypes in New Zealand (Kirk 2001).

Until 1998 onion growers in New Zealand successfully controlled foliar infestations of *T. tabaci* with sprays of synthetic pyrethriod insecticides. In 1998, however, these insecticides failed to provide adequate field control in many crops in the northern half of the North Island (Martin *et al.* 2003). It is suspected that synthetic pyrethroid resistance in *T. tabaci* was introduced into New Zealand as a new imported biotype (Martin pers. com. 2008).

Both of the biotype introductions into New Zealand described above have been very costly to local growers (Martin pers. com. 2008). Variability in thrips populations between different geographic areas is expected to be high due to different crop management practices and the available thrips genotypes (Shelton *et al.* 2003). When population characteristics of genetic variability and rapid growth combine, rapid development of resistant populations or populations with other new and economically important biological traits would be expected to occur. Limiting the extent of genetic variability within New Zealand populations of both *F. occidentalis* and *T. tabaci* would therefore limit the opportunity for new biotypes to develop and cause unwanted economic impacts.

Therefore *F. occidentalis* and *T. tabaci* biotypes existing on onions in China are considered to have a low likelihood of causing moderate to high impacts on economically important host species in New Zealand.

Environmental consequences

While there is no evidence of *F. occidentalis* and *T. tabaci* biotypes differentially infesting New Zealand native flora, these thrips have a wider host range overseas than in New Zealand that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species. As such, the likelihood is low that *F. occidentalis* and *T. tabaci* biotypes could differentially establish on a native species or significant urban species and have a low environmental impact within New Zealand.

Human health consequences

F. occidentalis and *T. tabaci* are not known to be of any significance to human health.

6.8.2.5. Conclusion of consequence assessment

Based on the above assessment it is concluded that if *F. occidentalis* or *T. tabaci* spread from private gardens to commercial growing areas, they could cause moderate to high economic and low environmental consequences to New Zealand.

6.8.2.6. Risk estimation

The likelihood estimate is moderate that *F. occidentalis* or *T. tabaci* would be associated with onion bulbs on entry into New Zealand; low that *F. occidentalis* or *T. tabaci* would be exposed to the environment; moderate that any *F. occidentalis* or *T. tabaci* that is exposed to the environment would successfully establish in private gardens in New Zealand; high that *F. occidentalis* or *T. tabaci* would spread from private garden areas to commercial onion production areas; and low that spread to commercial production areas would result in moderate to high unwanted economic consequences and low for environmental consequences to New Zealand.

As a result, the risk estimate for *F. occidentalis* and *T. tabaci* associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible and should be considered a hazard.

6.8.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and wider impacts of strains of *F. occidentalis* and *T. tabaci* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

6.8.3. Risk management

6.8.3.1. Risk evaluation

Since the risk estimate for *F. occidentalis* and *T. tabaci* associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible, options for phytosanitary measures are provided for consideration.

6.8.3.2. Option evaluation

There are a number of biosecurity risk management options available for *F. occidentalis* and *T. tabaci* on onion (*Allium cepa*) bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *F. occidentalis* and *T. tabaci*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *F. occidentalis* and *T. tabaci*;
- **c.** Inspection of onion bulbs for *F. occidentalis* and *T. tabaci*;
- **d.** Treatment of onion bulbs for *F. occidentalis* and *T. tabaci* by a suitably efficacious method.
- **e.** Systems approach involving two or more management steps.

Pest free area (PFA)

Given the existence of *F. occidentalis* and *T. tabaci* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *F. occidentalis* and *T. tabaci* in the absence of human assistance can be over large distances, and symptoms of *F. occidentalis* and *T. tabaci* infestation may not be readily apparent when infestation levels are low, establishing a PFPP should not be feasible.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear *F. occidentalis* and *T. tabaci* pupae or adults, and these thrips would not be detected easily by visual examination, inspection of healthy bulbs for thrips infestations would not be an effective phytosanitary measure. This inspection could be used in with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

Page *et al.* (2002) investigated the use of carbon dioxide fumigation as a treatment for *T. tabaci* on onions for international trade. While mortality levels were high on treated onions they were also high on control (untreated) onions and as such the level of efficacy of the treatment could not be determined.

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. *Thrips* species may infest onions bulbs as pupae under the outer layers of the bulb. No efficacy information has been provided for the following methyl bromide treatment schedule. Given the relatively low likelihood of successful establishment of *F. occidentalis* and *T. tabaci* in New Zealand from imported onion bulbs, the following treatment schedule is likely to be more than 99.95% effective against *F. occidentalis* and *T. tabaci* and therefore provide an adequate level of efficacy.

Methyl bromide fumigation schedule for internal feeders (and leafminers) in onion bulbs.

Temperature (ºC)	Rate (g/m^3)	Minimum Concentration Readings (g/m^3) at:					C/T Value ($g\ h/m^3$)
		0.5 hr	2 hrs	2.5 hrs	3 hrs	3.5 hrs	
33 ºC or above	32	26	19	—	—	—	51
26-32 ºC	40	32	24	—	—	—	64
21-25 ºC	48	38	29	—	—	—	77
16-20 ºC	48	38	26	26	—	—	92
11-15 ºC	48	38	26	—	26	—	104
4-10 ºC	48	38	26	—	—	26	117

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should be considered an effective phytosanitary measure for *F. occidentalis* and *T. tabaci* on onion (*Allium cepa*) bulbs imported from China for consumption:

a) Field survey just prior to harvesting to ensure *F. occidentalis* and *T. tabaci* levels are very low (e.g. 0.01%)[13]; and

b) Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8); and

c) Onion bulbs showing symptoms of infestation (discolouration of any kind) after removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic infestation of *F. occidentalis* and *T. tabaci* from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

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7. Analysis of potential hazards - Mites

Aceria tulipae (Keifer, 1938) (Dry bulb mite) is listed as a potential hazard based on the ability of this mite to vector Onion mite-borne latent allexivirus. As this virus is no longer considered a hazard associated with onion (*Allium cepa*) bulbs imported from China (see section 12.1), this potential vector relationship is no longer of concern. As such *Aceria tulipae* should no longer be considered a potential hazard.

7.1. *Rhizoglyphus setosus* and *Steneotarsonemus furcatus*

7.1.1. Hazard identification

7.1.1.1. Aetiologic agent

Rhizoglyphus setosus (Manson 1972) Acari: Acaridae. Otherwise known as a Bulb mite.

Steneotarsonemus furcatus (De Leon 1956) Acari, Tarsonemidae. Otherwise known as the Taro tarsonemid mite.

7.1.1.2. New Zealand status

Neither *Rhizoglyphus setosus* or *Steneotarsonemus furcatus* been recorded in New Zealand (PPIN 2008, Fan & Zhang 2004).

7.1.1.3. Biology and epidemiology

Rhizoglyphus setosus

The developmental stages of *Rhizoglyphus* mites are (in order of progression): egg, larva, protonymph, heteromorphic deutonymph (or hypopus), tritonymph, and adult (Diaz *et al.* 2000). Reproduction is strictly sexual (Gerson *et al.* 1983), and mating begins one to two days after adult eclosion, usually after feeding (Diaz *et al.* 2000).

There are two forms of males of *R. robini* and other Acaridae. One male morph has a modified third pair of legs and is regarded as a fighter male. The other morph has unmodified legs. The role of the two males in *Rhizoglyphus* is uncertain (Diaz *et al.* 2000).

Eggs are laid singly and apparently at random. The number of eggs laid per female is variable and depends upon temperature and food quality (Diaz *et al.* 2000). The numbers of eggs laid by a female *R. echinops* varies from 100-460 (Diaz *et al.* 2000) and is higher in *R. robini*, reaching over 690.

The mites grow well on fragments of peanuts and garlic, but poorly on filter paper (colonised by fungi) (Gerson *et al.* 1983). They feed on both saprophytic fungi (Wooddy & Fashing 1993) and plant pathogenic fungi (Abdel-Sater & Eraky 2002). They can feed on undamaged plant bulbs (Okabe & Amano 1991). Although apparently healthy produce may bear mites, populations are likely to be much lower than on fungal infested produce (Okabe & Amano 1991).

The heteromorphic deutonymph is facultative, with most protonymphs moulting directly to tritonymphs (Diaz *et al.* 2000). The moulting of protonymphs into deutonymphs appears to be linked to poor food quality, high concentrations of waste products, and extremes of temperature and humidity (Diaz *et al.* 2000). The deutonymphs are more resistant to adverse environmental conditions than other stages. Dispersal of the deutonymphs (hypopi in earlier literature) is by arthropods such as scarab and other beetles, flies and fleas (Diaz *et al.* 2000). The transformation from deutonymph to tritonymph is affected by temperature and humidity, but there is conflicting information about conditions favouring high rates of moulting (Diaz *et al.* 2000).

R. setosus has a wide known host range and appears to be associated with tropical and subtropical regions. Hosts include (Fan & Zhang 2004).

Steneotarsonemus furcatus

Species of mite in the genus *Steneotarsonemus* have apparently undergone significant modification in general body contour in adaptation to their particular feeding habits. Both sexes are depressed dorsoventrally and females are quite elongated to permit activity between the sheaths and stems of grass and other monocotyledon hosts. The mouthparts of these mites are unsuitable for effective penetration of mature leaf tissue (Denmark & Nickerson 1981). Adults move short distances by walking, but are dispersed long distances by wind or by attaching to and 'hitch-hiking' on winged insects such as aphids and whiteflies.

7.1.1.4. Hazard identification conclusion

Both *R. setosus* and *S. furcatus* could be associated with onion bulbs imported from China, and both of these mite species could establish in New Zealand. It is therefore proposed that *R. setosus* and *S. furcatus* be considered potential hazards requiring further analysis.

7.1.2. Risk assessment

7.1.2.1. Entry assessment

Rhizoglyphus species are more likely to enter New Zealand as hypopi, adult mites, or as colonies consisting of eggs, larvae, and nymphs. Colonies are likely to be associated with rotting bulbs, especially if fungi are present. Adult mites and hypopi may not be associated with active colonies, but could be with soil or plant debris. Hypopi may be associated with insects, but these vectors are most likely to be associated with rotting bulbs. In addition to the host plants the mites could be in host plant trash, packaging or equipment which has been used to handle infested host plant material.

S. furcatus is only likely to be associated with young leaf tissue within an onion bulb. Neither *R. setosus* nor *S. furcatus* would be significantly affected by periods in cold storage. There is no information available on the relative abundance of these mites on onion plants in China or on onion bulbs prepared for export. Neither mite was listed in China (2008) as being significant on onions in China and therefore should not be considered particularly common.

The likelihood of entry of *R. setosus* and *S. furcatus* into New Zealand on onion bulbs from China is considered low and is therefore, non-negligible.

7.1.2.2. Assessment of exposure

For *R. setosus*, any infested bulb material that ends up on a compost heap represents a potential exposure pathway. It is considered unlikely that more than 1% of the onion bulbs will be discarded into the environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Although apparently healthy produce may bear *R.*

setosus mites, populations are likely to be much lower than on fungal infested produce (Okabe & Amano 1991). The deutonymph life stage is more resistant to adverse environmental conditions than other stages. Dispersal of the deutonymphs (hypopi in earlier literature) is by arthropods such as scarab and other beetles, flies and fleas (Diaz *et al.* 2000).

The likelihood of exposure of *R. setosus* in New Zealand from onion bulbs imported from China is considered very low and is therefore likely to be negligible, however due to uncertainties around waste disposal patterns in New Zealand the likelihood will be considered non-negligible at this time.

For *S. furcatus* only whole bulbs that end up being planted in suitable growing conditions represent a potential exposure pathway. The proportion of whole onion bulbs from China entering these pathways is unknown but is considered negligible. The likelihood of exposure of *S. furcatus* in New Zealand from onion bulbs imported from China is considered negligible. As such *S. furcatus* does not warrant further assessment.

7.1.2.3. Assessment of establishment

If *R. setosus* mites are actively breeding and especially if rots are present, flies and beetles could be attracted to these sites. These insects could be vectors for the phoretic heteromorphic deutonymph and this would significantly increase the likelihood of establishment. Environmental conditions in the northern parts of New Zealand would not restrict the ability of these mites to establish under normal conditions.

The likelihood of establishment of *R. setosus* from onion (*Allium cepa*) bulbs imported from China is considered moderate and is therefore non-negligible.

7.1.2.4. Consequence assessment

Spread

Once successfully established in warmer areas on New Zealand, *R. setosus* would be expected to spread relatively quickly through the many hosts available as weeds in disturbed ecosystems. The likelihood of spread is considered high and is therefore non-negligible.

Economic consequences

Economic consequences of *R. setosus* mites are likely to be restricted to increased spoilage of stored products and fungal infected produce in the field. Although the bulb mite is not considered a primary pest of bulbs, it is often responsible for serious losses; the slightest injury to a bulb will allow bulb mites to enter and become established. Once the mites are inside the bulb, they rapidly turn the bulbs into rotten pulp. Infestations of the bulb mite generally indicate that the bulbs have already been injured. Therefore *R. setosus* is considered to have a moderate likelihood of causing moderate impacts on economically important host species in northern (warmer) areas of New Zealand.

Environmental consequences

As *R. setosus* primarily act as saprophyte of plant material or consume saprophytic (Wooddy & Fashing 1993) or pathogenic fungi (Abdel-Sater & Eraky 2002), environmental impacts within New Zealand are likely to be minimal. As such, the likelihood is low that *R. setosus* could establish on a native species and have an environmental impact within New Zealand.

Human health consequences

R. setosus is not known to be of any significance to human health.

7.1.2.5. Conclusion of consequence assessment

Based on the above assessment it is concluded that if *R. setosus* spread from private gardens to commercial growing areas, it could cause moderate to high economic and low environmental consequences to New Zealand.

7.1.2.6. Risk estimation

The likelihood estimate is moderate that *R. setosus* would be associated with onion bulbs on entry into New Zealand; low that *R. setosus* would be exposed to the environment; moderate that any *R. setosus* that is exposed to the environment would successfully establish in private gardens in New Zealand; low that *R. setosus* would spread from private garden areas to commercial onion production areas; and high that spread to commercial production areas would result in moderate unwanted economic consequences and low for environmental consequences to New Zealand.

The likelihood of exposure of *R. setosus* in New Zealand from onion bulbs imported from China is considered very low and is therefore likely to be negligible, however due to uncertainties around waste disposal patterns in New Zealand the likelihood will be considered non-negligible at this time. *R. setosus* is therefore considered a hazard.

The likelihood of exposure of *S. furcatus* in New Zealand from onion bulbs imported from China is considered negligible and is therefore not considered a hazard on this commodity.

7.1.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *R. setosus* and *S. furcatus* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

7.1.3. Risk management

7.1.3.1. Risk evaluation

Since the risk estimate for *R. setosus* associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible, options for phytosanitary measures are provided for consideration.

7.1.3.2. Option evaluation

There are a number of biosecurity risk management options available for *R. setosus* on onion (*Allium cepa*) bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** No phytosanitary measures required if the non-negligible level of risk is considered acceptable;
- **b.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *R. setosus*;

c. Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *R. setosus*;

d. Inspection of onion bulbs for *R. setosus*;

e. Treatment of onion bulbs for *R. setosus* by a suitably efficacious method.

f. Systems approach involving two or more management steps.

No phytosanitary measures required

Although the likelihood of *R. setosus* entering the country on infected onion bulbs is considered moderate, the inoculum level in the environment is predicted to be very low because the likelihood of exposure is considered very low (disposal of onions). If this level of risk is considered acceptable, no phytosanitary measures may be taken for *R. setosus*.

Pest free area (PFA)

Given the existence of *R. setosus* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *R. setosus* in the absence of human assistance is limited to relatively small distances, and symptoms of *R. setosus* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *R. setosus* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *R. setosus*.

Inspection of onion plants or bulbs

As apparently healthy bulbs may bear mites, and these mites would not be detected easily by visual examination, inspection of healthy bulbs for mite infestations would not be an effective phytosanitary measure.

Mite populations will be significantly more apparent on bulbs showing bruising or decay. During harvesting onion bulbs showing decay or bruising should be inspected for mite colonies. This inspection could be used with other phytosanitary measures that in combination provide an adequate level of efficacy.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *R. setosus* without also negatively affecting the condition of the onion bulbs. Mites would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Miticides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. No efficacy information has been provided for this methyl bromide treatment schedule against *R. setosus* in particular and mites in general. Other research on mite susceptibility to methyl bromide fumigation indicates that the level of efficacy achieved is unlikely to be adequate for *R. setosus* (Jamieson *et al*. 2005).

Ethyl formate has shown a degree of efficacy against mites at the rate of 3-4% (99-132 g/m^3). However onions only tolerated up to 1.8% (60 g/m^3) ethyl formate vapour before bulb softening developed (Ryan *et al*. 2003). As such this treatment is not considered further.

As the pathway for establishment of *R. setosus* in New Zealand requires bulb waste to be deposited into a suitable environment, treatments that significantly reduce the level of bulb waste should be considered. A physical treatment that removes roots and the outer (hard) skin layers should be considered a partially effective treatment for *R. setosus*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8. This treatment could be considered in combination with other phytosanitary measures that together provide an adequate level of efficacy.

Systems approach

Combining several mitigation steps into a systems approach is likely to provide a significantly greater overall level of protection. Combining the following mitigation steps should therefore be considered an effective phytosanitary measure for *R. setosus* on onion (*Allium cepa*) bulbs imported from China for consumption:

a) Field survey just prior to harvesting to ensure *R. setosus* infestation levels are very low (e.g. 0.01%)[14]; and

b) Onion bulbs are cleaned and have their outer (hard) skin layers and root material removed (see figure 3.2b in section 3.2.3.8); and

c) Onion bulbs that have been cleaned and had their outer layer(s) removed are washed in an appropriate sanitizing solution (see section 3.2.3.7); and

d) Onion bulbs showing symptoms of infestation (discolouration of any kind) after cleaning and removal of the outer (hard) layer are excluded from consignments exported to New Zealand.

While this phytosanitary measure would not necessarily prevent an asymptomatic *R. setosus* infestation from entering on onion bulbs, the significant reduction in waste that is likely to be generated from cleaned bulbs is expected to reduce adequately the likelihood of any subsequent establishment.

7.1.4. References

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14 A 0.01% infestation rate would equate to around 30 infected plants per hectare (assuming the planting density is around 300,000 plants per hectare)

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PPIN (2008) Plant Pest Information Network. New Zealand Ministry of Agriculture and Forestry

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8. Analysis of potential hazards - Mollusca

8.1. *Lissachatina fulica*

8.1.1. Hazard identification

8.1.1.1. Aetiologic agents

Lissachatina fulica (Bowdich 1822) (synonym *Achatina fulica* Bowdich 1822 formerly Férussac 1821). Commonly referred to as the 'Giant African Snail' (GAS) (CPC 2007)

8.1.1.2. New Zealand status

Lissachatina fulica has not been recorded in New Zealand (PPIN 2008).

8.1.1.3. Biology and epidemiology

The biological characteristics of *Lissachatina fulica* have been discussed extensively in a previous risk analysis completed for imported vehicles (MAF 2007) and will not be repeated here. From the information presented in this previous risk analysis the following factors are considered important for this analysis:

- *Lissachatina fulica* activity is largely restricted to areas with at least 80 percent relative humidity;
- Eggs are several millimetres in diameter and hatch in anything from a few hours to 17 days;
- Eggs have a transparent shell and are vulnerable to desiccation;
- Eggs are laid in a cluster in a concavity in the soil;

Onion growing areas in China are comparatively dry, experiencing suitable relative humidity's of between 60%-70%. *Lissachatina fulica* is therefore unlikely to be found in significant numbers in onion-growing regions. Dry environmental conditions are also considered necessary for bulb storage (see section 3.4). It should therefore be considered unlikely that the eggs or small immature snails would survive shipment, unless buffered in a clod of soil.

8.1.1.4. Hazard identification conclusion

Given the expectation that consignments will be free of soil clods or clumps (see section 3.1.5), and such contaminants will be required for the successful movement of *Lissachatina fulica* on this pathway, this mollusc should not be considered a hazard on onion (Allium cepa) bulbs imported into New Zealand from China.

8.1.1.5. Assessment of uncertainty

This assessment assumes that *Lissachatina fulica* will not be common in onion-growing regions and will only survive onion-associated transport within clods of soil, and that shipments of onion bulbs from China will be free of soil clods. Should all of these assumptions prove to be incorrect that risk assessment should be considered for review.

8.1.2. References

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9. Analysis of potential hazards - Nematodes

9.1. General hazard assessment

Eight nematodes are listed as potential hazards in Appendix 2. These include *Aphelenchoides besseyi* (Christie 1942), *Ditylenchus dipsaci* (Kühn 1857), *Heterodera glycines* (Ichinohe, 1952), *Meloidogyne graminicola* (Golden & Birchfield 1965), *Paratrichodorus minor* (Colbran 1956), *Paratrichodorus porosus* (Allen 1957), *Pratylenchus zeae* (Graham 1951), and *Rotylenchulus reniformis* (Linford and Oliveira 1940). Two of these nematodes, namely *Paratrichodorus minor* and *Paratrichodorus porosus*, have been recorded in New Zealand however are known to vector another potential hazard, Tobacco rattle tobravirus (TRV) (ICTVdB Management 2006). As TRV is not considered a hazard on this pathway (see section 13.3), *Paratrichodorus minor* and *Paratrichodorus porosus* are also not considered hazard organisms on onion (*Allium cepa*) bulbs from China.

Of the remaining 6 nematodes:

Aphelenchoides besseyi is a foliar pest, and is not expected to be associated with underground plant parts (CPC 2007) and therefore is not considered able to enter on onion bulbs from China. As such *Aphelenchoides besseyi* is not considered a hazard organism on onion (*Allium cepa*) bulbs from China.

Ditylenchus dipsaci is listed as a potential hazard due to strains or isolates of this nematode that are not in New Zealand but may be associated with onions in China. *Ditylenchus dipsaci* occurs in more than 20 biological races, some of which have a limited host range (CPC 2007). The races that breed on rye, oats and onions seem to be polyphagous and can also infest several other crops, whereas those breeding on lucerne, *Trifolium pratense* and strawberries are virtually specific for their named hosts and appear to have relatively few alternative host plants (CPC 2007). As *Ditylenchus dipsaci* is recorded on onion and garlic in New Zealand (PPIN 2008), it is not expected that isolates or strains associated with onions in China will be significantly different from those already in New Zealand. As such *Ditylenchus dipsaci* is not considered a hazard organism on onion (*Allium cepa*) bulbs from China.

Heterodera glycines and *Meloidogyne graminicola* have been recorded on all parts of host plants and are analysed together in section 9.1 below.

Pratylenchus zeae and *Rotylenchulus reniformis* have been recorded in associated with roots of plants and soil and are analysed together in section 9.2 below.

9.1.1. References

CPC (2007) Crop Protection Compendium on Internet. *CAB International*, Wallingford, UK; http://www.cabi.org/compendia/CPC/

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PPIN (2008) Plant Pest Information Network. New Zealand Ministry of Agriculture and Forestry

9.2. *Heterodera glycines* and *Meloidogyne graminicola*

9.2.1. Hazard identification

9.2.1.1. Aetiologic agents

Heterodera glycines (Ichinohe 1952); Nematoda: Tylenchida: Heteroderidae. Otherwise known as the 'Soybean cyst nematode'.

Meloidogyne graminicola (Golden & Birchfield 1965); Nematoda: Tylenchida: Meloidogyninae. Otherwise known as the 'Rice root knot nematode'.

9.2.1.2. New Zealand status

Heterodera glycines and *Meloidogyne graminicola* have not been recorded in New Zealand (PPIN 2008, Knight *et al.* 1997).

9.2.1.3. Biology and epidemiology

Heterodera glycines

H. glycines is a bisexual cyst-forming species. First-stage juveniles moult to second stage within the eggs and hatch under stimulation from exudates from host roots. They invade the root and begin feeding on a group of cells which become modified into a multinucleate syncytium. The female nematode remains at this feeding site as it develops through the vermiform juvenile stages into the swollen adult form. The swelling of the female disrupts the tissues of the host root and the body of the nematode finally protrudes from the surface. The males remain vermiform; they leave the root and are attracted towards the female, where copulation takes place. Eggs are formed within the female and some are laid into an egg sac or "gelatinous matrix". Males may sometimes be found in the gelatinous matrix. When the female dies the body becomes a hardened protective cyst enclosing the eggs (EPPO 2008).

In the field, there are three to five generations per year. Optimum development occurs at 23-28°C; development stops below 14°C and above 34°C (Burrows & Stone 1985). Survival of a small percentage of juveniles occurred after 6 months at -24°C (Slack & Hamblen 1961). In the absence of a host, contents of cysts may remain viable in soil for 6-8 years (Slack *et al.* 1972).

By itself, the nematode is completely sedentary apart from a small amount of independent movement (at most, a few centimetres) by juveniles and males. The durability of the cyst, however, allows considerable passive transport. Cysts with viable juveniles have been recovered from excrement of birds (Epps 1971). International transport is most likely to occur with soil or growing medium attached to plants or seeds; *H. glycines* was shown to be viable for up to 8 months in soil particles mixed in with seed stocks (Epps 1969). Nematodes can also be readily carried in the roots of infected plants.

H. glycines is widespread in Asia (including China) and North and South America, but absent form or under control in the EU countries and the pacific region (EPPO/CABI 1997).

Symptoms

Affected plants show stunting and discoloration (yellow dwarf disease). At low to moderate infestation levels, there is over-production of lateral roots. A low rate of nodulation may also be observed (EPPO/CABI 1997).

Host range

Soybeans are the major economic host of *H. glycines*. Other cultivated hosts, mainly in the Fabaceae, are *Lespedeza* spp., *Lupinus albus*, *Penstemon* spp., *Phaseolus vulgaris*, *Vicia villosa*, *Vigna angularis* and *V. radiata*. Sugarbeet and tomatoes have been found to be experimental hosts. In general, *H. glycines* has a wide host range, mainly on weeds, of at least 23 families (e.g. Boraginaceae, Capparaceae, Caryophyllaceae, Chenopodiaceae, Brassicaceae, Lamiaceae, Fabaceae, Scrophulariaceae, Solanaceae) (EPPO/CABI 1997).

Meloidogyne graminicola

M. graminicola is found in upland soils, shallow-flooded soils and deep-flooded soils. It is well adapted to flooded conditions and can survive in waterlogged soil as eggs in egg masses or as juveniles for long periods. Numbers of *M. graminicola* decline rapidly after 4 months but some egg masses can remain viable for at least 14 months in waterlogged soil (CPC 2007).

Infective, second-stage juveniles of *M. graminicola* invade rice roots in upland conditions just behind the root tip. Females develop within the root and eggs are mainly laid in the cortex. Juveniles can remain in the maternal gall or migrate intercellularly through the aerenchymatous tissues of the cortex to new feeding sites within the same root. This behaviour appears to be an adaptation by *M. graminicola* to flooded conditions enabling it to continue multiplying within the host tissues even when roots are deeply covered by water. Juveniles that migrate from rice roots in flooded soil cannot re-invade (CPC 2007).

Certain crops are resistant or poor hosts of *M. graminicola* and could be used in rotation to reduce nematode populations e.g. castor, cowpea, sweet potatoes, soybeans, sunflower, sesame, onion, turnip, *Phaseolus vulgaris*, jute and okra (CPC 2007). Mycorrhizal inoculant increased the tolerance of onion from root knot nematode damage (Gergon *et al.* 2008) suggesting *M. graminicola* is principally associated with the roots of onion plants.

M. graminicola from Bangladesh has a very short life cycle on rice of less than 19 days at temperatures of 22-29°C, and an isolate from the USA completed its cycle in 23-27 days at 26°C (CPC 2007). In India the life cycle of *M. graminicola* is reported to be 26-51 days, depending on time of year (CPC 2007).

M. graminicola has been recorded in Asia, North and South America, and South Africa (CPC 2007).

Symptoms

The nematode can reduce the bulb diameter and weight of the onion cultivar “Yellow Granex” from 20% to 95% depending on the nematode population density at the start of the cropping period (Gergon *et al.* 2002).

Host range

The main hosts are *Oryza sativa* (rice) and species in the *Poaceae* (grasses). Important minor or wild hosts include *Allium cepa* (onion), *Brassica* spp., *Eleusine coracana* (finger millet), *Glycine max* (soyabean), *Panicum miliaceum* (millet), *Sorghum bicolor* (sorghum), *Triticum aestivum* (wheat), *Zea mays* (maize), and grass weeds (CPC 2007)

Certain crops are resistant or poor hosts of *M. graminicola* and could be used in rotation to reduce nematode populations e.g. castor, cowpeas, sweet potatoes, soybeans, sunflower, sesame, onion, turnip, *Phaseolus vulgaris*, jute and okra (CPC 2007).

9.2.1.4. Hazard identification conclusion

Both *Heterodera glycines* and *Meloidogyne graminicola* could be associated with onion bulbs imported from China either on associated soil or attached roots, and both of these nematode species could establish in New Zealand. It is therefore proposed that *Heterodera glycines* and *Meloidogyne graminicola* be considered potential hazards requiring further analysis.

9.2.2. Risk assessment

9.2.2.1. Entry assessment

Onion (*Allium cepa*) is considered only a minor host of *Heterodera glycines* and *Meloidogyne graminicola*, with onions being recommended as a rotation crop to reduce *M. graminicola* populations. *H. glycines* is expected to be associated with soil and root material on onion bulbs while *M. graminicola*, while principally being associated with soil and roots also, may also be found internally in the bulb. Should these nematodes be found in onion production areas in China, the onion bulbs produced from these areas will be associated with these nematodes although the infection rates are likely to be low unless susceptible weed plants are common in the affected production areas.

The likelihood of entry of *Heterodera glycines* and *Meloidogyne graminicola* into New Zealand on onion bulbs from China is considered low and is therefore, non-negligible.

9.2.2.2. Assessment of exposure

For *Heterodera glycines* and *Meloidogyne graminicola*, any infested bulb material that ends up on a compost heap represents a potential exposure pathway. It is considered unlikely that more than 1% of the onion bulbs will be discarded into the environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). *H. glycines* cysts with viable juveniles have been shown to be viable for up to 8 months in soil particles mixed in with seed stocks (Epps 1969). *M. graminicola* is well adapted to flooded conditions and can survive in waterlogged soil as eggs in egg masses or as juveniles for at least 14 months (CPC 2007).

The likelihood of exposure of *Heterodera glycines* and *Meloidogyne graminicola* in New Zealand from onion bulbs imported from China is therefore considered to be non-negligible.

9.2.2.3. Assessment of establishment

As *H. glycines* has a relatively limited host range, any nematode populations that establish in a home garden are unlikely to be spread beyond the site of establishment. As it is very unlikely that the principle host of *H. glycines*, soybean, will be planted in home gardens any established population of *H. glycines* in these circumstances would be expected to die-off within a few years. The likelihood of establishment of *H. glycines* from onion (*Allium cepa*) bulbs imported from China is considered negligible. As such *Heterodera glycines* does not warrant further assessment.

M. graminicola has a much broader host range that includes many grass species commonly found in New Zealand as weeds. Should *M. graminicola* establish in home garden from a planted onion, the population would be expected to become persistent. The likelihood of *Meloidogyne graminicola* establishing from onion (*Allium cepa*) bulbs imported from China is considered low and is therefore non-negligible.

9.2.2.4. Consequence assessment

Spread

Once successfully established in warmer areas on New Zealand, *M. graminicola* would be expected to spread through the many hosts available as weeds in disturbed ecosystems. The likelihood of spread is considered moderate and is therefore non-negligible.

Economic consequences

The main economic hosts of *M. graminicola* are the grasses (Poaceae) and rice. Rice cultivation in New Zealand is not a significant industry and as such is of little concern. Grasses support a significant part of our agricultural sector which in turn is a major part of New Zealand's economy. However *M. graminicola* requires a relatively warm climate to complete its life cycle in a manner appropriate to it becoming a significant plant pest.

Given the association between *M. graminicola* and grasses, and the importance of grasses to the New Zealand economy, this nematode has a moderate likelihood of causing low to moderate impacts in northern (warmer) areas of New Zealand.

Environmental consequences

There are a number of New Zealand grass species that may be adversely affected by *M. graminicola* should it become established in New Zealand. Significant impacts would be restricted to warmer areas. It is therefore considered that *M. graminicola* has a low likelihood of causing low impacts to some types of natural ecosystems in New Zealand.

Human health consequences

M. graminicola is not known to be of any significance to human health.

9.2.2.5. Conclusion of consequence assessment

Based on the above assessment it is concluded that if *M. graminicola* spread from private gardens to commercial growing areas, it could cause high economic and low environmental consequences to New Zealand.

9.2.2.6. Risk estimation

The likelihood estimate is low that *M. graminicola* would be associated with onion bulbs on entry into New Zealand; low that *M. graminicola* would be exposed to the environment; low that any *M. graminicola* that is exposed to the environment would successfully establish in private gardens in New Zealand; moderate that *M. graminicola* would spread from private garden areas to commercial onion production areas; moderate that spread to commercial production areas would result in low economic consequences; and low for environmental consequences to New Zealand.

The likelihood of exposure of *Meloidogyne graminicola* in New Zealand from onion bulbs imported from China is considered non-negligible. As such *M. graminicola* is considered a hazard on this commodity.

The likelihood estimate is low that *H. glycines* would be associated with onion bulbs on entry into New Zealand; very low that *H. glycines* would be exposed to the environment; and negligible that any *H. glycines* that is exposed to the environment would successfully establish in private gardens in New Zealand. As a result, the risk estimate for *Heterodera glycines* associated with onion (*Allium cepa*) bulbs imported from China for consumption is negligible and as such should not be considered a hazard.

9.2.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *H. glycines* and *M. graminicola* on onion. As such, the risk assessment should be reviewed once further relevant information becomes available.

9.2.3. Risk management

9.2.3.1. Risk evaluation

Since the risk estimate for *M. graminicola* associated with onion (*Allium cepa*) bulbs imported from China for consumption is non-negligible, options for phytosanitary measures are provided for consideration.

9.2.3.2. Option evaluation

There are a number of biosecurity risk management options available for *M. graminicola* on onion (*Allium cepa*) bulbs imported from China for consumption. The following risk management options are assessed:

- **a.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *M. graminicola*;
- **b.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *M. graminicola*;
- **c.** Inspection of onion bulbs for *M. graminicola*;
- **d.** Treatment of onion bulbs for *M. graminicola* by a suitably efficacious method.

Pest free area (PFA)

Given the existence of *M. graminicola* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *M. graminicola* in the absence of human assistance is limited to relatively small distances, and symptoms of *M. graminicola* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *M. graminicola* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *M. graminicola*.

Inspection of onion plants or bulbs

As the life stages of *M. graminicola* infesting mature bulbs are not expected to be visually apparent unless field contamination rates are very high, post harvest inspections prior to export or on arrival in New Zealand would not be effective at detecting *M. graminicola* infestation.

M. graminicola can be detected when plants are uprooted as it causes swellings and galls throughout the root system. Infected root tips become swollen and hooked, a symptom which is especially characteristic of this nematode (CPC 2007). Inspecting onion roots during harvesting for symptoms of *M. graminicola*, and using standard nematode root staining techniques as conformation, should be considered an appropriate screening process. As the risk attributes leading to successful establishment of *M. graminicola* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated.

Under appropriate conditions, inspection of onion roots during harvesting for symptoms of *M. graminicola* infection, and rejection of produce sourced from an infected field, should be considered an effective phytosanitary measure against *M. graminicola*.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *M. graminicola* without also negatively affecting the condition of the onion bulbs. Nematicides applied at the doses required to achieve adequate levels of efficacy are likely to exceed residue limits considered suitable for human consumption. Nematodes would not be significantly affected by temperatures at the lower limit of what would otherwise damage onion bulbs; namely -3ºC. The USDA Treatment Manual (see section 3.2.3.3 for details) provides a heat treatment that involves pre-soaking bulbs in water at 75°F (24°C) for 2 hours, then at 110°F–111°F (43°C-44°C) for 4 hours. No information is available on the level of efficacy this treatment may provide on *M. graminicola*. However as the risk attributes leading to successful establishment of *M. graminicola* in New Zealand are relatively restricted (a very low likelihood of establishment) a treatment achieving a relatively modest level of effectiveness against nematodes (99.99%) should be considered an effective phytosanitary measure. The heat treatment provided above is expected to provide an efficacy level of at least 99.99%.

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. No efficacy information has been provided for this methyl bromide treatment schedule against *M. graminicola* in particular and nematodes in general. Other research on nematode susceptibility to methyl bromide fumigation indicates that the level of efficacy achieved by application of C/T values of 100 g h/m^3 at 20ºC is unlikely to be adequate for *M. graminicola* (Soma *et al.* 2003).

As the pathway for establishment of *M. graminicola* in New Zealand requires bulb waste to be disposed into a suitable environment, treatments that reduce the level of bulb waste should be effective. A physical treatment that removes roots and the outer (hard) skin layers from bulbs and excludes bruised or decayed bulbs from export shipments should be considered an effective treatment for *M. graminicola*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

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9.3. *Pratylenchus zeae* and *Rotylenchulus reniformis*

9.3.1. Hazard identification

9.3.1.1. Aetiologic agents

Pratylenchus zeae (Graham 1951); Nematoda: Tylenchida: Pratylenchidae. Commonly known as a 'Root lesion nematode'.

Rotylenchulus reniformis (Linford & Oliveira 1940); Nematoda: Tylenchida: Hoplolamidae. Commonly known as a 'Reniform nematode'.

9.3.1.2. New Zealand status

Pratylenchus zeae and *Rotylenchulus reniformis* have not been recorded in New Zealand (PPIN 2008, Knight *et al.* 1997).

9.3.1.3. Biology and epidemiology

Pratylenchus zeae

P. zeae is a migratory endoparasite of the root cortex, entering smaller roots at any point. All stages are found in the outer parenchyma cells and never in the vascular tissues. Eggs are laid either singly or in small groups of 3-4, in roots and in the soil. Hatching takes 15-20 days and reproduction of *P. zeae* is greatest at 30°C. The generation time on rice is approximately 30 days (CPC 2007).

P. zeae causes a mechanical breakdown of root cells and necrosis of stelar and cortical tissues resulting in formation of cavities. Necrotic lesions can be observed on the root surface. The effects of root damage can be seen in the field as a reduction in top and root growth visible as stunted and chlorotic plants in patches in the field (CPC 2007).

On maize and sorghum, *P. zeae* is one of the most commonly encountered root lesion nematodes in subtropical and tropical regions. *P. zeae* is found on rice and sugar cane crops worldwide (CPC 2007).

Host range

P. zeae is a pest of rice and other graminaceous crops: principally, maize, sorghum and sugarcane. It has a wide host range (CPC 2007).

The major hosts of *P. zeae* include *Nicotiana tabacum* (tobacco), *Oryza sativa* (rice), *Psidium guajava* (guava), *Saccharum officinarum* (sugarcane), *Solanaceae*, *Sorghum bicolor* (sorghum), and *Zea mays* (maize). Allium species (*A. cepa* and *A. sativum*) are considered minor hosts only (CPC 2007).

Rotylenchulus reniformis

R. reniformis is a soil inhabiting semi-endoparasite of roots (Robinson *et al.* 1997). *R. reniformis* is very widely distributed but is largely confined to the subtropical and tropical regions of the world although it has also been found in warm temperate localities in Europe, USA, China and Japan (CPC 2007).

R. reniformis has four juvenile stages, an immature female and mature female/male stages. Mature females lay single-celled eggs, which develop into the first stage juveniles that moult into the second-stage juvenile before emerging from the egg. Further moults occur producing the third and fourth juvenile stages, all of them retaining the cuticles of the previous stages. None of these juvenile stages are parasitic and they do not feed on the plant roots. The final moult produces an immature vermiform female or male. *R. reniformis* has both males and females but is also known to reproduce parthenogenetically. Males are not parasitic. The vermiform immature female is the infective stage and it partly penetrates the cortex of host plant root. A permanent feeding site in the root endodermis is developed at the head of the nematode and it becomes sedentary. The posterior body of the female remains protruding from the root and swells as the nematode reaches maturity producing a very characteristic kidney or reniform shape. The swollen females lay eggs into a gelatinous matrix, which covers the body on the surface of the root. The life cycle from egg to egg can be as short as 3 weeks and is affected by the host and environmental conditions, in particular temperature (CPC 2007).

R. reniformis is disseminated on the roots of host plants and in soil either in potted plants or as bare rooted seedlings (CPC 2007).

Host range

R. reniformis has an extremely wide host range covering most of the plant families and almost certainly contains other as-yet unrecorded host plants. However, most of the known hosts are secondary and pest damage is either minor or has not been investigated. The nematode is recognized as an economically important damaging pest particularly on cotton, pineapple, sweet potato and soybean. Other reported important crop host plants include cowpea, banana, aubergine, cabbage, okra, melon, pigeon pea, tea and tobacco. There are conflicting reports on some plants that have been described both as hosts and non-hosts. Examples are *Allium* spp., *Brassica* spp., citrus, coffee and rice (Robinson *et al.* 1997).

9.3.1.4. Hazard identification conclusion

Both *Pratylenchus zeae* and *Rotylenchulus reniformis* could be associated with onion bulbs imported from China; however *Pratylenchus zeae* is distributed in tropical and sub-tropical regions only and is unlikely to find conditions suitable for establishing in New Zealand. It is therefore proposed that *Pratylenchus zeae* not be considered a potential hazard on onion bulbs imported from China.

Rotylenchulus reniformis has been recorded as establishing in warm-temperate regions and as such should be considered potential hazards requiring further analysis.

9.3.2. Risk assessment

9.3.2.1. Entry assessment

R. reniformis is likely to be associated with onion bulbs in attached root material. This nematode was not listed in China (2008) as being significant on onions in China and therefore should not be considered particularly common.

The likelihood of entry of *R. reniformis* into New Zealand on onion bulbs from China is very low and is therefore likely to be negligible, however due to uncertainties around the association of this nematode with commercially grown onions in China the likelihood will be considered non-negligible at this time.

9.3.2.2. Assessment of exposure

For *R. reniformis*, any infested bulb material that ends up on a compost heap or being planted in suitable growing conditions represents potential exposure pathways as this nematode has a very wide host range. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). *R. reniformis* is disseminated in soil as either eggs or as juvenile live stages (CPC 2007).

The likelihood of exposure of *R. reniformis* in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

9.3.2.3. Assessment of establishment

R. reniformis has a very wide host range and would be expected to find suitable host material at most of the exposure sites in the warmer parts of New Zealand.

The likelihood of establishment of *R. reniformis* from onion (*Allium cepa*) bulbs imported from China into warmer parts of New Zealand is considered moderate and is therefore non-negligible.

9.3.2.4. Consequence assessment

Spread

Once successfully established in warmer areas on New Zealand, *R. reniformis* would be expected to spread relatively quickly through the many hosts likely to be available. The likelihood of spread is considered high and is therefore non-negligible.

Economic consequences

While *R. reniformis* has a very wide host range, most of the known hosts are secondary and pest damage is either minor or has not been investigated. In relation to New Zealand crop plants, *R. reniformis* is recognized as an economically important damaging pest on sweet potato, aubergine, cabbage and tobacco. Any likely economic impacts on New Zealand are therefore likely to be low to moderate only.

Environmental consequences

While there is no evidence of *R. reniformis* infesting New Zealand native flora, this pathogen has a wide host range that includes plant species that are either socially or culturally important within the urban environment, or are from families that are closely related to native plants or important urban species. As such, the likelihood is low that *R. reniformis* could establish on a native species or significant urban species and have an unwanted environmental impact within New Zealand.

Human health consequences

R. reniformis is not known to be of any significance to human health.

9.3.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that should *R. reniformis* establish in New Zealand it could result in unwanted impacts the New Zealand's economy and environment.

The likelihood that establishment of these plant species in New Zealand result in unwanted consequences is non-negligible.

9.3.2.6. Risk estimation

The likelihood estimate is very low that *R. reniformis* would be associated with onion bulbs on entry into New Zealand; low that *R. reniformis* would be exposed to an appropriate environment to establish in New Zealand; moderate that *R. reniformis* would successfully establish in New Zealand; and high that *R. reniformis* would spread and result in unwanted consequences to New Zealand.

The likelihood of entry of *R. reniformis* in New Zealand on onion bulbs imported from China is considered very low and is therefore likely to be negligible, however due to uncertainties around the association of the nematode with commercially produced onions in China the likelihood will be considered non-negligible at this time. Therefore *R. reniformis* is considered a hazard.

9.3.2.7. Assessment of uncertainty

The greatest and most significant area of uncertainty in this risk analysis is related to our knowledge of the onion food-waste disposal patterns and home gardener seed harvesting in New Zealand. There is also some uncertainty in terms of epidemiology, spread and symptoms of *P. zeae* and *R. reniformis* on onions in China. As such, the risk assessment should be reviewed once further relevant information becomes available.

9.3.3. Risk management

9.3.3.1. Risk evaluation

Since the risk estimate for *R. reniformis* associated with onion bulbs imported from China for consumption is non-negligible, options for phytosanitary measures are provided for consideration.

9.3.3.2. Option evaluation

There are a number of biosecurity risk management options available for *R. reniformis* imported onion bulbs. The following risk management options are assessed:

- **a.** No phytosanitary measures required if the non-negligible level of risk is considered acceptable;
- **b.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of *R. reniformis*;
- **c.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of *R. reniformis*;
- **d.** Inspection of onion bulbs for *R. reniformis*;
- **e.** Treatment of onion bulbs by a suitably efficacious method.

No phytosanitary measures required

Although the likelihood of *R. reniformis* entering New Zealand on onion bulbs from China is considered non-negligible, there is considerable uncertainty regarding the potential for *R. reniformis* to be associated with commercially produced onion bulbs. . If this level of risk and uncertainty is considered acceptable, no phytosanitary measures may be taken for *R. reniformis*.

Pest free area (PFA)

Given the existence of *R. reniformis* in China on crops and weed plant species, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

As spread of *R. reniformis* in the absence of human assistance is limited to relatively small distances, and symptoms of *R. reniformis* infestation are readily apparent, establishing a PFPP should be feasible. As the risk attributes leading to successful establishment of *R. reniformis* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated. Efforts would need to be made to ensure alternative host availability was limited within the production areas.

Under appropriate conditions a PFPP declaration should be considered an effective phytosanitary measure against *R. reniformis*.

Inspection of onion plants or bulbs

R. reniformis can be detected when roots are severely infested, as they can appear dirty because of soil particles adhering to the gelatinous matrices of the nematodes on the surface of the root. To determine its presence or association with disease symptoms the nematode has to be extracted either from the soil or roots by standard nematode extraction procedures (CPC 2007). Inspecting onion roots during harvesting for symptoms of *R. reniformis*, and using standard nematode root staining techniques as conformation, should be considered an appropriate screening process. As the risk attributes leading to successful establishment of *R. reniformis* in New Zealand are relatively restricted (a very low likelihood of establishment), occasional instances of localised field contamination should be tolerated.

Under appropriate conditions, inspection and testing of onion roots during harvesting for symptoms of *R. reniformis* infection, and rejection of produce sourced from an infected field, should be considered an effective phytosanitary measure against *R. reniformis*.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against *R. reniformis* without also negatively affecting the condition of the onion bulbs. Nematicides applied at the doses required to achieve adequate levels of efficacy are likely to exceed residue limits considered suitable for human consumption. Nematodes would not be significantly affected by temperatures at the lower limit of what would otherwise damage onion bulbs; namely -3ºC. The USDA Treatment Manual (see section 3.2.3.3 for details) provides a heat treatment that involves pre-soaking bulbs in water at 75°F (24°C) for 2 hours, then at 110°F–111°F (43°C-44°C) for 4 hours. No information is available on the level of efficacy this treatment may provide on *R. reniformis*. However as the risk attributes leading to successful establishment of *R. reniformis* in New Zealand are relatively restricted (a very low likelihood of establishment) a treatment achieving a relatively modest level of effectiveness against nematodes (99.99%) should be considered an effective phytosanitary measure. The heat treatment provided above is expected to provide an efficacy level of at least 99.99%.

The USDA treatment manual (see section 3.2.3.3 for details) provides a methyl bromide fumigation schedule for insects that are "internal feeders" of onion bulbs. No efficacy information has been provided for this methyl bromide treatment schedule against *R. reniformis* in particular and nematodes in general. Other research on nematode susceptibility to methyl bromide fumigation indicates that the level of efficacy achieved by application of C/T values of 100 g h/m^3 at 20ºC is unlikely to be adequate for *R. reniformis* (Soma *et al.* 2003).

As the pathway for establishment of *R. reniformis* in New Zealand requires bulb waste to be disposed into a suitable environment, treatments that reduce the level of bulb waste should be effective. A physical treatment that removes roots and the outer (hard) skin layers from bulbs and excludes bruised or decayed bulbs from export shipments should be considered an effective treatment for *R. reniformis*. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

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10. Analysis of potential hazards – Phytoplasma

10.1. *Candidatus* Phytoplasma *asteris*

10.1.1. Hazard identification

10.1.1.1. Aetiologic agent

Candidatus phytoplasma *asteris* (Lee *et al.* 2004) or Onion yellows phytoplasma (synonym to Aster yellows phytoplasma group (AY)), is a member of the 16SrI-B '*Candidatus* Phytoplasma *asteris*' subgroup (Lee *et al.* 2004).

10.1.1.2. New Zealand status

AY has not been recorded in New Zealand (Pearson *et al* 2006, PPIN 2008).

10.1.1.3. Biology and epidemiology

Phytoplasmas are phloem-limited cell wall-less bacteria that are associated with diseases in several-hundred plant species. The AY phytoplasma group (16SrI) represents the most diverse and widespread phytoplasma group. The Onion yellows disease that was first detected in Japan is caused by a member of the AY subgroup 16SrI-B (Lee *et al.* 2004).

Epidemiology of AY

AY phytoplasmas affect plants by causing extensive abnormalities in plant growth and development, suggestive of profound disturbance in plant hormone balance. Such abnormalities result a general reduction in quantity and quality of yield, although symptoms can vary depending on the phytoplasma strain (Lee *et al.* 2004). Symptoms typical on herbaceous plant hosts include yellowing of the leaves, stunting, proliferation of auxiliary shoots resulting in a witches'-broom appearance, bunchy appearance of growth at the ends of stems, virescence of flowers and sterility, phyllody, shortening of internodes, elongation and etiolation of internodes, small and deformed leaves (Lee *et al.* 2004). The most severely affected hosts are carrot, lettuce, aster, onion and spinach. Disease incidence may vary from year to year depending on the population trend of the vectors in the field (CPC 2007). After inoculation the concentration of Onion yellows phytoplasma increased six fold over a week (Wei *et al.* 2004).

AY agents are graft- but not seed-transmissible and spread naturally by insect vectors ((Lee *et al.* 2004). As phytoplasmas are phloem-limited, only phloem-feeding insects can potentially acquire and transmit the pathogen. Only a small number of potential vectors have been shown to act as vectors of phytoplasmas, namely the leafhoppers (Cicadelloidea), the planthoppers (Fulgoroidea), and a few psyllids (Psyllidea). Members of the 16SrI-B subgroup of AY are reported to have low insect-vector specificity (Lee *et al.* 1998a). Several leafhoppers are reported to transmit AY however of the recorded vectors only *Macrosteles striiformis* is known from Asia. *Macrosteles quadrilineatus* (from North America) is reported to be the principal vector (Lee *et al.* 1998a). These leafhopper species are polyphagous and can transmit the pathogens to a wide range of host plants (Lee *et al.* 1998a). New Zealand has one recorded leafhopper in the *Macrosteles* genus, namely *M. fieberi* (PPIN 2008), although other New Zealand leaf or plant hoppers may be able to vector AY. Aspects of vector biology, such as longevity, fecundity and host preference, may be altered by phytoplasma uptake (Weintraub & Beanland 2006).

Epidemiology of leafhoppers (vectors)

Weintraub and Beanland (2006) provide a summary of the processing involved in the interactions between phytoplasmas and their insect vectors:

> "Phloem-feeding insects acquire phytoplasmas passively during feeding in the phloem of infected plants. The feeding duration necessary to acquire a sufficient titre of phytoplasma is the acquisition period (APP). The APP can be as short as a few minutes but is generally measured in hours, and the longer the APP, the greater the chance of acquisition. The APP may also depend on the titre of phytoplasmas in the plants."
>
> …….
>
> "The time that elapses from the initial acquisition to the ability to transmit the phytoplasmas is known as the latent period (LP) and is sometimes called the incubation period. The LP is temperature dependent and ranges from a few to 80 days. During the LP the phytoplasmas move through and replicate in the competent vector's body."
>
> ……
>
> "To be transmitted to plants, phytoplasmas must penetrate specific cells of the salivary glands and high levels must accumulate in the posterior acinar cells of the salivary gland before they can be transmitted."
>
> …….
>
> "As leafhoppers or planthoppers feed, they constantly secrete a small amount of sheath saliva into the leaf environment that encases and protects the delicate stylets when it solidifies. Phytoplasmas are introduced into the phloem probably via watery saliva as the leafhopper stylets penetrate sieve element membranes."

Some phytoplasmas, including strains of AY, can be transovarially transmitted (from female to progeny) from the vector (Weintraub and Beanland 2006).

Leafhoppers feed on above-ground plant parts such as leaves and stems. Leaf- or plant-hoppers are not expected to be associated with onion bulbs in international trade. These vectors are also unlikely to feed on onion bulbs that have become exposed above-ground. As such onion bulbs will only become infected with AY through vector transfer to above ground leaves and within-plant translocation from these leaves into the bulbs.

Host range

The following plants are listed as "major hosts" in CPC (2007) and are commercially significant in New Zealand:

Allium cepa (onion), *Apium graveolens* (celery), *Brassica oleracea var. capitata* (cabbage), *Brassica oleracea* var. *italica* (broccoli), *Brassica rapa* subsp. *rapa* (turnip), *Daucus carota* (carrot), *Fragaria ananassa* (strawberry), *Lactuca sativa* (lettuce), *Spinacia oleracea* (spinach), *Trifolium repens* (white clover), *Zea mays* (maize) (CPC 2007)

It is likely however that the strain associated with onions, namely Onion yellows phytoplasma, as a member of the 16SrI-B '*Candidatus* Phytoplasma *asteris*' subgroup (Lee *et al.* 2004), may have a more narrow host range.

Given the wide host range of AY it should be expected that weeds and other local plants may act as inoculate reservoirs while commercial hosts are unavailable.

Geographical distribution

AY is widespread and has been recorded in Asia, Europe, North and South America, South Africa, and Australia. Members of subgroup 16SrI-B (and their vectors) are widespread in North America, Europe and Japan (CPC 2007).

While strains of AY have been recorded in China, no record could be found of AY on onions. The list of pests and diseases of onions in China (China 2008) makes no mention of any phytoplasma-related diseases although a condition referred to as "Onion physiological yellows" is noted. No record could be found of the Asian vector of AY, *Macrosteles striiformis*. It should be expected that in the absence of this vector other phloem-feeding insects may act as vectors of the AY phytoplasma.

For the purposes of this risk analysis it will be assumed that AY is present in China in onion-growing areas however the prevalence of vectors will be considered to be very low, hence the absence of any significant occurrence of AY in commercial production.

10.1.1.4. Hazard identification conclusion

Based on the accepted absence of AY in New Zealand, the potential ability of this phytoplasma to be imported on onion bulbs, and the potential ability of this phytoplasma to cause disease symptoms on onion and a wide range of economically important host plants in New Zealand, it is proposed that AY be considered a potential hazard requiring further assessment.

10.1.2. Risk assessment

10.1.2.1. Entry assessment

Onion bulbs will become infected with AY alone with all other parts of the onion plant should a suitably conditioned insect vector of AY feed on above-ground leaves. Infection early in the growing season would limit onion bulb development in infected plants and effectively exclude those bulbs from international trade, as they would no meet commercial bulb standards. Plants that became infected late in the growing season may not show significant symptoms before harvest and effectively act as symptomless hosts. As mentioned above, the overall prevalence of AY in onion grown in China is not expected to be high. These factors are expected to combine to limit the likely infection rate for onion bulbs imported from China to low levels. The assumptions underpinning this assessment could be confirmed simply by ensuring symptoms of AY are not widespread in the onion fields prior to harvesting.

Assuming there are no significant symptoms of AY in the onions fields prior to harvesting, the likelihood of entry of AY into New Zealand on onion bulbs from China is considered low and is therefore non-negligible.

10.1.2.2. Assessment of exposure

As imported onion bulbs are primarily destined for consumption, it is expected that most will be consumed or otherwise processed. It is estimated that only around 1% of the bulbs will be discarded into household composting systems (see section 3.2.1.1). Only whole bulbs that end up in compost bins represent potential exposure pathways. The proportion of whole onion bulbs from China entering these pathways is unknown but is likely to be small. The proportion of onion bulbs from China that are both infected with AY and are subject to potential exposure is likely to be very small.

The likelihood of exposure of AY in New Zealand from onion bulbs imported from China is considered very low and is therefore likely to be negligible, however due to uncertainties around waste disposal patterns in New Zealand the likelihood will be considered non-negligible at this time.

10.1.2.3. Assessment of establishment

For AY to become established via these exposure pathways a suitable vector would need to feed on the above-ground leaves of an infected plant, successfully acquire the AY phytoplasma from the plant, and successfully transfer the phytoplasma to an alternative persistent host within the surrounding environment. As the vectors are not expected to feed on exposed onion bulbs, only bulbs planted in gardens or sprouting on compost heaps would be expected to act as a potential source of inoculum for any vector. While potential vectors of AY are known in New Zealand, none are recorded as having significant associations with onions. Therefore while this pathway for establishment of AY via onion bulbs imported from China is a theoretical possibility, the extent of the assumptions and uncertainties supporting such a scenario make it inappropriate to consider the likelihood of establishment to be a probability.

The likelihood of establishment of AY from onion bulbs imported from China is therefore considered negligible and as such AY does not warrant further assessment.

10.1.2.4. Risk estimation

The likelihood estimate is low that AY would be associated with onion bulbs on entry into New Zealand; very low that AY would be exposed to the environment; and negligible that AY would become established in New Zealand from onions bulbs imported from China.

As a result, the risk estimate for AY associated with onion bulbs imported from China for consumption is negligible and should not be considered a hazard.

10.1.2.5. Assessment of uncertainty

There is considerable uncertainty associated with aspects of the epidemiology of AY and its potential vectors on onions, and the fate of onion bulbs that are imported into New Zealand for human consumption. More specifically the more important areas of uncertainty relate to the following:

- The association of AY and its vectors with onion production areas in China;
- The potential for vectors to acquire the AY phytoplasma from onion bulbs;
- The association of potential vectors of AY with onion plants in New Zealand;
- The disposal patterns of onion bulbs in New Zealand, most specifically concerning the planting of sprouted onion bulbs in domestic gardens.

The risk assessment should be reviewed once further relevant information becomes available.

10.1.3. Risk management

10.1.3.1. Risk evaluation

Since the risk estimate for AY associated with onion bulbs imported from China is negligible, no phytosanitary measures are required.

10.1.4. References

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11. Analysis of potential hazards - Plants

11.1. Plant weed species

The 19 plant species listed in Appendix 2 are recorded as being associated with cultivated onions and are found in China. These species are either not recorded in New Zealand, recorded in New Zealand but under official control, or recorded in New Zealand but the seeds of which are considered capable of carrying other organisms that are considered economic, environmental and/or human health hazards to New Zealand. It is likely that other plant species could potentially be associated as hitchhikers with consignments of onion bulbs from China. This list should therefore not be considered complete but rather a representative sample of the kinds of plant species potentially found in onion fields in China.

For all of these plants species their association with shipments of onion (*Allium cepa*) bulbs from China to New Zealand will only likely be in the form of a propagable seed or seed containing fruit. As such all 19 plant species are considered together in this risk analysis schedule.

11.1.1. Hazard identification

In table 11.1 below are listed the 26 plant species considered potential hazards in Appendix 2. The only information provided for each plant species focuses on their mode of distribution and the physical characteristics of the dispersal form. While some of these plant species may not easily establish in New Zealand, as they are all recognised as weed species or they already have restrictions on entry into New Zealand, it is assumed that the consequences of their establishment in New Zealand is considered unacceptable. As such no information related to their ability to establish in New Zealand or the likely consequences of them do so is provided in this risk analysis.

Table 11.1: Potential hazard plant species and their mode of distribution.

Weed species	Common name	Mode of Distribution	References
Alopecurus myosuroides	Black-grass	The dispersal unit is a spikelet (commonly called a 'seed') consisting of a caryopsis with the lemma and glumes attached. One seedhead commonly produces 100 to 200 seeds.	Aldrich-Markham (1991), CPC (2007)
Amaranthus blitum	Livid amaranth	Seeds are dark brown to black and shiny, with duller margins. The seeds are compressed, 1-1.8 mm long, faintly reticulate, and minutely punctate-roughened.	PIER (2008), CPC (2007)
Avena fatua	Wild oat	*A. fatua* has relatively large seeds, the majority of which fall close to the parent plant. It produces up to 1000 seeds per plant, and is an obligate inbreeding species.	CPC (2007)
Borreria latifolia	Broadleaf buttonweed	*B. latifolia* produces numerous small seeds which are likely to be transported by animals and by the movement of contaminated soil, produce or machinery.	CPC (2007)
Cenchrus echinatus	Southern sandbur	Seed grains are ovoid, 1.6-3.2 mm long, 1.3 to 2.2 mm wide. Seed burs are covered with numerous, sharp bristles which usually turn purple with age and may be strong enough to penetrate shoe leather. Burrs detach easily from the spike and attach to clothing or animals.	PIER (2008), CPC (2007)

Weed species	Common name	Mode of Distribution	References
Cuscuta europaea	European dodder	*Cuscuta* species are obligate parasites with negligible chlorophyll, and are totally dependent on attachment to a host plant within a few days after germination. They are propagated mainly by seed. Seeds are pale brown, elliptic, about 1 mm in size, and are scabrous.	CPC (2007)
Cynodon dactylon	Bermuda grass	Bermuda grass can produce up to 230 seeds per panicle during the first three months after the initiation of seed set. Seeds are small (0.25-0.30 mg).	PIER (2008), CPC (2007)
Cyperus esculentus	Yellow nutsedge	Mainly spread through movement of tubers, though seed contamination can be important in some areas.	EPPO (2008)
Cyperus rotundus	Purple nutsedge	The fruit (often, but erroneously, known as the seed) is a 3-angled achene, 1.5 mm long and dark brown or black. These "seeds" are distributed by wind or sheet erosion, transported in mud, or floated onto fields by flooding streams or with irrigation water. Spread of *C. rotundus* by seed is generally considered unimportant. Dispersal occurs when tubers are moved in soil attached to transplanted material.	PIER (2008), CPC (2007)
Echinochloa crus-galli	Barnyard grass	*E. crus-galli* reproduces only by seed and a high capacity for seed production allows large populations to establish rapidly. Seeds are ovoid, compressed, and between 1.5-2 mm in length.	PIER (2008), CPC (2007)
Emex australis	Doublegee	*E. australis* only reproduces by seed. Achenes contain a single, trigonous seed and are commonly >10 mm wide (spine tip to spine tip) and are the main method of spread. They have the strong, sharp, impaling spines which attachment to the tyres of vehicles, aircraft and machinery.	PIER (2008), CPC (2007)
Eragrostis cilianensis	Stink grass	*E. cilianensis* is seed dispersed. Seeds are spherical, yellow-brown, flattened, very finely rough and around 0.5 mm in diameter.	PIER (2008), CPC (2007)
Hordeum murinum subsp. *leporinum*	Hare barley	*Hordeum murinum* subsp. *leporinum* is seed dispersed. It is widely distributed wherever cereals are grown suggesting that it has spread with cereal cultivation.	PIER (2008)
Lolium temulentum	Darnel	*L. temulentum* is seed dispersed. It is widely distributed wherever cereals are grown suggesting that it has spread with cereal cultivation.	PIER (2008), CPC (2007)
Medicago polymorpha	California burclover	Seeds are smooth and 2-7-3.1 x 1.5-1.8 mm.	PIER (2008)
Melilotus indica	Indian sweet clover	*M. indica* is seed dispersed. Seeds are light brown and around 1.5-2 mm in length.	PIER (2008), CPC (2007)
Orobanche ramosa	Branched broomrape	*O. ramosa* is an obligate parasite. A single plant carries ten to several hundred flowers and hence may produce up to a quarter million seeds. Seeds are about 0.2 x 0.4 mm in size. The very small seeds easily move from one field to another by water, wind, animals and man. Seeds are not easily seen by the naked eye but are visible under a light microscope.	CPC (2007)
Panicum dichotomiflorum	Fall panicum	*Panicum dichotomiflorum* is seed dispersed. It is widely distributed wherever cereals are grown suggesting that it has spread with cereal cultivation.	PIER (2008)
Parthenium hysterophorus	Parthenium weed	Seeds (achenes) are black, flattened, about 2 mm long, each with two thin, white, spathulate appendages (sterile florets) at the apex which act as air sacs and aid dispersal. Seed is dispersed by wind, water, as a contaminant of harvested material and by vehicles, machinery or animals. Seeds are light and produced in large quantities, often within three weeks of germination.	PIER (2008), CPC (2007)

Weed species	Common name	Mode of Distribution	References
Phalaris canariensis	Canary grass	*Phalaris canariensis* is seed dispersed. It is widely distributed wherever cereals are grown suggesting that it has spread with cereal cultivation.	PIER (2008)
Poa annua	Annual meadowgrass	*Poa annua* is seed dispersed and is a common contaminant of grass seed crops.	PIER (2008), CPC (2007)
Setaria verticillata	Bristly foxtail	*S. verticillata* reproduces solely by seed. Although the seeds eventually separate from the inflorescence, dispersal is very often assisted by the complete inflorescence being carried on clothing or animal fur. Individual spikelets are 2-2.4 mm long, each subtended by 1-3 bristles about 2-8 mm long. These spikelets, with their retrorsely barbed bristles, are distributed by small mammals; and of late by stockings and trousers.	PIER (2008), CPC (2007)
Setaria viridis	Green foxtail	*S. viridis* reproduces solely by seed. There is no specialized mechanism for seed dispersal, but long-distance spread is known to have occurred through contaminated crop seed.	CPC (2007)
Sida acuta	Sida	Awned mericarps of *S. acuta* are spread by adhering to clothing and livestock, in mud on vehicles, and as contaminants in hay and seed crops. Seeds are dark reddish-brown and around 1.5 mm long.	PIER (2008), CPC (2007)
Sorghum halepense	Johnsongrass	High seed production is found in plants with high tiller production. Seeds can remain viable in soil for periods of up to 6 years.	PIER (2008)
Tribulus terrestris	Puncture vine	Fruit is dispersed by adhering to the feet of animals and humans or vehicle and bicycle tyres. Fruit also sticks to sheep wool and is often found in hay, straw and manure. Fruit are 5-12 mm in diameter and bear 2 stout hard spines 2.5-7 mm long. Seeds are yellow, variable in shape but more or less ovoid and 2-5 mm long.	PIER (2008), CPC (2007)

These 26 plant species are mostly characterised by having relatively small seeds that are produced either abundantly or in close association with crop plants. These seeds are not expected to be found inside the onion bulbs but may be associated with the outside of the bulbs under the looser outer skin layers. Seeds may also be associated with packaging material that has not been adequately protected from field plants or contaminated bulbs.

11.1.1.1. Hazard identification conclusion

All of the listed plant species are distributed by seed via the movement of agricultural planting material. As such as a group these plant species are considered potential hazards requiring further analysis.

11.1.2. Risk assessment

11.1.2.1. Entry assessment

The plant species listed in table 11.1 are all widely distributed internationally as weed plants, through the movement of agricultural material between regions. Onion bulbs are likely to have loose outer skins after harvesting and sorting for commercial sale. Many of the seeds of these weed plants could be trapped under these loose outer layers and transported with the bulbs. While the onion farms in China are relatively free of weed plants (Appendix 3), weeds were present in sufficient numbers to remain a concern.

The likelihood of entry of plant species into New Zealand on onion bulbs from China is considered very low and is therefore likely to be negligible, however due to uncertainties around the association of weed seeds with commercially produced onion bulbs the likelihood will be considered non-negligible at this time.

11.1.2.2. Assessment of exposure

For contaminating plant seeds, any infested bulb material that ends up on a compost heap represents potential exposure pathway. It is considered unlikely that more than 1% of the onion bulbs will be discarded into an environment suitable for transfer to local plants; namely household composting systems (see section 3.2.1.1). Many of the weed seeds would find the compost environment suitable for germination and growth or would remain dormant until after the compost had been distributed into the garden.

The likelihood of exposure of plant seeds in New Zealand from onion bulbs imported from China is considered low and is therefore non-negligible.

11.1.2.3. Assessment of establishment

As discussed above, it is assumed for the purposes of this analysis that these plant species are all successfully invasive and as such will have little difficulty establishing in New Zealand should such an opportunity be provided.

The likelihood of establishment of these plant species from onion (*Allium cepa*) bulbs imported from China is considered high and is therefore non-negligible.

11.1.2.4. Consequence assessment

Spread

All of these plant species are considered invasive and are adapted to successful spread agricultural (disturbed) ecosystems. The likelihood of these plant species spread in New Zealand is therefore considered high and as such is non-negligible.

Economic consequences

Aside from the usual economic impacts from the competition by weeds with economic crops for the resources required in production (e.g. water, light, nutrients), a number of these plant species have other consequences. For example, *Parthenium hysterophorus* contains sesquiterpines and phonolics which make this weed allelopathic (suppressive) and causes dermatitis and other allergic reactions in humans and livestock, especially horses.

Environmental consequences

As was the case with economic crops, weed plant species can successfully compete within natural ecosystems for the resources required in production (e.g. water, light, nutrients), negatively affecting the environment. Most of the weeds listed are considered primarily agricultural rather than environmental weeds although some are

Human health consequences

While many of these plant species would be expected to have few direct impacts on human health, *Parthenium hysterophorus* is an allergenic or killer weed for agricultural labourers and city-dwellers that are sensitive to it.

11.1.2.5. Conclusion of consequence assessment

Based on the above assessment, it is concluded that should these plant species establish in New Zealand (beyond their current distributions in some cases) they could cause unwanted impacts the New Zealand's economy, environment and, in a few cases, to the health of New Zealanders.

The likelihood that establishment of these plant species in New Zealand result in unwanted consequences is non-negligible.

11.1.2.6. Risk estimation

The likelihood estimate is very low that plant seeds would be associated with onion bulbs on entry into New Zealand; low that these seeds would be exposed to an appropriate environment to establish in New Zealand; high that any plant seeds that are exposed to the environment would successfully establish in private gardens in New Zealand; and high that these weed plants would spread from private garden areas and result in unwanted consequences to New Zealand.

The likelihood of entry of weed seeds in New Zealand on onion bulbs imported from China is considered very low and is therefore likely to be negligible, however due to uncertainties around the association of weed seeds with commercially produced onions in China the likelihood will be considered non-negligible at this time. Therefore weed plants are considered a hazard.

11.1.2.7. Assessment of uncertainty

As mentioned above there is uncertainty around weed-seed association with commercially produced onion bulbs and waste disposal patterns in New Zealand of imported plant foods. The assumptions underpinning this uncertainty are critical to the outcome of this risk analysis.

11.1.3. Risk management

11.1.3.1. Risk evaluation

Since the risk estimate for plant seeds associated with onion bulbs imported from China for consumption is non-negligible, options for phytosanitary measures are provided for consideration.

11.1.3.2. Option evaluation

There are a number of biosecurity risk management options available for plant seeds on imported onion bulbs. The following risk management options are assessed:

- **a.** No phytosanitary measures required if the non-negligible level of risk is considered acceptable;
- **b.** Pest free area (PFA) (see section 3.2.2 for background information): onion bulbs are imported from areas that are free of plant weed species that are of concern to New Zealand;
- **c.** Pest free place of production (PFPP) (see section 3.2.2 for background information): onion bulbs are imported from places of production that are free of plant weed species that are of concern to New Zealand;

d. Inspection of onion bulbs for plant seeds;

e. Treatment of onion bulbs by a suitably efficacious method.

No phytosanitary measures required

Although the likelihood of plant seeds entering New Zealand on onion bulbs from China is considered non-negligible, there is considerable uncertainty regarding the potential for weed seeds to be associated with commercially produced onion bulbs. If this level of risk and uncertainty is considered acceptable, no phytosanitary measures may be taken for plant seeds.

Pest free area (PFA)

Given the existence of these and many more weedy plant species in all agricultural areas including China, it is unlikely that a PFA could successfully be established for all of the plant species of concern. Should a PFA be successfully established however, a PFA declaration would be considered an effective phytosanitary measure.

Pest free place of production (PFPP)

A pest free place of production would require not only the suppression or removal of plant weeds from the production sites during the growing season, seeds already in the viable soil from previous years would also need to be removed or made non-viable. As many plant weed seeds can survive for over 10 years, and some plant species produce seeds that are wind dispersed over long distances, it is unlikely that a PFPP could successfully be established for all of the plant species of concern.

Inspection of onion bulbs for plant seeds

A number of the seeds from the plants listed in table 11.1 have very small seeds (e.g. *Orobanche ramose* at 0.2 x 0.4 mm, *Eragrostis cilianensis* at 0.5 mm in diameter) and visible only with a light microscope. As any contaminating seeds could also be obscured from view by the loose outer layers of onion skin, the use of a visual inspection as a phytosanitary measure would not seem appropriate. Without information on the detection efficacy of seeds on onion bulbs it is not currently possible to determine appropriate inspection criteria.

Treatment of onion bulbs

There are unlikely to be any chemical or environmental (heat, cold, irradiation) treatments that would achieve adequate levels of efficacy against contaminating seeds without also negatively affecting the condition of the onion bulbs. Seeds would not be significantly affected by temperatures at the limits of what would otherwise damage onion bulbs; namely -3ºC minimum and 50ºC maximum. Herbicides applied at the doses required to achieve adequate levels of efficacy would exceed residue limits considered suitable for human consumption.

As any contaminating seeds are only likely to be associated with the outer loose layers of skin on the onion bulbs, physical treatments that remove this outer layer and any contaminating soil should be considered an effective treatment for seed contamination. A more detailed description of a bulb cleaning treatment is provided in section 3.2.3.8.

11.1.4. References

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12. Analysis of potential hazards - Viruses

The Oxford English Dictionary defines a "*virus*" as:

> *"An infectious organism that is usually sub microscopic, can multiply only inside certain living host cells (in many cases causing disease) and is now understood to be a non-cellular structure lacking any intrinsic metabolism and usually comprising a DNA or RNA core inside a protein coat"*

This chapter assesses the biosecurity risks from viruses that are potentially associated with onions growing in China for export to New Zealand.

12.1. Onion mite-borne latent allexivirus

12.1.1. Hazard identification

12.1.1.1. Aetiologic agents

Onion mite-borne latent allexivirus (OMbLV) (ICTVdB Management 2006).

12.1.1.2. New Zealand status

OMbLV has not been recorded in New Zealand (Pearson *et al* 2006, PPIN 2008).

12.1.1.3. Biology and epidemiology

Two strains of OMbLV have been recorded in the literature. The strain that is associated with onions (*Allium cepa, A cepa* var. *ascalonicum, A porrum*, *A. chinense, A vineale*) has been recorded as occurring in France, the Netherlands, Spain, and the USSR (former) (ICTVdB Management 2006). The garlic strain differs from the type strain by not infecting onion, shallot and rakkyo, and infecting garlic and sand leek. The garlic strain is also found in other countries including Chile, China, Iran, Japan, Morocco, Philippines and Syria (ICTVdB Management 2006).

While virus particles can be best detected in all parts of an infected host plant, the infected plants are usually symptomless, though sometimes they may show a slight mottling (ICTVdB Management 2006). Vegetative propagation of the most important hosts, latent infection and omnipresence and abundance of the vector imply that the virus is readily spread and that it is difficult to control (ICTVdB Management 2006).

Virus is transmitted by a vector, *Aceria tulipae* (Keifer, 1938), and by mechanical inoculation. Virus is not transmitted by other the common vectors *Acyrthosiphon pisum, Myzus (Sciamyzus) ascalonicus, M. persicae*, or by seed.

Status of OMbLV in China and New Zealand

The strain associated with onions has not been recorded from New Zealand or China. It should be noted that this strain is usually symptomless in the onion hosts and as such is not likely to be detected unless blind (symptomless) samples are taken.

A survey of *Allium* crops in New Zealand in 2004-2005 sampled only plants showing symptoms of bacterial, fungal and phytoplasma diseases. Following the same pattern 100 leaves were randomly collected for virus assays and to estimate virus incidence (Fletcher *et* *al.* 2005). This provides some confidence that at least in the 2004-2005 years OMbLV was not common in *Allium* crops in New Zealand.

As the vector, *Aceria tulipae* (Keifer, 1938), is present in both New Zealand and China (PPIN (2008) and Song *et al.* (2008) respectively), the potential for this virus to establish and spread in both countries should be considered relatively high.

12.1.1.4. Hazard identification conclusion

As the strain of OMbLV associated with onions (*Allium cepa*) has not been reported in China, this virus should not be considered a hazard at this time. However should the presence of OMbLV in China be established in the future the hazard status of this virus should be re-assessed.

12.1.2. References

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12.2. Shallot yellow stripe potyvirus

12.2.1. Hazard identification

12.2.1.1. Aetiologic agents

Shallot yellow stripe potyvirus (SYSV) (ICTVdB Management 2006a, van Dijk 1993). The Welsh onion yellow strip potyvirus (WoYSV) is considered a strain of SYSV (van der Vlugt *et al.* 1999, ICTVdB Management 2006b).

12.2.1.2. New Zealand status

SYSV (and the strain WoYSV) has not been recorded in New Zealand (Pearson *et al* 2006, PPIN 2008).

12.2.1.3. Biology and epidemiology

SYSV has only been found naturally on shallots (*Allium cepa* var. *ascalonicum*), which show symptoms of mild striping of young leaves when infected. The WoYSV strain has been recorded naturally on shallot and the welsh or spring onion (*Allium fistulosum* L. var. *giganteum*) (Chen *et al.* 2005).

As the scope of this risk analysis covers onion (*Allium cepa*) bulbs from China only, and shallots (*Allium cepa* var. *ascalonicum*) or the welsh or spring onion (*Allium fistulosum* L. var. *giganteum*) are excluded (see section 2.1.9), SYSV should not be considered associated with this pathway.

12.2.1.4. Hazard identification conclusion

As the strains of SYSV have not been recorded as associated with onions (*Allium cepa*) bulbs, this virus should not be considered a hazard at this time. However should SYSV be recorded naturally on bulb-forming onion (*Allium cepa*) varieties, or these alterative Alliums (*Allium cepa* var. *ascalonicum* or *Allium fistulosum* L. var. *giganteum*) be considered for import, in the future the hazard status of this virus should be re-assessed.

12.2.2. References

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12.3. Tobacco rattle tobravirus

12.3.1. Hazard identification

12.3.1.1. Aetiologic agents

Tobacco rattle tobravirus (TRV) (ICTVdB Management 2006).

12.3.1.2. New Zealand status

TRV has been recorded in New Zealand as the synonym Paeony ringspot virus on species of *Narcissus* and *Paeonia* only (Pearson *et al* 2006, PPIN 2008) and with no evidence of proliferation (ICTVdB Management 2006).

12.3.1.3. Biology and epidemiology

Natural hosts of TRV include *Stellaria media*, *Viola arvensis*, *Beta vulgaris*, *Spinacia oleracea*, *Capsicum annuum*, *Solanum tuberosum*, *Narcissus pseudonarcissus, Tulipa* sp., *Hyacinthus* sp. and the host from which TRV was first isolated, *Nicotiana tabacum* (ICTVdB Management 2006). TRV is considered to have a large host range and many plant species have been successfully infected experimentally, including *Allium cepa* (ICTVdB Management 2006).

Recorded strains of TRV include Fraxinus virus, Oregon yellow virus, PRN (Scottish type strain), and spinach yellow mottle (ICTVdB Management 2006). There is no record available of TRV on *Allium cepa* in China.

12.3.1.4. Hazard identification conclusion

While TRV in New Zealand is restricted to only a few hosts and seems at this stage to be a relatively limited pathogen, there is no evidence to suggest that onions imported from China would act as a pathway for the introduction into New Zealand of more virulent strains or isotypes of TRV. When considering the biosecurity risks associated with onion bulbs imported from China, TRV should therefore not be considered a hazard at this time.

12.3.2. References

ICTVdB Management (2006). 00.072.0.01.001. Tobacco rattle virus. In: *ICTVdB - The Universal Virus Database*, version 4. Büchen-Osmond, C. (Ed), Columbia University, New York, USA. http://www.ncbi.nlm.nih.gov/ICTVdb/ICTVdB/00.072.0.01.001.htm

Pearson M N, Clover G R G, Guy P L, Fletcher J D, Beever R E (2006) A review of the plant virus, viroid and mollicute records for New Zealand. *Australasian Plant Pathology* 35; pp 217–252

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Glossary of terms

Area	An officially defined country, part of a country or all or part of several countries, as identified by the competent authorities (SPS agreement 1994)
Biosecurity	The exclusion, eradication or effective management of risks posed by pests and diseases to the economy, environment and human health (Biosecurity Strategy 2003).
Commodity	A good being moved for trade or other purposes. Packaging, containers, and craft used to facilitate transport of commodities are excluded unless they are the intended good (MAF 2006).
Consequences	The adverse effects or harm as a result of entry and establishment of a hazard, which cause the quality of human health or the environment to be impaired in the short or longer term (MAF 2006).
Disease	A finite abnormality of structure or function with an identifiable pathological or clinicopathological basis, and with a recognizable syndrome of clinical signs. Its cause may not be known, or may be from infection with a known organism (MAF 2006)
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (Convention on Biological Diversity 1992)
Entry (of a organism or disease)	Movement of an organism or disease into a risk analysis area (MAF 2006).
Environment	(Biosecurity Act 1993) Includes: (a) Ecosystems and their constituent parts, including people and their communities; and (b) All natural and physical resources; and (c) Amenity values; and (d) The aesthetic, cultural, economic, and social conditions that affect or are affected by any matter referred to in paragraphs (a) to (c) of this definition
Establishment	Perpetuation, for the foreseeable future, of an organism or disease within an area after entry (MAF 2006).
Exposure	The condition of being vulnerable to adverse effects (MAF 2006).
FAO	Food and Agriculture Organization, United Nations.
Hazard organism	Any disease or organism that has the potential to produce adverse consequences (MAF 2006).
Import health standard (IHS)	A document issued under section 22 of the Biosecurity Act 1993 by the Director General of MAF, specifying the requirements to be met for the effective management of risks associated with the importation of risk goods before those goods may be imported, moved from a biosecurity control area or a transitional facility, or given a biosecurity clearance (MAF 2006). Note: An import health standard is also an "import permit" as defined under the IPPC
Import risk analysis	A process to identify appropriate risk-mitigating options for the development of import health standards. These risk analyses can focus on an organism or disease, a good or commodity, a pathway, or a method or mode of conveyance such as shipping, passengers or packaging (MAF 2006).
IPPC	International Plant Protection Convention (1997), FAO
MAF	New Zealand Ministry of Agriculture and Forestry

Micro-organism A protozoan, fungus, bacterium, virus or other microscopic self-replicating biotic entity (ISPM No. 5 2009)

Nursery stock Whole plants or parts of plants imported for growing purposes, e.g. cuttings, scions, budwood, marcots, off-shoots, root divisions, bulbs, corms, tubers and rhizomes (MAF 2006).

Organism (Biosecurity Act 1993)

(a) Does not include a human being or a genetic structure derived from a human being:
(b) Includes a micro-organism:
(c) Subject to paragraph (a) of this definition, includes a genetic structure that is capable of replicating itself (whether that structure comprises all or only part of an entity, and whether it comprises all or only part of the total genetic structure of an entity):
(d) Includes an entity (other than a human being) declared by the Governor-General by Order in Council to be an organism for the purposes of this Act:
(e) Includes a reproductive cell or developmental stage of an organism:
(f) Includes any particle that is a prion.

Pathway Any means that allows the entry or spread of a potential hazard (MAF 2006).

Pest Any species, strain or biotype of plant, animal or pathogenic agent, injurious to plants or animals (or their products) or human health or the environment (MAF 2006).

Note: the definition given for "pest" here is different from that used in the Biosecurity Act 1993 "an organism specified as a pest in a pest management strategy". The Biosecurity Act 1993 deals more with "risks" and "risk goods".

Pest risk assessment A process to measure the level and nature of biosecurity risk posed by an organism. A pest risk assessment can be used to inform biosecurity surveillance activities or identify pests of high risk to New Zealand (MAF 2006).

Phytosanitary measure Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (ISPM No. 5 2009).

Post-entry quarantine (PEQ) Quarantine applied to a consignment after entry (ISPM No. 5 2009).

Residual risk The risk remaining after risk management requirements have been implemented (MAF 2006).

Risk The likelihood of the occurrence and the likely magnitude of the consequences of an adverse event (MAF 2006).

Risk analysis The process composed of hazard identification, risk assessment, risk management and risk communication (MAF 2006).

Risk analysis area The area in relation to which a risk analysis is conducted (MAF 2006).

Risk assessment The evaluation of the likelihood, and the biological and economic consequences, of entry, establishment, or exposure of an organism or disease (MAF 2006).

Risk good (Biosecurity Act 1993) Means any organism, organic material, or other thing, or substance, that (by reason of its nature, origin, or other relevant factors) it is reasonable to suspect constitutes, harbours, or contains an organism that may:

(a) Cause unwanted harm to natural and physical resources or human health in New Zealand; or
(b) Interfere with the diagnosis, management, or treatment, in New Zealand, of pests or unwanted organisms

Risk management	The process of identifying, selecting and implementing measures that can be applied to reduce the level of risk (MAF 2006).
Spread	Expansion of the geographical distribution of a potential hazard within an area (MAF 2006).
Tissue culture	See "Plants *in vitro*"
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalization (ISPM No. 5 2009)

References for Glossary

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Appendix 1: Organisms intercepted on onion bulbs

The following is a list of organisms that have been intercepted, diagnosed and recorded from onion bulbs imported into New Zealand since 1955 (up to June 2008).

Organism type	Common name	Family (or Order)	Genus/species	Life stage intercepted
Invertebrates				
Ant	White-footed ant	Formicidae	*Technomyrmex albipes*	Queen
Aphid	Onion aphid	Aphididae	*Neotoxoptera formosana*	Apterous (adult)
Beetle	Cigarette beetle	Anobiidae	*Lasioderma serricorne*	Not recorded
Beetle	Drugstore beetle	Anobiidae	*Stegobium paniceum*	Adult
Beetle	Red-legged ham beetle	Cleridae	*Necrobia rufipes*	Adult
Beetle	Silken fungus beetles	Cryptophagidae		Larva
Beetle	Hairy fungus beetle	Mycetophagidae	*Typhaea stercorea*	Adult
Beetle	Hairy fungus beetles	Mycetophagidae		Adult
Beetle	Dried fruit beetle	Nitidulidae	*Carpophilus hemipterus*	Adult, larva
Beetle	Dried fruit beetles	Nitidulidae	*Carpophilus* sp.	Larva
Beetle	Sap beetles	Nitidulidae	*Haptoncus* sp.	Adult
Beetle	Pineapple sap beetle	Nitidulidae	*Carpophilus humeralis*	Not recorded
Beetle	Sap beetles	Nitidulidae		Larva
Beetle	Rove beetles	Staphylinidae	*Atheta* sp.	Adult
Beetle	Rove beetles	Staphylinidae		Larva
Beetle	Black fungus beetle	Tenebrionidae	*Alphitobius laevigatus*	Adult
Beetle	Flour beetles	Tenebrionidae	*Tribolium* sp.	Larva
Beetle	Darkling beetles	Tenebrionidae		Adult
Book Louse	Psocids	Psocoptera (order)		Not recorded
Book Louse	Psocids	Psocoptera (order)		Adult
Book Louse	Grain psocids	Lachesillidae	*Lachesilla* sp.	Adult
Bug	True bugs	Hemiptera (order)		Nymph
Cockroach	Cockroaches	Dictyoptera:		Juvenile
Cricket	Crickets	Gryllidae		Not recorded
Earwig	European earwig	Forficulidae	*Forficula auricularia*	Adult
Fly	Flies	Diptera (order)		Pupa
Fly	Ferment flies	Drosophilidae	*Drosophila* sp.	Adult, egg, pupa, larva
Fly	Vinegar flies	Drosophilidae		Adult, pupa, larva
Fly	Lance flies	Lonchaeidae		Larva
Fly	Leaf-mining flies	Opomyzoidea		Larva
Fly	Picture-winged fly	Otitidae	*Acrosticta* sp.	Adult, larva
Fly	Black onion fly	Otitidae	*Tritoxa flexa*	Not recorded
Fly	Scuttle flies	Phoridae	*Megaselia* sp.	Pupa
Fly	Scuttle flies	Phoridae		Adult, larva
Fly	Compost fly	Scatopsidae	*Scatopse* sp.	Not recorded
Fly	Dark-winged fungus gnats	Sciaridae		Larva
Fly	Onion bulb fly	Syrphidae	*Eumerus strigatus*	Pupa, larva
Fly	Crane flies	Tipulidae		Adult
Mite	Storage mite	Acaridae	*Caloglyphus berlesei*	Not recorded
Mite	Storage mite	Acaridae	*Caloglyphus* sp.	Not recorded
Mite	Groceries mite	Acaridae	*Lepidoglyphus destructor*	Not recorded
Mite	Bulb mite	Acaridae	*Rhizoglyphus echinopus*	Not recorded
Mite	Bulb mite	Acaridae	*Rhizoglyphus robini*	Adult, egg, juvenile, immature
Mite	Bulb mite	Acaridae	*Rhizoglyphus setosus*	Not recorded
Mite	Bulb mite	Acaridae	*Rhizoglyphus* sp.	Adult, larva, nymph
Mite	Cereal mite	Acaridae	*Tyrophagus putrescentiae*	Not recorded
Mite	Soil mite	Acaridae	*Tyrophagus similis*	Adult
Mite	Whirligig mites	Anystidae	*Anystis* sp.	Adult

Organism type	Common name	Family (or Order)	Genus/species	Life stage intercepted
Mite	Predatory mites	Cheyletidae	*Cheyletus* sp.	Not recorded
Mite	House mite	Glycyphagidae	*Glycyphagus domesticus*	Adult
Mite	Slime mites	Histiostomatidae	*Histiostoma feroniarum*	Adult
Mite	Slime mites	Histiostomatidae	*Histiostoma sapromyzarum*	Adult
Mite	Saprophytic mite	Parasitidae		Adult
Mite	Predatory mites	Phytoseiidae		Adult
Mite	Tarsonemid mite	Tarsonemidae	*Tarsonemus confusus*	Adult
Mite	Soft-bodied mite	Tarsonemidae	*Tarsonemus* sp.	Adult
Moth	Indian meal moth	Pyralidae	*Plodia interpunctella*	Not recorded
Moth	Grass moths	Pyralidae		Larva
Moth	Smoky moths	Zygaenidae		Pupa
Thrips	Thrips	Thysanoptera (order)		Adult, larva, nymph
Thrips	Thrips	Terebrantia		Not recorded
Thrips	Western flower thrips	Thripidae	*Frankliniella occidentalis*	Adult
Thrips	Thrips	Thripidae		Adult
Thrips	Potato thrips	Thripidae	*Thrips tabaci*	Adult, larva, nymph
Tick	Brown dog tick	Ixodidae	*Rhipicephalus sanguineus*	Not recorded
Molluscs				
Slug/Snail	Tawny garden slug	Limacidae	*Lehmannia flavus*	Not recorded
Nematodes				
Nematode	Nematode	Rhabditidae		Adult, juvenile
Fungi				
Fungus	Collar rot	Trichocomaceae	*Aspergillus niger*	N/A
Fungus	Storage rot	Trichocomaceae	*Penicillium notatum*	N/A
Fungus		Trichocomaceae	*Penicillium* sp.	N/A
Fungus	Grey mould	Sclerotiniaceae	*Botrytis aclada*	N/A
Fungus	Black mould	Mycosphaerellaceae	*Mycosphaerella tassiana*	N/A

The following is a list of organisms that have been recorded as being intercepted from onion bulbs imported into countries or regions other than New Zealand.

Organism type	Common name	Family (or Order)	Genus/species	Life stage intercepted
Invertebrates				
Beetle	Colorado potato beetle	Chrysomelidae	*Leptinotarsa decemlineata*	Not recorded (EPPO)
Leaf miner	American serpentine leafminer	Agromyzidae	*Liriomyza trifolii*	Not recorded (EPPO)
Leaf miner	Serpentine leafminer	Agromyzidae	*Liriomyza huidobrensis*	Not recorded (EPPO)
Nematodes				
Nematode	White potato cyst nematode	Heteroderidae	*Globodera pallida*	Not recorded (EPPO)

References for Appendix 1

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MAF (2008) MAF databases and interception records. Ministry of Agriculture and Forestry.

EPPO (2008) EPPO Reporting Service. European and Mediterranean Plant Protection Organization. http://www.eppo.org/PUBLICATIONS/reporting/reporting_service.htm

Appendix 2: Organisms recorded on onions in China (or region)

Based on commodity association records held in online databases; namely CPC (2007), EPPO PQR (2006), ICTVdB Management (2006), and Farr *et al* (2008); and from information kindly provided by the AQSIQ in China (China 2008), the following organisms have been recorded as potentially being associated with onion bulbs in China. The organisms identified as potential hazards will be further assessed to determine if they are hazards and if any biosecurity (phytosanitary) measures may be necessary. The table headings are described in more detail in the MAF BNZ risk analysis procedures (2006) which are available online at www.maf.govt.nz.

Scientific name	Common name and Authority	Commodity association (reference)	Present in China (reference) (see note 1)	Present in NZ (reference) (see note 2)	Vector of a potential hazard	In NZ but association with goods increases hazard	In NZ but geographically bounded	In NZ but has different host associations or strains	No or little information on organism	Under official control or notifiable	Potential hazard
Bacteria											
Burkholderia cepacia	Sour skin of onion: (Yabuuchi *et al.* 1993)	CPC (2007)	Y (ubiquitous)	Y (Young 2000)	No	No	No	No	No	No	No
Burkholderia gladioli pv. *alliicola* (syn *Pseudomonas gladioli* pv. *alliicola*)	Bacterial leaf blight of tomato: (Burkholder 1942)	CPC (2007)	Y (CPC 2007) N (China 2006)	Y (ICMP 2008, PPIN 2008)	No	No	No	No	No	No	No
Enterobacter cloacae	Bacterial grapevine blight: (Jordan 1890)	Bishop & Davis 1990	Y (ubiquitous)	Y (Young 2000)	No	No	No	No	No	No	No
Erwinia carotovora subsp. *atroseptica*	Bacterial soft rot: ((van Hall 1902) Dye 1969)	CPC (2007)	Y (Bradbury 1986)	Y (ICMP 2008, PPIN 2008)	No	No	No	No	No	No	No
Erwinia carotovora subsp. *carotovora*	Bacterial soft rot: ((Jones 1901) Bergey *et al.* 1923)	China (2008), CPC (2007), Wright *et al* (1993)	Y (China 2008, Tang *et al* 1996)	Y (Wright *et al* 1993, PPIN 2008)	No	No	No	No	No	No	No
Erwinia chrysanthemi	Kansas lettuce disease: ((Burkh.) Young *et al.* 1978)	CPC (2007)	Y (Yang 1990) N (China 2006)	Y (Boesewinkel 1975, PPIN 2008)	No	No	No	No	No	No	No

Scientific name	Common name and Authority	Commodity association (reference)	Present in China (reference) (see note 1)	Present in NZ (reference) (see note 2)	Vector of a potential hazard	In NZ but association with goods increases hazard	In NZ but geographically bounded	In NZ but has different host associations or strains	No or little information on organism	Under official control or notifiable	Potential hazard
Erwinia chrysanthemi pv. *chrysanthemi*	Lettuce marginal leaf blight: ((Burkholder *et al.* 1953) Dye 1969)	CPC (2007)	Y (Yang 1990, EPPO 2006)	N (CPC 2007, NZFungi 2008, ICMP 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Pantoea agglomerans	bacterial grapevine blight: ((Beijerinck 1888) Gavini *et al.* 1989)	Hattingh and Walters (1981)	Y (CPC 2007)	Y (NZFungi 2008, Young 2000, PPIN 2008)	No	No	No	No	No	No	No
Pantoea ananatis	Fruitlet rot of pineapple: ((Serrano 1928) Mergaert *et al.* 1993)	CPC (2007), Schwartz *et al.* (2000)	Y (Zhang *et al* 1999)	N (CPC 2007, NZFungi 2008, Young 2000, ICMP 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Pseudomonas marginalis	Crown gall: ((Brown 1918) Stevens 1925)	CPC (2007)	Y (Tzeng *et al* 1994)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Pseudomonas marginalis pv. *marginalis*	Gall, hairy root: ((Brown 1918) Stevens 1925)	CPC (2007)	Y (Tzeng *et al* 1994)	Y (ICMP 2008)	No	No	No	No	No	No	No
Pseudomonas syringae pv. syringae	Bacterial canker: (van Hall 1902)	CPC (2007)	Y (CABI/EPPO (336) 1988)	Y (ICMP 2008, PPIN 2008)	No	No	No	No	No	No	No
Pseudomonas viridiflava	Bacterial leaf blight: ((Burkholder 1930) Dowson 1939)	CPC (2007)	Y (CABI/EPPO (917) 2004)	Y (ICMP 2008, PPIN 2008)	No	No	No	No	No	No	No
Rhizobium radiobacter (syn *Agrobacterium tumefaciens*)	Kansas lettuce disease: ((Beijerinck & van Delden 1902) Young *et al.* 2001)	CPC (2007)	Y (Bradbury 1986)	Y (ICMP 2008, Young 2000, PPIN 2008) as *Agrobacterium tumefaciens*	No	No	No	No	No	No	No

Scientific name	Common name and Authority	Commodity association (reference)	Present in China (reference) (see note 1)	Present in NZ (reference) (see note 2)	Vector of a potential hazard	In NZ but association with goods increases hazard	In NZ but geographically bounded	In NZ but has different host associations or strains	No or little information on organism	Under official control or notifiable	Potential hazard
Fungi											
Alternaria alternata	Alternaria leaf spot: ((Fr.) Keissl. (1912))	CPC (2007), Farr *et al* (2008)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Alternaria palandui	Leaf spot: (Ayyangar)	Farr *et al* (2008)	Y (Zhang-Tian Yu 1999)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Alternaria porri (syn *Macrosporium porri*)	Purple blotch: ((Ellis) Cif. 1930)	China (2008), CPC (2007), Farr *et al* (2008) (also as *A. dauci* var. *porri*)	Y (CABI/EPPO (350) 1985, China 2008, Zhang 2000, Tai 1979 as *A. dauci* var. *porri*)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Alternaria solani (syn. *Alternaria allii*)	Leaf spot: (Sorauer 1896)	Farr *et al* (2008) (as *Alternaria allii*)	Y (Zhuang 2005) (as *Alternaria allii*)	Y (NZFungi 2008, Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Alternaria tenuissima	Alternaria leaf spot: ((Kunze) Wiltshire 1933)	Farr *et al* (2008)	Y (Zhang 2000)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Aspergillus flavus	Green mould: (Link 1809)	Farr *et al* (2008)	Y (CPC 2007)	Y (Neill 1939, PPIN 2008)	No	No	No	No	No	No	No
Aspergillus niger	Black mould: (Tiegh. 1867)	CPC (2007), Farr *et al* (2008) Appendix 1	Y (Huang and Scott 1985)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Aspergillus ustus	Green mould: ((Bainier) Thom & Church 1926)	Farr *et al* (2008)	Y (BCCM 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Athelia rolfsii	Sclerotium rot: ((Curzi) C.C. Tu & Kimbr. 1978)	Farr *et al* (2008)	Y (CABI/EPPO (311) 1992)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Botryosphaeria rhodina (anamorph *Lasiodiplodia theobromae*)	Black rot: (Berk. & M.A. Curtis) Arx 1970)	CPC (2007)	Y (CABI/EPPO (561) 1985)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Botryotinia fuckeliana	Grey mould-rot: ((de Bary) Whetzel 1945)	CPC (2007) Farr *et al* (2008)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No

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Botryotinia squamosa	Leaf blight of onion: (Vienn.-Bourg. 1953)	China (2008) (as *Botrytis squamosa*), CPC (2007) Farr *et al* (2008)	Y (CABI/EPPO (164) 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Botrytis aclada	Grey mould of onion: (Fresen. 1850)	CPC (2007), Farr *et al* (2008) Appendix 1	Y (CABI/EPPO (169) 1987) (Zhuang 2005)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Botrytis byssoidea	Onion sclerotinia rot: (J.C. Walker 1925)	China (2008) (as *Sclerotinia allii*)	Y (China 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Cladosporium allii	Leaf spot: ((Ellis & G. Martin) P.M. Kirk & J.G. Crompton 1984)	China (2008), CPC (2007), Farr *et al* (2008)	Y (Zhuang 2005, China 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Cladosporium cladosporioides	Cladosporium leaf spot: ((Fresen.) G.A. de Vries 1952)	Farr *et al* (2008)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Cladosporium oxysporum	Seedlings blight of passion fruit: (Berk. & M.A. Curtis 1868)	CPC (2007)	Y (CPC 2007)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Cochliobolus eragrostidis (anamorph *Curvularia eragrostidis*) (syn. *Pseudocochliobolus eragrostidis*)	Leaf spot: ((Tsuda & Ueyama) Sivan. 1987)	Farr *et al* (2008) (as a *Curvularia* anamorph)	Y (Zhu & Qiang 2004)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Cochliobolus lunatus	Leaf spot: (R.R. Nelson & F.A. Haasis 1964)	Farr *et al* (2008)	Y (Jin 1989)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Colletotrichum circinans	Onion smudge: ((Berk.) Voglino 1907)	China (2008), CPC (2007), Farr *et al* (2008)	Y (Shi and Tong 1997, China 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No

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Colletotrichum dematium	Leaf spot, spongy dry rot: ((Pers.) Grove 1918)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (986) 2006)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Davidiella allii-cepae	Black mould: ((M.M. Jord., Maude & Burchill) Crous & U. Braun 2003)	Farr *et al* (2008) (*Cladosporium* anamorph)	Y (Zhang 2000)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Davidiella tassiana	Black mould: ((De Not.) Crous & U. Braun 2003)	Farr *et al* (2008) *Mycosphaerella schoenoprasi*) Appendix 1 (as *M. tassiana*)	Y (Tai 1979)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Diaporthe phaseolorum var. sojae	Pod blight: soyabean: ((Lehman) Wehm. 1933)	CPC (2007), Farr *et al* (2008)	Y (Wu and Lee 1985)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Fusarium oxysporum	Basal rot: (Schltdl. 1824)	CPC (2007), Farr *et al* (2008)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Fusarium oxysporum f. sp. *cepae* (syn. *Fusarium vasinfectum var. zonatum*)	Fusarium blight: ((Hanzawa) W.C. Synder & H.N. Hansen 1940)	Farr *et al* (2008) as *F. vasinfectum var. zonatum*	Y (Tai 1979)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Fusarium redolens	Root rot: (Wollenw. 1913)	China (2008)	Y (China 2008)	Y (NZFungi 2008, PPIN 2008 as syn *F. oxysporum* var. *redolens*)	No	No	No	No	No	No	No
Gibberella avenacea	Fusarium blight: (R.J. Cook 1967)	Farr *et al* (2008) (as a *Fusarium* anamorph)	Y (CABI/EPPO (950) 2005)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Gibberella baccata	Collar rot of coffee: ((Wallr.) Sacc. 1883)	Farr *et al* (2008) (as a *Fusarium* anamorph)	Y (Tai 1979)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No

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Gibberella fujikuroi var. subglutinans (syn. *Fusarium moniliforme*)	Fusarium blight: (E.T. Edwards 1933)	Farr *et al* (2008) as *Fusarium moniliforme*	Y (CABI/EPPO (102) 1990)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Gibberella intricans	Damping-off of safflower: (Wollenw. 1931)	CPC (2007), Farr *et al* (2008) (as a *Fusarium* anamorph)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Gibberella tricincta	Blight or foot rot: (El-Gholl *et. al* 1978)	CPC (2007) (as *Fusarium tricinctum*)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Gibberella zeae	Headblight of maize: ((Schwein.) Petch 1936)	Farr *et al* (2008) (as a *Fusarium* anamorph)	Y (CABI/EPPO (763) 1998)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Gliocladium catenulatum	Fungal antagonist: (Gilman & E. Abbot)	CPC (2007)	Y (PRD 2008-03)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Glomerella cingulata	Anthracnose: ((Stoneman) Spauld. & H. Schrenk 1903)	CPC (2007)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	Yes (CPC 2007)	No	No	Yes
Haematonectria haematococca	Dry rot of potato: ((Berk. & Broome) Samuels & Nirenberg 1999)	CPC (2007), Farr *et al* (2008) (as a *Nectria* synonym)	Y (CPC 2007)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Hyaloperonospora parasitica	Downy mildew: ((Pers.) Constant. 2002)	Farr *et al* (2008) (as a *Botrytis* synonym)	Y (CABI/EPPO (170) 1987)	Y (NZFungi 2008, Pennycook 2003, PPIN 2008 as *Peronospora parasitica*)	No	No	No	No	No	No	No
Leveillula taurica	Powdery mildew: ((Lév.) G. Arnaud 1921)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (217) 1996)	Y (PPIN 2008, PPIN 2008)	No	No	No	No	No	No	No

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Macrophomina phaseolina	Charcoal rot of bean/tobacco: ((Tassi) Goid. 1947)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (566) 1985)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Mycosphaerella olivaceum	Black mould: (Wehum)	Farr *et al* (2008)	Y (Tai 1979)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Myrothecium verrucaria	Myrothecium blotch: ((Alb. & Schwein.) Ditmar 1813)	CPC (2007)	Y (CPC 2007)	Y (NZFungi 2008)	No	No	No	No	No	No	No
Olpitrichum tenellum	Black rot: ((Berk. & M.A. Curtis) Hol.-Jech. 1975)	Farr *et al* (2008) (as *Oidium tenellum*)	Y (Chen *etal*. 2005)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Penicillium digitatum	Green mould: ((Pers.) Sacc. 1881)	CPC (2007)	Y (CABI/EPPO (975) 2006)	Y (Pennycook 2003, PPIN 2008)	No	No	No	No	No	No	No
Penicillium expansum	Blue mould of stored apple: (Link 1809)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (976) 2006)	Y (Pennycook 2003, PPIN 2008)	No	No	No	No	No	No	No
Penicillium italicum	Blue mould: (Wehmer 1894)	CPC (2007)	Y (CABI/EPPO (977) 2006)	Y (Pennycook 2003, PPIN 2008)	No	No	No	No	No	No	No
Penicillium oxalicum	Blue mould: (Currie & Thom 1915)	Mohan & Schwartz (2005)	Y (CPC 2007)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Peronospora destructor	Downy mildew of onion: ((Berk.) Fr. 1849)	China (2008) (*P. schleidenii*), CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (76) 1990, China 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Phomopsis longicolla	Pod and stem blight: (Hobbs *et al.* 1985)	CPC (2007)	Y (Cui *et al.* 2009)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phyllosticta sp.	(Pers. 1818)	China (2008)	Y (China 2008)	N (NZFungi 2008, PPIN 2008) if *Phyllosticta allii.*	No	No	No	No	No	No	Yes

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Phytophthora capsici	Soft rot: (Leonian 1922)	Farr *et al* (2008), Ho (1990)	Y (Erwin and Ribeiro 1996)	N (NZFungi 2008, Beever *et al* 2006, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phytophthora cinnamomi	Stem canker: (Rands 1922)	Farr *et al* (2008)	Y (CABI/EPPO (302) 1991)	Y (NZFungi 2008, Beever *et al* 2006, PPIN 2008)	No	No	No	Yes (cited in Ormsby 2008)	No	No	Yes
Phytophthora cryptogea	Tomato foot rot: (Pethybr. & Laff. 1919)	CPC (2007)	Y (Zheng and Lu 1990)	Y (Beever *et al* 2006, PPIN 2008)	No	No	No	No	No	No	No
Phytophthora drechsleri	Tuber rot: (Tucker 1931)	Farr *et al* (2008)	Y (CABI/EPPO (281) 1979)	N (Beever *et al* 2006)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phytophthora meadii	Rubber leaf drop: (McRae 1918)	Farr *et al* (2008)	Y (CABI/EPPO (548) 1982, CPC 2007)	N (Beever *et al* 2006, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phytophthora nicotianae	Black shank: (Breda de Haan 1896)	China (2008), Farr *et al* (2008)	Y (CABI/EPPO (613) 1989, China 2008)	Y (Beever *et al* 2006, PPIN 2008)	No	No	No	No	No	No	No
Phytophthora palmivora	Black rot: ((E.J. Butler) E.J. Butler 1919)	Farr *et al* (2008)	Y (CABI/EPPO (725) 1996)	N (Beever *et al* 2006, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phytophthora porri	White tip of leek: (Foister 1931)	CPC (2007), Farr *et al* (2008)	Y (Ho and Lu 1997)	N (PPIN 2008, Beever *et al* 2006)	No	N/A	N/A	N/A	N/A	N/A	Yes
Plasmodiophora brassicae	Cabbage club root: (Woronin 1877)	CPC (2007)	Y (CABI/EPPO (101) 1977)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Pleospora allii	Onion blight: ((Rabenh.) Ces. & De Not. 1863)	Farr *et al* (2008)	Y (CABI/EPPO, 2006)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Pleospora herbarum	Leaf blight of onion: ((Fr.) Rabenh. 1857)	China (2008) (*Stemphylium botryosum*) CPC (2007), Farr *et al* (2008)	Y (CPC 2007, Teng 1996, China 2008)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No

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Pleospora tarda	Leaf blight of onion: (E.G. Simmons 1986)	China (2008) (*Stemphylium botryosum*) CPC (2007), Farr *et al* (2008)	Y (CPC 2007, Teng 1996, China 2008)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Puccinia allii	Rust of allium, onion, leek and garlic: (F. Rudolphi 1829)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (400) 1984)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Puccinia asparagi	Asparagus rust: (DC. 1805)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (216) 1979)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Pythium graminicola	Seedling blight of grasses: (Subraman. 1928)	CPC (2007)	Y (CABI/EPPO (296) 1968)	Y (PPIN 2008, Robertson 1980)	No	No	No	No	No	No	No
Pythium intermedium	Pythium root rot: (de Bary 1881)	Farr *et al* (2008)	Y (Waterhouse & Waterstan 1964)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Pythium irregulare	Dieback: carrot: (Buisman 1927)	CPC (2007)	Y (Jiang *et al* 1990)	Y (NZFungi 2008, PPIN 2008, Robertson 1980)	No	No	No	No	No	No	No
Pythium spinosum	Pythium root rot: (Sawada 1926)	Farr *et al* (2008)	Y (CPC 2007)	Y (Pennycook 1989, PPIN 2008, Robertson 1980)	No	No	No	No	No	No	No
Pythium ultimum	Pythium root and stem rot: (Trow 1901)	Farr *et al* (2008)	Y (CPC 2007)	Y (Pennycook 1989, PPIN 2008, Robertson 1980)	No	No	No	No	No	No	No
Pythium vexans	Pythium root rot: (de Bary 1876)	Farr *et al* (2008)	Y (CABI/EPPO (205) 1980)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Rhizopus stolonifer	Black mould rot: ((Ehrenb.) Vuill. 1902)	Farr *et al* (2008)	Y (CPC 2007)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Schizothyrium pomi	Fly speck: ((Mont. & Fr.) Arx 1959)	Farr *et al* (2008) (as *Zygophiala jamaicensis*)	Y (CPC (2007)	Y (NZFungi 2008) (as *Zygophiala jamaicensis*)	No	No	No	No	No	No	No
Sclerotinia minor	Sclerotinia disease of lettuce: (Jagger 1920)	Farr *et al* (2008)	Y (CABI/EPPO (889) 2003)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Sclerotinia sclerotiorum	Cottony soft rot: ((Lib.) de Bary 1884)	CPC (2007), Farr *et al* (2008)	Y (CABI/EPPO (971) 2005)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Sclerotium cepivorum	White rot of onion and garlic: (Berk. 1841)	China (2008), CPC (2007), Farr *et al* (2008)	Y (EPPO PQR 2006, China 2008)	Y (NZFungi 2008, PPIN 2008)	No	No	No	No	No	No	No
Stemphylium allii-cepae	Leaf blight: (.G. Zhang & T.Y. Zhang 2003)	Farr *et al* (2008)	Y (Zhang *et al* 2003)	N (NZFungi 2008, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Stemphylium lycopersici	Grey leaf spot: ((Enjoji) W. Yamam. 1960)	Farr *et al* (2008)	Y (Matsushima 1980)	Y (Pennycook 1989, PPIN 2008)	No	No	No	No	No	No	No
Thanatephorus cucumeris	Leaf blight: ((A.B. Frank) Donk 1956)	China (2008), Farr *et al* (2008) (as *Rhizoctonia solani*)	Y (China 2008, Tai 1979)	Y (NZFungi 2008, PPIN 2008)	No	No	No	Yes (Ceresini 1999)	No	No	Yes
Thielaviopsis basicola (syn. *Chalara elegans*)	Black root rot: ((Berk. & Broome) Ferraris 1912)	CPC (2007), Farr *et al* (2008) (*Thielaviopsis basicola*)	Y (CABI/EPPO (218) 2006, CPC 2007)	Y (NZFungi 2008, Pennycook 2003)	No	No	No	No	No	No	No
Tompetchia webberi (syn. *Aegerita webberi*)	Brown fungus of whitefly: (H.S. Fawc. 1910)	Farr *et al* (2008)	Y (CPC 2007)	Y (NZFungi 2008)	No	No	No	No	No	No	No

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Trichoderma harzianum	Hyperparasite of *Thanatephorus cucumeris*: (Rifai 1969)	CPC (2007)	Y (EPPO PQR 2006)	Y (Grant 1990, NZFungi 2008)	No	No	No	No	No	No	No
Urocystis cepulae	Onion smut: (Frost 1877)	China (2008), CPC (2007), Farr *et al* (2008 as *U. magica*)	Y (Guo 1988, China 2008)	Y (NZFungi 2008 as *U. magica*, PPIN 2008)	No	No	No	No	No	No	No
Insects											
Acrolepia manganeutis	Stone leek miner: (Meyrick 1913)	China (2008)	Y (China 2008)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Acrolepiopsis sapporensis	Stone leek miner: (Matsumura 1931)	CPC (2007) (as *Acrolepia sapporensis*), Landry (2007)	Y (Wang *et al*.1999) (as *Acrolepia alliella)*	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Agrotis ipsilon	Black cutworm: (Hufnagel 1766)	CPC (2007)	Y (CPC 2007)	Y (Allan 1975, Scott and Emberson 1999)	No	No	No	No	No	No	No
Alphitobius laevigatus	Black fungus beetle: (Fabricius 1758)	Appendix 1	Y (CPC 2007)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Atherigona orientalis	Pepper fruit fly: (Schiner 1868)	CPC (2007)	Y (Pont 1992)	N (PPIN 2008, Scott and Emberson 1999)	Yes (CPC 2007)	N/A	N/A	N/A	N/A	N/A	Yes

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Autographa gamma	Silvery moth: (Linnaeus 1758)	EPPO PQR (2006)	Y (CPC 2007, USDA PRA 2003)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Bemisia tabaci	Tobacco whitefly: (Gennadius 1889)	EPPO PQR (2006)	Y (CABI/EPPO (284) 1999)	Y (PPIN 2008, Scott and Emberson 1999)	No	No	No	Yes (CPC 2007)	No	No	Yes
Bradysia odoriphaga	Chinese chive maggot: (Yang & Zhang 1985)	China (2008)	Y (China 2008)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Calliphora vomitoria	Bluebottle fly: (Linnaeus 1758)	CPC (2007)	Y (Banziger *et al.* 2008)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Delia antiqua	Onion fly: (Meigen 1826)	China (2008), CPC (2007), EPPO PQR (2006)	Y (CPC 2007)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Delia floralis	Turnip maggot: (Fallén 1824)	CPC (2007)	Y (CABI/EPPO (510) 1989)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Delia platura	Bean seed fly: (Meigen 1826)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (141) 1989)	Y (PPIN 2008, Pont 1989, Scott and Emberson 1999)	No	No	No	No	No	No	No
Exomala orientalis (syn *Blitopertha orientalis*)	Oriental beetle: (Waterhouse 1875)	EPPO PQR (2006) as *Blitopertha orientalis*	Y (CPC 2007)	N (Leschen *et al.* 2003, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Euxesta notata	Cherry worm: (Wiedemann 1830)	CPC (2007)	Y (CPC 2007)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Frankliniella occidentalis	Western flower thrips: (Pergande 1895)	CPC (2007), EPPO PQR (2006), Appendix 1	Y (Nakahara 1997)	Y (PPIN 2008, Nakahara 1997, Scott and Emberson 1999)	No	No	No	Yes (CPC 2007)	No	No	Yes
Gryllotalpa africana	African mole cricket: (Palisot de Beauvois 1805)	CPC (2007)	Y (Zhang 1994)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Hadula trifolii	Clover cutworm: (Hufnagel 1766)	CPC (2007)	Y (Tsia & Ding 1982)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Helicoverpa armigera	Cotton bollworm: (Hübner 1809)	EPPO PQR (2006)	Y (CABI/EPPO (15) 1993)	Y (PPIN 2008, Scott and Emberson 1999)	No	No	No	Yes (Ahmad 2007)	No	No	Yes
Icerya seychellarum	Seychelles scale: (Westwood 1855)	EPPO PQR (2006)	Y (CABI/EPPO (52) 1955)	N (Morales 1991, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Leptinotarsa decemlineata	Colorado potato beetle: (Say 1824)	EPPO PQR (2006), Appendix 1	Y (CABI/EPPO (139) 2003)	N (Leschen *et al.* 2003, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza bryoniae	Tomato leafminer: (Kaltenbach 1858)	EPPO PQR (2006)	Y (CABI/EPPO (599) 1999)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Liriomyza cepae	Miner, stone leek leaf: (Hering 1927)	CPC (2007)	Y (CAB International 1955 as *Phytobia cepae*)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza chinensis	Stone Leek Leafminer: (Kato 1949)	China (2008)	Y (China 2008)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza huidobrensis	Serpentine leafminer: (Blanchard 1926)	CPC (2007), EPPO PQR (2006), Appendix 1	Y (CABI/EPPO (568) 2002)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza nietzkei	Leafminer (Spencer 1973)	CPC (2007)	Y (Ulenberg 2008)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza sativae	Vegetable leafminer: (Blanchard 1938)	EPPO PQR (2006)	Y (CABI/EPPO (477) 1997)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Liriomyza trifolii	American serpentine leafminer: (Burgess in Comstock 1880)	CPC (2007), EPPO PQR (2006), Appendix 1	Y (CABI/EPPO (450) 1997) N (China 2006)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Listroderes costirostris	Vegetable weevil: (Schönherr 1826)	CPC (2007)	Y (CABI/EPPO (178) 2000)	Y (PPIN 2008)	No	No	No	No	No	No	No
Loxostege sticticalis	Beet webworm: (Linnaeus 1761)	CPC (2007)	Y (Sun & Chen 1995)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Luperomorpha suturalis	Flea beetle: (Chen 1938)	China (2008)	Y (China 2008)	N (Leschen *et al.* 2003, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Mamestra brassicae	Cabbage moth: (Linnaeus 1758)	CPC (2007), EPPO PQR (2006)	Y (CPC 2007)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Necrobia rufipes	Red-legged ham beetle: (de Geer 1775)	Appendix 1	Y (CPC 2007)	Y (PPIN 2008, Scott and Emberson 1999)	No	No	No	No	No	No	No
Neotoxoptera formosana	Onion aphid: (Takahashi 1921)	China (2008), EPPO PQR (2006), Appendix 1	Y (MacLeod 2007)	Y (PPIN 2008)	No	No	No	No	No	No	No
Peridroma saucia	Pearly underwing moth: (Hübner 1808)	CPC (2007)	Y (Kuang 1985)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Phaedon brassicae	Leaf beetle: (Baly 1874)	EPPO PQR (2006)	Y (CABI/EPPO (699) 2007)	N (Leschen *et al.* 2003, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Sarcopolia illoba	Mulberry caterpillar: (Butler 1878)	CPC (2007)	Y (Bai *et.al*. 2001)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Scirtothrips dorsalis	Chilli thrips: (Hood 1919)	CPC (2007), EPPO PQR (2006)	Y (EPPO PQR 2006)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Spodoptera exigua	Beet armyworm: (Hübner 1808)	CPC (2007)	Y (CABI/EPPO (302) 1972)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Spodoptera litura	Taro caterpillar: (Fabricius 1775)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (61) 1993)	Y (PPIN 2008, Malone and Wigley 1980, Scott and Emberson 1999)	No	No	No	No	No	No	No
Stegobium paniceum	Drugstore beetle: (Linnaeus 1761)	CPC (2007)	Y (Janisch 1923)	Y (PPIN 2008, Scott and Emberson 1999)	No	No	No	No	No	No	No
Thrips palmi	Melon thrips: (Karny 1925)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (149) 1998)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Thrips parvispinus	Melon thrips: (Karny 1925)	EPPO PQR (2006)	Y (CPC 2007)	N (PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Thrips tabaci	Onion thrips: (Lindeman 1889)	China (2008), CPC (2007), Appendix 1	Y (CABI/EPPO (20) 1969, China 2008)	Y (PPIN 2008, CIE 1969, Scott and Emberson 1999)	No	No	No	Yes (CPC 2007)	No	No	Yes

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Thysanoplusia orichalcea	Slender burnished brass moth: (Fabricius 1775)	CPC (2007)	Y (Hu 1987)	Y (PPIN 2008, Beck and Cameron 1990, Scott and Emberson 1999)	No	No	No	No	No	No	No
Trichoplusia ni	Cabbage looper: (Hübner 1802)	CPC (2007)	Y (CABI/EPPO (328) 1974)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Typhaea stercorea	Hairy fungus beetle: (Linnaeus 1758)	Appendix 1	Y (Dunkel *et al* 1985)	Y (PPIN 2008, Scott and Emberson 1999)	No	No	No	No	No	No	No
Xestia c-nigrum	Spotted cutworm: (Linnaeus 1758)	CPC (2007)	Y (Hampson 1903, CAB International 1979)	N (Dugdale 1988, Hoare 2001, PPIN 2008, Scott and Emberson 1999)	No	N/A	N/A	N/A	N/A	N/A	Yes
Mites											
Aceria tulipae	Dry bulb mite: (Keifer 1938)	CPC (2007)	Y (Song *et al.* 2008)	Y (PPIN 2008, Lammerink 1990, Manson 1984)	Yes (CPC (2007)	No	No	No	No	No	Yes
Glycyphagus domesticus	House mite: (de Geer 1778)	Appendix 1	Y (Cosmopolitan)	Y (Spain & Luxton 1971)	No	No	No	No	No	No	No
Histiostoma feroniarum	Damp mite: (Dufour 1839)	Appendix 1	Y (Jiang *et.al.* 2005)	Y (PPIN 2008)	No	No	No	No	No	No	No
Histiostoma sapromyzarum	Slime mite: (Dufour 1839)	Appendix 1	Y (Li 1988)	Y (PPIN 2008)	No	No	No	No	No	No	No
Petrobia latens	Brown wheat mite: (Müller 1776)	CPC (2007)	Y (CPC 2007)	Y (PPIN 2008, Zhang *et al* 2002)	No	No	No	No	No	No	No

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Rhizoglyphus echinopus	Bulb mite: (Fumouze & Robin 1868)	CPC (2007) Appendix 1	Y (Zhang 2003)	Y (PPIN 2008, Zhang 2003)	No	No	No	No	No	No	No
Rhizoglyphus robini	Bulb mite: (Claparède 1869)	CPC (2007) Appendix 1	Y (CPC 2007, Fan & Zhang 2007)	Y (PPIN 2008, Zhang 2003)	No	No	No	No	No	No	No
Rhizoglyphus setosus	Bulb mite: (Manson 1972)	CPC (2007) Appendix 1	Y (CPC 2007)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Steneotarsonemus furcatus	Taro tarsonemid mite: (De Leon 1956)	CPC (2007)	Y (Lin & Zhang 1999)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Tarsonemus confusus	Fungus mite: (Ewing 1939)	Appendix 1	Y (Lin & Zhang 1999)	Y (PPIN 2008)	No	No	No	No	No	No	No
Tyrophagus similis	Acarid mite: (Volgin 1949)	Appendix 1	Y (Li 1999)	Y (PPIN 2008, Fan and Zhang 2007)	No	No	No	No	No	No	No
Molluscs											
Lissachatina fulica (synonym *Achatina fulica*)	Giant African snail: (Bowdich 1822)	EPPO PQR (2006) as *Achatina fulica*	Y (Mead 1961, CPC 2007)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Nematodes											
Aphelenchoides besseyi	Rice leaf nematode: (Christie 1942)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (796) 2000, Hunt 1993)	N (PPIN 2008, Knight *et al* 1997)	No	N/A	N/A	N/A	N/A	N/A	Yes
Aphelenchoides fragariae	Strawberry crimp nematode: (Ritzema Bos 1891)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (863) 2002) N (China 2006)	Y (PPIN 2008, Knight *et al* 1997)	No	No	No	No	No	No	No
Ditylenchus destructor	Potato tuber nematode: (Thorne 1945)	CPC (2007)	Y (CABI/EPPO (837) 2001) N (China 2006)	Y (PPIN 2008, Knight *et al.* 1997, Foot & Wood 1982)	No	No	No	No	No	No	No
Ditylenchus dipsaci	Stem and bulb nematode: (Kühn 1857)	CPC (2007), EPPO PQR (2006)	Y (CABI/EPPO (791) 1999) N (China 2006)	Y (PPIN 2008)	No	No	No	Yes (CPC 2007)	No	No	Yes

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Helicotylenchus dihystera	Common spiral nematode: (Cobb 1893)	CPC (2007)	Y (CPC 2007)	Y (PPIN 2008, Wouts and Yeates 1994)	No	No	No	No	No	No	No
Helicotylenchus pseudorobustus	Spiral nematode: ((Steiner 1914) Golden 1945)	CPC (2007)	Y (CABI/EPPO (882) 2003)	Y (PPIN 2008, Knight *et al* 1997)	No	No	No	No	No	No	No
Heterodera glycines	Soybean cyst nematode: (Ichinohe 1952)	EPPO PQR (2006)	Y (CABI/EPPO (802) 2000)	N (PPIN 2008, Knight *et al* 1997)	No	N/A	N/A	N/A	N/A	N/A	Yes
Meloidogyne arenaria	Peanut root knot nematode: ((Neal 1889) Chitwood 1949)	Gonzaga (1995)	Y (CABI/EPPO (900) 2003)	Y (PPIN 2008 as carrot strain)	No	No	No	No	No	No	No
Meloidogyne graminicola	Rice root knot nematode: (Golden & Birchfield 1965)	CPC (2007)	Y (Mulk 1976)	N (PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Meloidogyne hapla	Root knot nematode: (Chitwood 1949)	CPC (2007)	Y (CABI/EPPO (853) 2002)	Y (PPIN 2008, Knight *et al* 1993)	No	No	No	No	No	No	No
Paratrichodorus minor	Stubby root nematode: (Colbran 1956)	CPC (2007)	Y (CABI/EPPO (870) 2002)	Y (PPIN 2008)	Yes (CPC (2007)	No	No	No	No	No	Yes
Paratrichodorus porosus	Stubby root nematode: (Allen 1957)	CPC (2007)	Y (Liu & Cheng 1990)	Y (PPIN 2008, Sturhan *et al* 1997)	Yes (CPC (2007)	No	No	No	No	No	Yes
Pratylenchus penetrans	Northern root lesion: (Cobb 1917)	CPC (2007)	Y (CABI/EPPO (888) 2003)	Y (PPIN 2008, Knight *et al* 1993)	No	No	No	No	No	No	No
Pratylenchus zeae	Root lesion nematode: (Graham 1951)	CPC (2007)	Y (Yin 1991)	N (PPIN 2008, Knight 1997)	No	N/A	N/A	N/A	N/A	N/A	Yes
Rotylenchulus reniformis	Reniform nematode: (Linford and Oliveira 1940)	Robinson *et al* (1997)	Y (CPC 2007, Robinson *et al* 1997)	N (PPIN 2008, Knight *et al* 1997)	No	N/A	N/A	N/A	N/A	N/A	Yes

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Phytoplasma											
Aster yellows phytoplasma	Yellow disease phytoplasmas: (Lee *et al.* 2004)	CPC (2007)	Y (Nakamura *et al* 1996)	N (Pearson *et al* 2006, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Plants (as seeds)											
Abutilon theophrasti	Velvet leaf: (Medicus 1787)	CPC (2007)	Y (Wood 1992)	Y (PBI 2008)	No	No	No	No	No	No	No
Alopecurus myosuroides	Black-grass: (Hudson 1762)	CPC (2007)	Y (CPC 2007)	N (PBI 2008)	U/K	N/A	N/A	N/A	N/A	N/A	Yes
Amaranthus blitum	Livid amaranth: (Linnaeus 1753)	CPC (2007)	Y (Holm *et al* 1979)	N (PBI 2008)	U/K	N/A	N/A	N/A	N/A	N/A	Yes
Amaranthus retroflexus	Redroot pigweed: (Linnaeus 1753)	CPC (2007)	Y (Wang 1990)	Y (PBI 2008)	No	No	No	No	No	No	No
Ambrosia artemisiifolia	Common ragweed: (Linnaeus 1753)	CPC (2007)	Y (Duan & Chen 2000)	Y (PBI 2008)	No	No	No	No	No	No	No
Anagallis arvensis	Scarlet pimpernel: (Linnaeus 1753)	CPC (2007)	Y (Holm *et. al.* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Avena fatua	Wild oat: (Linnaeus 1753)	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Borreria latifolia	Broadleaf buttonweed: ((Aubl.) K. Schum 1888)	CPC (2007)	Y (Parker 1992)	N (PBI 2008)	U/K	N/A	N/A	N/A	N/A	N/A	Yes
Capsella bursa-pastoris	Shepherd's purse: ((Linnaeus 1753) Medikus 1792)	CPC (2007), UC IPM (2008)	Y (Li 1983)	Y (PBI 2008)	No	No	No	No	No	No	No
Cenchrus echinatus	Southern sandbur: (Linnaeus 1753)	CPC (2007)	Y (Waterhouse 1993)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Chenopodium album	Common lambsquarters: (Linnaeus 1753)	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No

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Cirsium arvense	Creeping thistle: (Linnaeus 1753)	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Cirsium vulgare	Spear thistle: ((Savi) Ten 1835)	CPC (2007)	Y (Moore & Frankton 1974)	Y (PBI 2008)	No	No	No	No	No	No	No
Convolvulus arvensis	Field bindweed	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No
Conyza bonariensis	Hairy fleabane	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No
Conyza canadensis	Horseweed	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No
Cuscuta europaea	European dodder: ()	CPC (2007)	Y (Wang *et al* 1990)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Cynodon dactylon	Bermuda grass: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1979)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Cyperus esculentus	Yellow nutsedge	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Cyperus rotundus	Purple nutsedge: ()	CPC (2007), UC IPM (2008)	Y (Xue 1996)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Echinochloa crus-galli	Barnyard grass: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1991)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Eleusine indica	Goose grass: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Emex australis	Doublegee: ()	CPC (2007)	Y (CPC 2007)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Emilia sonchifolia	Red tasselflower: ()	CPC (2007)	Y (Wang 1990)	Y (PBI 2008)	No	No	No	No	No	No	No
Eragrostis cilianensis	Stink grass: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Euphorbia heterophylla	Wild poinsettia: ()	CPC (2007)	Y (Lin & Hsieh 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Euphorbia hirta	Garden spurge: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Galinsoga parviflora	Gallant soldier: ()	CPC (2007)	Y (Sun and Huang 1995)	Y (PBI 2008)	No	No	No	No	No	No	No
Hibiscus trionum	Venice mallow: ()	CPC (2007)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Hordeum murinum ssp. *leporinum*	Hare barley	UC IPM (2008)	Y (eFloras 2008)	Y (Conner & Edger 1994)	Yes	No	No	No	No	No	Yes
Lactuca serriola	Prickly lettuce (L.)	UC IPM (2008)	Y (USDA, ARS 2009)	Y (PBI 2008)	No	No	No	No	No	No	No

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Lamium amplexicaule	Henbit	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No
Lolium temulentum	Darnel: ()	CPC (2007)	Y (Holm *et al* 1979) N (China pest list 2006)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Malva parviflora	Little mallow (cheeseweed)	UC IPM (2008)	Y (eFloras 2008)	Y (PBI 2008)	No	No	No	No	No	No	No
Medicago polymorpha	California burclover	UC IPM (2008)	Y (eFloras 2008) (as *Medicago polymorpha)*	Y (PBI 2008) (as *Medicago nigra*)	Yes	No	No	No	No	No	Yes
Melilotus indica	Indian sweet clover: ()	CPC (2007)	Y (Kuang 1985)	N (PBI 2008)	U/K	N/A	N/A	N/A	N/A	N/A	Yes
Nicandra physalodes	Apple of Peru: ()	CPC (2007)	Y (Wang 1990)	Y (PBI 2008)	No	No	No	No	No	No	No
Orobanche ramosa	Branched broomrape: ()	CPC (2007)	Y (Parker 1994)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Oxalis latifolia	Sorrel: ()	CPC (2007)	Y (Holm *et al* 1979) N (China pest list 2006)	Y (PBI 2008)	No	No	No	No	No	No	No
Panicum dichotomiflorum	Fall panicum	UC IPM (2008)	Y (eFloras 2008)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Papaver rhoeas	Common poppy: ()	CPC (2007)	Y (Holm et.al.1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Parthenium hysterophorus	Parthenium weed: ()	CPC (2007)	Y (Aneja *et al* 1991)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Phalaris canariensis	Canary grass	UC IPM (2008)	Y (eFloras 2008)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Poa annua	Annual meadowgrass: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1991)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Polygonum arenastrum	Common knotweed	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	No	No	No	No	No	No	No
Polygonum aviculare	Prostrate knotweed: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Polygonum convolvulus	Black bindweed: ()	CPC (2007)	Y (Holm *et al* 1977)	Y (PBI 2008)	No	No	No	No	No	No	No
Polygonum hydropiper	Marsh pepper: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Polygonum lapathifolium	Pale persicaria: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No

Scientific name	Common name and Authority	Commodity association (reference)	Present in China (reference) (see note 1)	Present in NZ (reference) (see note 2)	Vector of a potential hazard	In NZ but association with goods increases hazard	In NZ but geographically bounded	In NZ but has different host associations or strains	No or little information on organism	Under official control or notifiable	Potential hazard
Polygonum persicaria	Redshank: ()	CPC (2007)	Y (Freedman 1998)	Y (PBI 2008)	No	No	No	No	No	No	No
Portulaca oleracea	Purslane: ()	CPC (2007)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Raphanus raphanistrum	Wild radish: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Rumex crispus	Curled dock: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Salsola kali (syn *Salsola tragus*)	Russian thistle	UC IPM (2008)	Y (eFloras 2008)	Y (PBI 2008)	No	No	No	No	No	No	No
Senecio vulgaris	Grinning (or Grundie)-swallow: ()	CPC (2007)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Setaria verticillata	Bristly foxtail: ()	CPC (2007)	Y (Kaul 1986)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Setaria viridis	Green foxtail: ()	CPC (2007)	Y (Holm *et al* 1979)	Y (PBI 2008)	Yes	No	No	No	No	No	Yes
Sida acuta	Sida: ()	CPC (2007)	Y (Holm *et al* 1977)	N (PBI 2008)	U/K	N/A	N/A	N/A	N/A	N/A	Yes
Sisymbrium irio	London rocket	UC IPM (2008)	Y (eFloras 2008)	Y (PBI 2008)	No	No	No	No	No	No	No
Solanum nigrum	Black nightshade: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1979)	Y (PBI 2008)	No	No	No	No	No	No	No
Sorghum halepense	Johnsongrass	UC IPM (2008)	Y (CPC 2007)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Spergula arvensis	Corn spurry: ()	CPC (2007)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Stellaria media	Common chickweed: ()	CPC (2007), UC IPM (2008)	Y (Holm *et al* 1977)	Y (PBI 2008)	No	No	No	No	No	No	No
Thlaspi arvense	Field pennycress: ()	CPC (2007)	Y (Holm *et al* 1991)	Y (PBI 2008)	No	No	No	No	No	No	No
Tribulus terrestris	Puncture vine: ()	CPC (2007), UC IPM (2008)	Y (Wang 1990)	Y (PBI 2008)	U/K	No	No	No	No	Yes	Yes
Viruses											
Leek yellow stripe potyvirus	LYSV: ()	Brunt *et al* (2008)	Y (CABI/EPPO (999) 2007)	Y (Pearson *et al* 2006, PPIN 2008)	No	No	No	No	No	No	No

Scientific name	Common name and Authority	Commodity association (reference)	Present in China (reference) (see note 1)	Present in NZ (reference) (see note 2)	Vector of a potential hazard	In NZ but association with goods increases hazard	In NZ but geographically bounded	In NZ but has different host associations or strains	No or little information on organism	Under official control or notifiable	Potential hazard
Onion mite-borne latent allexivirus	OMbLV: ()	ICTVdB Management (OMbLV 2006)	Y (AVRDC 2001, ICTVdB Management (OMbLV) 2006)	N (Pearson *et al* 2006)	No	N/A	N/A	N/A	N/A	N/A	Yes
Onion yellow dwarf potyvirus	OYDV: ()	CPC (2007)	Y (Chen et.al. 2001)	Y (Pearson *et al* 2006, PPIN 2008)	No	No	No	No	No	No	No
Shallot latent carlavirus	SLV: ()	CPC (2007), ICTVdB Management (SLV 2006)	Y (AVRDC 2001) N (ICTVdB Management (SLV) 2006)	Y (Pearson *et al* 2006, PPIN 2008)	No	No	No	No	No	No	No
Shallot virus X (allexivirus)	ShVX: ()	ICTVdB Management 2006) as ShMbLV	Y (ICTVdB Management 2006) as ShMbLV	Y (PPIN 2008)	No	No	No	No	No	No	No
Shallot yellow stripe potyvirus	SYSV: ()	ICTVdB Management (SYSV 2006)	Y (ICTVdB Management (SYSV) 2006)	N (Pearson *et al* 2006, PPIN 2008)	No	N/A	N/A	N/A	N/A	N/A	Yes
Tobacco rattle tobravirus	TRV: ()	CPC (2007), ICTVdB Management (TRV 2006)	Y (ICTVdB Management (TRV) 2006)	Y (Pearson *et al* 2006, PPIN 2008)	No	No	No	Yes ((ICTVdB Management (TRV) 2006)	No	No	Yes

Note 1: The reference provided indicates that these organisms may be in China; however there may not be any available record of these organisms being associated with *Allium cepa* in China.

Note 2: The references provided may indicate that the organism or disease is not in New Zealand, or may indicate that the organism or disease is absent from a list of organisms and diseases considered present in New Zealand.

References for Appendix 2

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Appendix 3: Trip report on onion production in China

The Ministry of Agriculture and Forestry Biosecurity New Zealand (MAFBNZ) requested that the General Administration for Quality Supervision and Inspection and Quarantine of the People's Republic of China (AQSIQ) and the Entry-Exit Inspection and Quarantine Bureau of the People's Republic of China (CIQ) provide access for a MAFBNZ technical expert, Dr Mike Ormsby, to examples of their production, processing and packaging sites for onions. Within a five-day period from the 17th to the 21st May 2008 Dr Ormsby visited an onion farm and processing and storage facility in Shandong province in P. R. China, and met with CIQ and AQSIQ officials to discuss pest management and assurance procedures relating to the production of onions in China.

Appendix 3.1: Trip Report

Onions are believed to have originated from Afghanistan/Iran/USSR region. Records of onion cultivation date back to 3020 BC in Egypt. Shandong province has over 1 million mu (over 67,000 hectare) in onion production, exporting to Japan, Russia and other S.E. Asian countries.

There are 3 main colour varieties grown in China, yellow, red-yellow and red. Around 520,000 tonnes are exported annually, with onions going to Japan having their outer skins removed. CIQ is responsible for overseeing the production, processing and export of onions in Shandong province. The system includes:

- Farm registration and audit;
- Chemical use during production;
- Pest surveillance, identification and reporting;
- Pre-export inspection and testing (food safety);
- Phytosanitary declarations (treatments are rare);
- Non-compliance emergency action plans.

Farm management are responsible for developing their own control system that regulates chemical and pest control activities and ensures compliance with phytosanitary requirements. All company systems will have pest control measures as standard with country requirements added (if required). Prior to export the company must also undertake inspection and testing.

CIQ inspected over 1 million export (~90%) and import (~10%) consignments in 2007, around $US 80 billion in value. Japan in particular has strict quarantine requirements with a detection failure threshold of 0.01%.

Onion farm

The company uses specialised (trained) staff for farm management and pesticide application and all pesticide suppliers are approved (presumably by CIQ or equivalent). The farm visited by the group was originally owned by a Danish company but is now under Chinese ownership and is considered an "Ecological" farm. Farm management principally involves crop rotation with specified areas set aside for certain crops such as onions. These crops are harvested seasonally (once per year from June to September) with alternative crops (mainly maize) planted in the off-season (August to October) and ploughed back into the soil. Onion production varies annually but from 400 mu (27 hectare) they have produced 2000 tonnes and from 900 mu (60 hectare), 3600 tonnes. Most of the onion production is yellow onions mainly for the Japanese market.

CIQ export registration must be completed for each different crop as different company management systems apply to each. The company quality control system covers and integrated grower to market process. Company manuals ensure staff follow the quality system. Re-registration is required each year or if the company changes the crop in an area (field). Onions crops are planted in October and harvest begins in June of the following year. Plastic sheets are used to help retain moisture and protect the seedlings (see figure 12). The company representative reported that pests have never been found on the onions in this farm. Herbicides are applied before planting and weeds are manually removed while the onions are growing.

Figure 12: An onion field showing weeds, the watering system and the plastic ground cover.

Before harvesting CIQ inspect crops in selected blocks for pests and test for food residue levels. If pests are found (or acceptable food residue levels are exceeded) registration is removed from the block unless remedial action can be taken (e.g. a quarantine treatment). Three days before harvest the crop is watered. Harvesting is done by tractor with staff picking over the fields afterwards. CIQ also inspect the company management records as part of the pre-harvest inspection.

Figure 13: Hosts and visitors touring an onion farm and processing facility

The company has been exporting onions to Japan for 8 years. The company has no pest expertise on staff but staff do receive 6 monthly training from CIQ on pest management. For CIQ registration to export onions the company must have at least 300 mu (20 hectares) growing onions. The company does apply pesticides and uses a fungicide dip of seedling roots before planting to target potential *Peronospora schleidenii (destructor)* infections.

Onion processing facility

The company only processes onions produced on their own farms with CIQ reconciling production records and export volumes as part of the yearly registration process. Application is made to CIQ for an export licence within three days of export. Onions not immediately going for export are stored in the cool store with their skin on. Onions can be exported with the skin on or the outer skin (leaf layer) removed. Onions being prepared for export (as de-skinned onions) have their skins removed outside the main (clean) processing room. According to the company representative all diseased onions are removed at this point and destroyed (deep buried) away from the processing facility and farm. A cursory examination of a bin of discarded onions peels and damaged onions outside the facility could not find any pests and only a small percentage of the waste was whole discarded onions. As we were not shown the peeling area we were not able to determine the volume of discarded substandard onions removed for alternative markets or uses (e.g. domestic supply or cooking).

Once the onions are peeled they pass through small doors into the main processing area for washing, size grading, and packaging, before finally being moved temporarily in cold storage. Washing (as seen in figure 14 on the conveyer belt) includes a wash with water and NaClO (Sodium hypochlorite) before a final rinse.

Figure 14: Raw onion cleaning and packaging after outer layers removed

Onions destined for different countries are processed at different times and stored in appropriately labelled cartons.

CIQ inspection involves monitoring of the processing activities, collecting samples for residual analysis, and visual inspection of a sample of onions and peeled layers for pests. Export is only permitted once residual test results have been returned (and are appropriate). Test results usually come back within 3-5 days. Inspectors use magnifying glasses when looking for pest and soil contamination, and will cut a sample of onions open if there is any evidence of possible internal contamination. The company representative reported that pests have never been detected or food residual limits exceeded.