Late Blight management

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Department of Primary Industries

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DEPARTMENT OF
PRIMARY INDUSTRIES

Late blight management

Final Report
Horticulture Australia PT04010

(July 2006)

Edwards *et al*
Primary Industries Research Victoria, Knoxfield Centre

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Purpose of project:
The purpose of this project was to prepare the Australian potato industry for the possible incursion of exotic strains of *Phytophthora infestans,* the cause of potato late blight. Relevant information was sourced from around the world and compiled into a Pest-Specific Contingency Plan, a Pest Risk Analysis and Grower Fact Sheets.

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Late blight is one of the most destructive diseases of potatoes worldwide, estimated to cause annual losses of 15% of global potato production. This is as a result of the spread of new and aggressive strains of the pathogen around the globe over the past 30 years. Australia is one of the few countries that do not have these new strains. Outbreaks of late blight in Australia are sporadic and localised and readily controlled with metalaxyl-based fungicides. If these new strains became established in Australia, production losses could be in excess of 100,000 tonnes p.a. and pesticide usage would increase substantially.

There are two 'mating types' of *P. infestans* known as A1 and A2. In Australia, we only have 'old' strains of A1. The presence of A2 results in the development of tough survival spores (oospores), and therefore, long-term survival in soil. The offspring from the mating of A1 and A2 strains are more adaptable and potentially able to cause major epidemics.

The Pest Risk Analysis and Pest-Specific Contingency Plan have been developed as appendices to the National Potato Industry Biosecurity Plan. Specific recommendations to industry to raise awareness and preparedness for potential incursions include simulated incursion responses, development of national diagnostic protocols, and surveillance programs to increase the likelihood of early detection of new strains and provide base-line data for pest-free area status to support market access.

Technical Summary

A Pest Risk Analysis and a Pest-Specific Contingency Plan developed through this project will put Australia in good stead to deal with potential incursions of exotic strains of the potato late blight pathogen *Phytophthora infestans*. This is the first pest-specific National response plan for the Australian potato industry and reflects serious concern by industry about the economic impact of late blight should the exotic strains enter and become established in Australia.

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A response plan, developed based on the guidelines outlined in PLANTPLAN, identifies experts within Australia and overseas, and lists the relevant government contacts. Current National and State quarantine measures were reviewed and survey procedures, quarantine zones and movement controls drafted for use in an incursion situation. Risk assessment methodology prescribed by the "International Standards for Phytosanitary Measures No. 2: Guidelines for Pest Risk Analysis" (FAO 1995) was used to determine the risk that these new strains pose to the Australian potato industry. Because Australia has excellent border control and import restrictions, the likelihood of entry was determined to be low. However, if entry did occur, the potential for spread and the subsequent consequences for industry were determined to be high.

Information was sourced worldwide regarding differences in host range, distribution, features, biology and epidemiology of the new strains of *P. infestans.* Diagnostic capabilities available in Australia were examined and identified that currently in Australia, Queensland is the only State with the capability to distinguish old strains from new. The diagnostic tests used, however, are not really suited for incursion purposes due to a turn-around time of at least two weeks for strain confirmation. Chemical control options available in Australia were compared with those used overseas and additional products were identified as potentially useful. Advice on the best options for managing a suspected incursion with fungicides must be sought from the major agrochemical companies at the time of the incursion.

The Pest Risk Analysis and Pest-Specific Contingency Plan were developed as appendices to the National Potato Industry Biosecurity Plan. Specific recommendations to industry to raise awareness and preparedness for potential incursions include:

- simulated incursion exercises to test the response plan;
- an immediate need to update and standardise National diagnostic protocols suitable for incursion purposes. Current diagnostic capability in Australia is inadequate. Diagnostic tests potentially more suitable for use in an incursion are under development in Scotland.
- A surveillance program should be conducted in areas where late blight is currently known to occur in Australia. This would serve several purposes: (1) provide the opportunity to develop robust diagnostic protocols and train diagnosticians in their use, (2) increase the likelihood of early detection of new strains, and (3) provide baseline data to support pest free area status for market access in the event of an incursion.
- The Plans should be reviewed and updated as required.

Introduction

Late blight of potatoes, caused by *Phytophthora infestans*, is regarded as one of the most destructive plant diseases in the world, estimated to cause losses of up to 15% of the annual global potato production (CIP, 1996). In the 1840s, late blight was responsible for widespread destruction of potato crops, including the Irish potato famine. Since then, late blight has been effectively managed through the use of resistant potato cultivars combined with fungicide spray programs. During the 1980s, however, potato farmers in Europe and North America experienced late blight outbreaks that were much more difficult to control than any they had dealt with over the previous fifty years. These epidemics were attributed to the development of resistance in the pathogen to commonly used fungicides, particularly metalaxyl, and breakdown of resistance in the commonly grown potato cultivars.

Phytophthora infestans, like many plant pathogens, is able to reproduce both sexually and asexually. Sexual reproduction is important for two reasons: (1) new combinations of genes result in the formation of new strains, and (2) the sexual spore, termed 'oospore', is very tough and can survive in soil and plant debris for several years without a host plant. For sexual reproduction to occur, two different mating types of *P. infestans* must be present, designated A1 and A2 mating types. In the 1800s when *P. infestans* was first spread to Europe and the rest of the world from South America, only the A1 type was introduced. From the mid-1800s until the late 1970s, the old A1 mating type strains were established in all major potato-growing regions of the world. This meant that no oospores were produced and the pathogen could only survive from one season to the next on volunteer potatoes and infected tubers. It also meant that evolution of new strains was restricted and control measures, once determined, adequately managed the disease for decades.

The A2 mating type and 'new' strains of A1 were first introduced into Europe in the late 1970s and have spread widely throughout the world except South Africa and Australasia (Table 1). These 'new' strains cause severe stem lesions, readily infect tubers and produce oospores that can survive for several years in the absence of a host. They can infect potato crops under a much wider range of environmental conditions and consequently, the onset of disease is much earlier and less predictable (Flier *et al.* 2002a). Many are resistant to metalaxyl and/or more aggressive than the 'old' strains (pre-1980s). Late blight control in most production areas of the world now relies heavily on costly fungicide spray programs and disease forecasting systems (Turkensteen *et al.* 1997, Schepers 2000). In the USA alone, the combined costs of controlling these 'new' strains plus associated yield losses was estimated at $US 3 billion pa (Duncan, 1999). Because of the presence of both mating types, the new strains are more genetically diverse and adaptable and have overcome the resistance genes bred into many potato cultivars, displacing the old strains in most parts of the world.

Although *P. infestans* has been present in Australia since the early 1900s (McAlpine 1911), we remain one of the few countries in the world not to be affected by a serious late blight problem. Disease outbreaks are sporadic and localised, and can still be effectively controlled with metalaxyl-based fungicides. Horticulture Australia Project No. PT98009 characterised Australian isolates of *P. infestans* in order to determine which strains are present (Drenth *et al.*, 2001). During this project, samples of diseased material were collected during the summers of 1998/99 and 1999/2000 and tested. There was no evidence of any new strains, and the report concluded that Australian isolates of *P. infestans* are closely related to the old US-1 clonal line, now displaced in most parts of the world (Drenth *et al*, 2001). These 'old' A1 strains of *P. infestans* are readily controlled with metalaxyl-based fungicides and cannot reproduce sexually. This means there is no threat of long-lived oospores which can persist for several years in soil and be spread by soil contamination on equipment, bins, etc.

Consequently, late blight is kept under control in Australian potato growing areas at relatively low cost, with minimal crop losses. However, the report noted that in order to maintain this status, the potato industry must be informed and vigilant.

Table 1: Differences between old and new strains of *P. infestans*

	Old strains	New strains
Mating types	• A1 only	• A1 • A2
Distribution	• Australia, New Zealand, parts of Africa (Kenya, Uganda, South Africa)	• rest of the world
Reproduction	• asexual only	• sexual • asexual
Inoculum sources	• dormant mycelium in infected tubers • cull piles • volunteer potatoes	• dormant mycelium in infected tubers • oospores in and on tubers • oospores in soil • cull piles • volunteer potatoes
Spread	• infected tubers • wind blown sporangia (asexual spores)	• infected tubers • wind blown sporangia (asexual spores) • soil containing oospores (sexual spores)
Environmental requirements	• av. temperature range 8-23°C • 8 hrs leaf wetness period required for infection @ 15°C	• av. temperature range 3-27°C • 4 hrs leaf wetness period required for infection @ 15°C
Response to fungicides	• usually susceptible (some South African isolates are reportedly resistant)	• may be metalaxyl-resistant

There are two potential scenarios of concern to the potato industry if an incursion were to occur: (1) the introduction of an exotic A1 strain which may bring with it some fungicide resistance which could cause new disease outbreaks if adequate controls were not available; (2) the introduction of the A2 mating type. If the A2 mating type is introduced into Australia, there is the additional risk of sexual reproduction occurring. This would result in oospore production and therefore long-term survival of the pathogen in soil, and the generation of new strains, potentially able to cause major epidemics and total crop loss.

Until recently, Papua New Guinea (PNG) was free of late blight and only susceptible cultivars (predominantly Sequoia) were grown. Consequently, when late blight occurred in March 2003, the entire potato crop in PNG was lost (Drenth *et al*. 2004). It was suspected that the pathogen had entered on tubers brought across from Indonesian Irian Jaya (Pitt and Wicks, 2003). The *P. infestans* strains responsible have been confirmed as 'new' strains, with genetic fingerprints comparable to isolates occurring in many parts of Europe (Alison Lees, pers comm.). Obviously, there is renewed concern now that these new strains are on Australia's doorstep.

Preparedness for incursion

The Australian Vegetable and Potato Growers' Federation is an industry member of Plant Health Australia (PHA), a limited company in which the Commonwealth, States and selected Industries are principle shareholders. Emergency response to incursions is recognised in its strategic plan as a priority. In 2002, PHA members endorsed the preparation of a formal cost sharing agreement for the plant industries, the Emergency Plant Pest Response Deed (EPPRD). Under the EPPRD, government and industry signatories will share the costs of eradicating emergency plant pests that will cause serious economic damage to Australian plant industries. This will reduce delays in the release of funds for eradication efforts and re-imbursements to industry members affected by crop destruction during eradication programs. The national potato industry had not formally ratified the EPPRD at the time of writing this document.

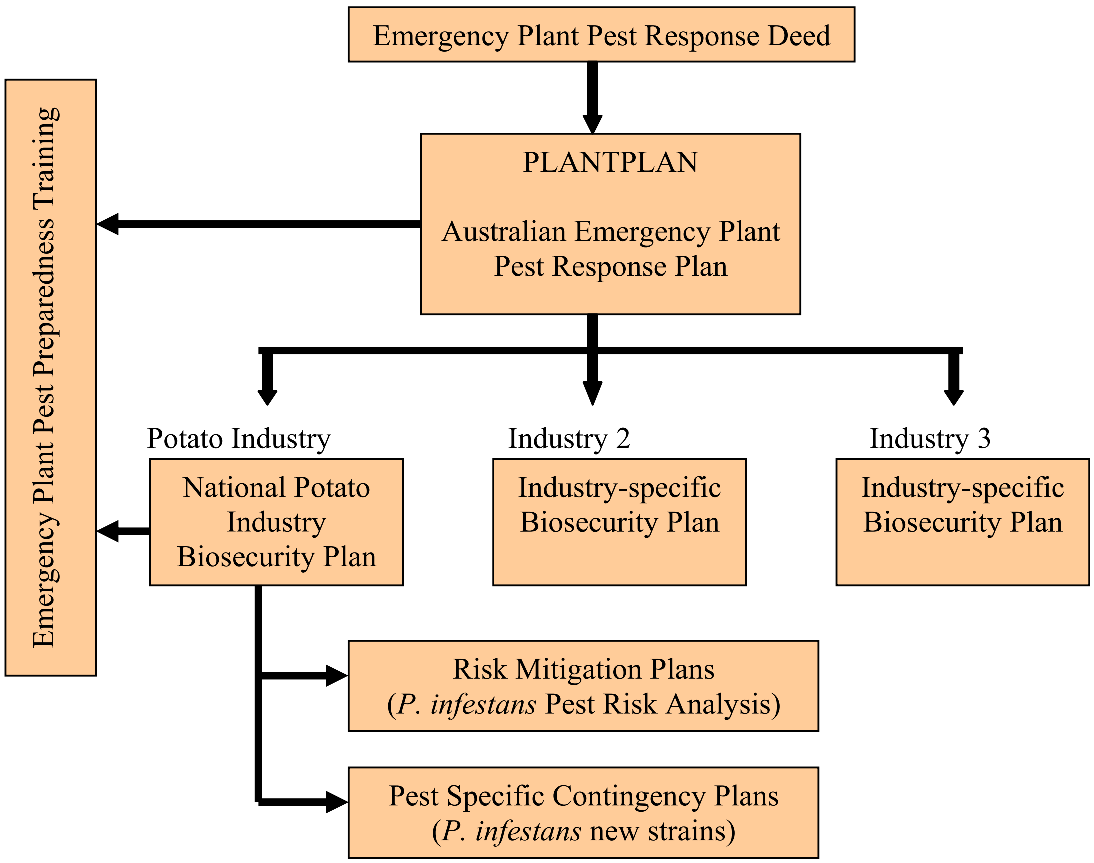

Figure 1. Flowchart of how the Pest Specific Contingency Plan and Pest Risk Analysis fit within the emergency preparedness and response arrangements of the Emergency Plant Pest Response Deed (EPPRD). (Adapted from PLANTPLAN, PHA 2004).

Industry-specific biosecurity plans are being developed for each PHA member, and in June 2005, a draft National Potato Industry Biosecurity Plan was made available. There is provision for pest-specific contingency plans and risk mitigation plans for key pests affecting each industry to be developed as appendices of the industry-specific biosecurity plans (Figure 1). The Australian potato industry identified the exotic strains of *P. infestans* as a key pest for their industry, and commissioned the development of a pest-specific contingency plan and an accompanying pest risk analysis as part of this Horticultural Australia Project PT04010.

Materials & Methods

A wealth of information exists regarding potato late blight and its causal organism, *Phytophthora infestans*. Late blight is one of the most important plant diseases worldwide, and as such, has been actively researched for 150 years. This research effort has intensified since the 1970s, when the new strains first appeared in Europe and North America. The objective of this project was to sift through all this information, and with the advice of the world's experts, use the most relevant to compile preparedness guidelines for the Australian potato industry, should an incursion occur.

Pest risk analysis methodology
The methodology used for pest risk analysis was that recommended in the Guidelines for Import Risk Assessment, Draft September 2001 (Biosecurity Australia 2001). The steps involved are:

- Pest categorisation
- Probability of entry, establishment and spread
- Assessment of consequences
- Conclusions: estimation of risk.

This allowed a systematic approach for assessing the risk that the A2 mating type and the 'new' strains of A1 mating type of *P. infestans* may pose to Australia.

The stages to be considered in the introduction and spread of the pest are schematically illustrated in Figure 2.

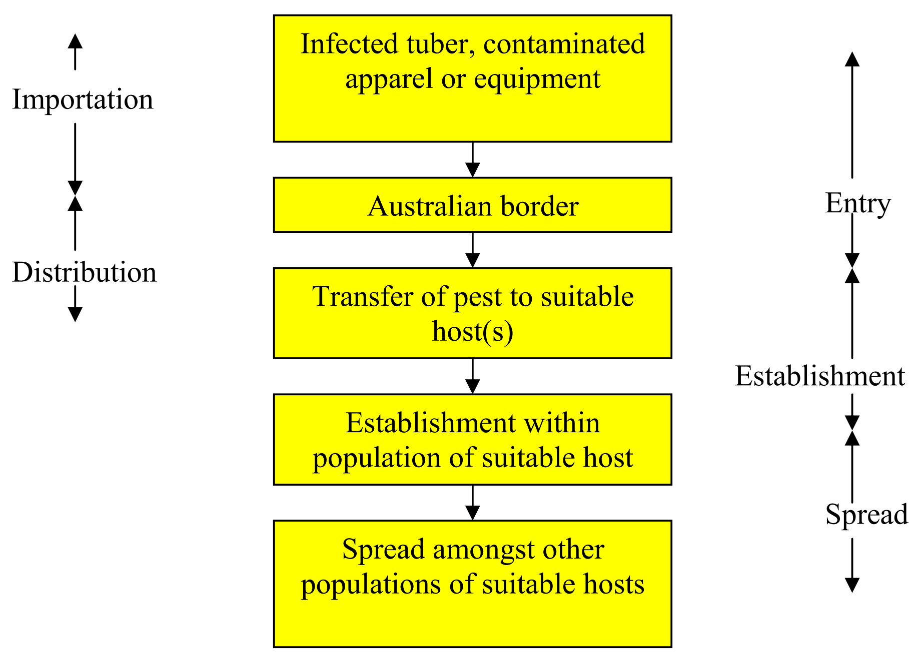

Figure 2. Stages in the entry, establishment and spread of a pest (adapted from Biosecurity Australia 2001).

Key resource documents used for determining the appropriate risk analysis methodology for this purpose were:

- 'International Standards for Phytosanitary Measures – Guidelines for Pest Risk Analysis. No. 2. Secretariat of the International Plant Protection Convention, Food and Agriculture Organisation of the United Nations, Rome 1995' (FAO 1995)
- 'Guidelines for Import Risk Analysis, Draft September 2001' (Biosecurity Australia 2001)
- Western Australian Department of Agriculture Final State Pesk Risk Analysis for Lettuce Aphid' (Poole *et al.* 2004)
- Pest Risk Analysis for Red Stele (*Phytophthora fragariae*), contained in the National Strawberry Industry Biosecurity Plan (PHA 2005)
- Pest Risk Analysis for Pierce's disease (*Xylella fastidiosa*), contained in Grape and Wine Research and Development Corporation Final Report DNR00/1 (Merriman *et al.* 2001)

The following tables and decision rules were adapted for use from Appendix 2: Method for development of Pest Risk Reviews, National Strawberry Industry Biosecurity Plan (PHA 2005)

The likelihoods of entry, establishment and spread were rated using the risk level ratings in Table 2.

Table 2. Nomenclature and ratings for qualitative likelihoods

Likelihood	Descriptive definition	Probability of occurrence
High	The event would be very likely to occur	0.7 to 1
Moderate	The event would occur with an even probability	0.3 to 0.7
Low	The event would be unlikely to occur	0.05 to 0.3
Very low	The event would be very unlikely to occur	0.001 to 0.05
Extremely low	The event would be extremely unlikely to occur	10^{-6} to 0.001
Negligible	The event would almost certainly not occur	0 to 10^{-6}
Unknown		N/a

After the risk for each criterion (entry, establishment and spread) was rated individually, a combined risk rating was determined using the qualitative risk analysis matrix presented in Table 3.

Table 3. A matrix of 'rules' for combining descriptive likelihoods

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

The following impact ratings (Table 4) were used to assess the economic, social and environmental consequences of an incursion.

Table 4. Factors used to rate the consequences of an incursion

Impact rating	Definition
Unlikely to be discernible	Not usually distinguishable from normal variation in the critierion
Minor	Not expected to threaten economic viability, but would cause a minor increase in mortality/morbidity or a minor decrease in production. For environmental and social factors, impact not expected to threaten the intrinsic 'value', but would be considered as 'disturbed'. Effects generally reversible.
Significant	Would threaten economic viability through a moderate increase in mortality/morbidity or moderate decreases in production. For environmental and social factors, the intrinsic 'value' would be significantly diminished or threatened. May not be reversible.
Highly significant	Would threaten economic viability through a large increase in mortality/morbidity or a large decrease in production. For environmental and social factors, the intrinsic 'value' would be considered severely or irreversibly damaged.

Economic, environmental and social impacts were assessed individually and were calculated for each of four geographic scales: local areas (ie. rural communities, towns or local government areas); districts (ie recognised sections of states); regions (ie. States), and Australia as a whole (Biosecurity Australia 2001). These values were then translated into an 'impact score' (range A-F) according to the guidelines in Table 5.

Table 5. Assessing consequences for incursion at local, district, regional and national levels.

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

The following decision rules were used to combine individual consequence ratings to produce an overall consequence rating (the following rules are mutually exclusive and should be addressed in order until one is found to apply):

1. Where any consequence has been rated as an 'F', the overall consequence is considered to be 'extreme'.
2. Where more than one consequence has been rated as an 'E', the overall consequence is considered to be 'extreme'.

3. Where one consequence is rated ‘E’ and all others are rated ‘D’, the overall consequence is considered to be ‘high’.
4. Where one consequence is rated ‘E’ and all others are not unanimously rated ‘D’, the overall consequence is considered to be ‘high’.
5. Where all consequences are rated ‘D’, the overall consequence is considered to be ‘high’.
6. Where at least one consequence is rated ‘D’, the overall consequence is considered to be ‘moderate’
7. Where all consequences are rated ‘C’, the overall consequence is considered to be ‘moderate’
8. Where one or more consequences are rated ‘C’, the overall consequence is considered to be ‘low’
9. Where all consequences are rated ‘B’, the overall consequence is considered to be ‘low’
10. Where one or more consequences are rated ‘B’, the overall consequence is considered to be ‘very low’
11. Where all consequences are rated ‘A’, the overall consequence is considered to be ‘negligible

Once the likelihoods of entry, establishment and spread were determined and the assessment of likely consequences was made, the information was combined to achieve a risk estimate using the following risk estimation matrix (Table 6).

Table 6. Risk estimation matrix

		Consequences of entry, establishment and spread					
Likelihoods of entry, establishment and spread		Negligible	V. low	Low	Moderate	High	Extreme
	High	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
	Moderate	Negligible risk	Very low risk	Low risk	Moderate risk	High risk	Extreme risk
	Low	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk	High risk
	V. low	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk	Moderate risk
	E. low	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk	Low risk
	Negligible	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Negligible risk	Very low risk

Definition of risk categories with respect to risk management:

- Extreme risk – specific action is required immediately to reduce risk.
- High risk – specific action is required. Generic risk mitigation plans should be adopted as soon as possible in the interim to increase the level of protection.
- Moderate risk – the current level of risk protection is insufficient. Appropriate risk reduction measures need to be identified and applied.
- Low risk – the current level of risk protection is insufficient. Appropriate risk reduction measures need to be identified and applied.
- Very low risk – an acceptable level of risk protection is in place. Additional risk management measures are not required.
- Negligible risk – an acceptable level of risk protection is in place for this threat. Risk management measures should be reviewed to ensure they are justifiable.

Pest specific contingency plan methodology

PLANTPLAN (Plant Health Australia 2004) was developed as the generic emergency response plan to guide management of emergency plant pest incursions. The pest specific contingency plans are to provide information on the host range, symptoms, biology and epidemiology of the key pest, along with guidelines for general and targeted surveillance programs, diagnosis, and control. They are to be used in conjunction with the emergency response guidelines in PLANTPLAN.

The Pest-Specific Contingency Plan for potato late blight was developed in consultation with Plant Health Australia, based on guidelines such as 'PLANTPLAN: Australian Emergency Plant Pest Response Plan' (Plant Health Australia 2004), 'Technical Guidelines for Development of Pest Specific Response Plans' (Merriman and McKirdy 2005) and the 'Revised Contingency Plan for Fire Blight' (Merriman 2002).

There are two basic components to contingency planning (Merriman 2002):

- awareness/preparedness which deal with pre-incursion plans
- response that deals with post-incursion activities usually associated with eradication or containment

Awareness aims to enhance the capabilities of stakeholders to recognise the symptoms and understand the biology and spread of the exotic strains of *P. infestans.* This increases the chances of early detection, decreases risks of illegal importation and maximises opportunities for eradication or containment.

Preparedness is concerned with the establishment of systems and processes, which will enhance the opportunities for early detection. It involves capitalising on the available knowledge and experience worldwide and 'mining' this information to identify the preferred diagnostic tools and best capabilities for rapid identification of the exotic strains. Equally important are preparation of detailed plans for surveillance, for establishment of quarantine zones and pest free areas, for treatment of affected sites, and for on-going disease management and on-farm biosecurity.

Response actions are those to be taken following the suspected incursion of an exotic strain of the pathogen. If an incursion is confirmed, the response may be either eradication or containment.

Resources used

During the course of this project, more than 190 websites were visited, 575 scientific papers were reviewed, 12 conference proceedings, 45 diagnostic protocols and 19 decision support systems were examined. Of these, 157 were cited in the contingency plan and 87 in the pest risk analysis. The information came from 63 countries.

Many people and organisations have been an integral part of the development of these documents. We gratefully acknowledge their assistance and advice:

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Ms. Leonie White, Department of Primary Industries Water and Environment, Tasmania
Dr. Ryan Wilson, Plant Health Australia, ACT

Results & Discussion

The following documents represent the results of this project and contain detailed information regarding contingency planning and risk analysis of late blight of potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type):

- Edwards J., Dawson, K., Gardner R., Perrone S.T. de Boer R.F. (2006) Pest Risk Analysis: Late Blight of Potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type). Department of Primary Industries, Victoria. 53 pp.

- Edwards J., Perrone S.T., Dawson K., Gardner R., de Boer R.F., Porter I.J. (2006). Pest-Specific Contingency Plan for late blight of potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type). Department of Primary Industries, Victoria. 166 pp.

In addition, grower fact sheets were compiled:
- Vegetable Matters of Fact: late blight of potatoes
- Vegetable Matters of Fact: late blight of potatoes – exotic strains of *Phytophthora infestans*
- Grower guide to late blight of potatoes: *Phytophthora infestans* A2 mating type and new strains of A1 mating type.

Summary of Pest Risk Analysis: Late Blight of Potato (Phytophthora infestans A2 mating type and exotic strains of A1 mating type).

ASSESSMENT OF LIKELIHOOD
(Tables 2 and 3)

Entry Potential
Rating: Low

Phytophthora infestans is transported on potatoes, tomatoes and in soil on used agricultural machinery. Spores can be carried on contaminated footware and clothing.

- Potatoes are considered a high risk crop and can only be imported into Australia through one of the Government post entry quarantine facilities. The imported potato material must comply with the import permit conditions and must only be in the form of tissue cultured plantlets.
- Fresh and unprocessed tomatoes are also considered high risk and are permitted entry into Australia only from New Zealand and the Netherlands, under strict import conditions. These conditions include the issuing of import permits prior to importation, inspection regimes prior to importation which include a check for freedom from disease symptoms, live insects, seed contaminants, soil, plant debris and appropriate plant packaging material. The inspections listed above are conducted again on arrival in Australia. There is an additional requirement for tomatoes sourced from the Netherlands, which involves the inspection of 600 trusses of fruit, prior to arrival in Australia.
- There are no restrictions on the importation of new agricultural machinery into Australia but used agricultural machinery, including spare parts, can only be imported into Australia from Canada. Second-hand agricultural machinery requires an import permit prior to importation which includes a history of the machinery's use over the past three years and

a phytosanitary certificate issued by Canadian agricultural authorities, certifying that the machine is clean and of Canadian origin.

We can conclude from the above import conditions that the paths of entry into Australia are most likely to be:

- as sporangia carried on clothing of Australian potato growers returning from visits to overseas potato production regions
- as oospores carried in soil on footware, clothing, backpacks, camping equipment, etc. of international travellers
- as undeclared illegal tubers carried by international travellers

Establishment Potential
Rating: Moderate

There are a number of environmental and plant husbandry factors which would influence the potential establishment of the new strains. They are as follows:

1. Infected plant material planted in close proximity to a host plant (i.e. close to potatoes, tomatoes or host weed and ornamental species)
2. Suitable climatic conditions both for the establishment of the disease and the growth of the tuber
3. Viability of the initial host tuber (the new strains can cause tuber breakdown)

It is estimated that approximately 80% of the potatoes grown in Australia are susceptible varieties such as Russett Burbank. The chance of an infected tuber being planted in close proximity to a potato paddock is low, but if that did occur and the infected plant grew it has a very high chance of infecting surrounding hosts. If it were planted in a home garden, there is also a high chance that other susceptible hosts such as potatoes, tomatoes, capsicum, eggplant, etc., will be growing nearby.

If *P. infestans* is carried on contaminated clothing, footware or apparel of travellers, the spores must be dislodged where they can infect a susceptible host. This is unlikely unless the contaminated item belonged to a potato grower.

Late blight is considered to be a 'weather-driven' disease. Therefore, if an exotic strain of *P. infestans* is introduced into a region with climatic conditions suitable for late blight, the risk of establishment (given the requirement for a susceptible host to be present) is considered to be moderate.

Spread Potential Following Establishment
Rating: High

Spread within a District
Rating: High
High risk due to the general movement of product and machinery within a district and the chance of rain and wind-borne sporangia being carried to neighbouring paddocks.

Spread between Districts
Rating: Moderate
Moderate risk due to the lack of restrictions on movement of product. Airborne spread is considered to be low due to the isolation of the different potato districts.

Spread between Eastern States (not inc TAS)
Rating: Moderate
Moderate risk due to the lack of restrictions on movement of product. Airborne spread is considered to be low due to distance.

Spread to Western Australia and Tasmania from Eastern States
Rating: Negligible
Negligible risk due to current domestic quarantine movement restrictions, which includes quarantine inspection points and mobile roadblocks.

Spread from Western Australia and Tasmania to Eastern States
Rating: Very Low
Very low risk due to current domestic quarantine movement restrictions.

Overall likelihood rating: Low
The overall likelihood of entry, establishment and spread is estimated to be low, because one of the criteria, the risk of entry, is estimated to be low.

ASSESSMENT OF CONSEQUENCES
(Tables 4 and 5)

Economic Impact
Impact score: E

Of all crops grown worldwide, potatoes are reputedly subject to the greatest production losses (estimated to be 21.8% annually) incurred through disease (Shaw 2001). A large proportion of this is due to late blight (James 1981).

Despite frequent fungicide use, late blight epidemics are becoming increasingly more difficult to control and cost the US industry up to $3 billion p.a. (Duncan 1999). The number of fungicide applications required to control the new strains of *P.infestans* in the Netherlands ranges from 7 - 20 applications per season, an increase of 40% over that required to control the old strains prior to the 1970s (Schepers, 2000, Flier *et al.* 2001).

At present the only isolates that have been identified in Australia are those of the A1 mating type. Therefore we would expect a significant change in the effects of late blight on an Australian crop if any of the new strains were introduced. From an economic perspective this could have very serious effects on both the Australian seed and ware potato industries. The conduct of a full economic impact analysis required more resources than were available for this pest risk analysis due to the necessary data-gathering and considerations of the market access implications within Australia and overseas (Bill Fisher, Manager Economic Services, DPI Vic, pers. comm.). However, an incursion and the potential spread of new more aggressive and fitter strains, especially those strains resistant to some of the chemicals currently used in Australia, could lead to:

- An increase in the percentage of crops needing to be treated for late blight
- An increase in the number of fungicide applications required to control late blight outbreaks
- An increase in the severity of late blight outbreaks and the rapidity of spread
- An increase in the frequency of late blight outbreaks
- Earlier onset of late blight in favourable regions
- Extended range of late blight outbreaks

- An decrease in the window of opportunity for growers to treat their crop, making it increasingly difficult to achieve effective fungicide coverage
- Less sensitivity to some commonly used fungicides
- Total crop loss in areas that do not attempt to control late blight outbreaks
- A decrease in the yield of marketable tubers
- An increase in the cost of grading due to removal of diseased tubers
- Trade barriers being put in place for the seed and ware industry both domestically and internationally

Impact on trade

If the presence of a new strain were confirmed, interstate and international trade would be suspended, at least temporarily. Our trading partners that are currently also free of the new strains, ie New Zealand, South Africa, Vietnam and Mauritius, would halt all imports of Australian potato tubers. The $AUD value of this trade to Victoria alone in 2005 was $11,341,559 (Tables 7 and 8).

Table 7. Victorian ware potato exports for 2005 (*Source: TradeData International & GILB*)

Country of destination	$AUD value of 2005 exports	Strain present in destination country
New Zealand	$11,115,200	Old A1
Indonesia	$864,797	new
Papua New Guinea	$855,141	new
Singapore	$243,010	new
Malaysia	$221,591	new
Hong Kong	$182,078	new
Philippines	$175,796	new
New Caledonia	$144,238	new
China	$129,319	new
Thailand	$101,899	new
Taiwan	$95,472	new
South Africa	$55,500	Old A1
Bahrain	$47,121	new
France	$41,822	new
Fiji	$30,356	new
Vanuatu	$26,862	new
Brunei	$25,852	new
Canada	$21,353	new
Maldives	$17,031	new
Cameroon	$15,439	new
Japan	$13,650	new
United Arab Emirates	$12,640	new
Qatar	$6,751	new
Tuvala	$4,365	new
Kiribati	$2,910	new
Samoa	$2,304	new
Cambodia	$2,153	new
Micronesia	$1,756	new
Sri Lanka	$1,587	new
Vietnam	$1,027	Old A1

It is reasonable to assume that all countries would suspend seed potato trade with Australia if a new isolate was found, potentially costing the Victorian seed industry alone $AUD 3,289,314 (Table 8).

Table 8. Victorian seed potato exports for 2005 (*Source: TradeData International & GILB*)

Country of Destination	$AUD value of 2005 exports	Old/New Strains Present in Country of Destination
Philippines	$895,221	New
Hong Kong	$804,461	New
Thailand	$670,170	New
Indonesia	$301,481	New
Mauritius	$169,832	Old
Singapore	$142,209	New
Papua New Guinea	$136,975	New
Malaysia	$122,140	New
New Caledonia	$37,040	New
Tonga	$9,785	New

Domestic Impact

Although it was not possible to conduct a full economic impact analysis, a benchmarking study for the Victorian french fry and seed potato industries was undertaken in 1998 as part of the ExpHORT 2000 Initiative (Aitken and Beattie 1998). During 1997-98, the average cost of chemical sprays per tonne of potatoes for a Victorian grower was $6.40 compared with $18.40 for US growers. The increased cost for the US grower was attributed to late blight. In Europe, fungicide use is 40% higher than in the late 1970s (pre-new strains) and the average number of sprays per crop has increased from seven to more than 20 per season (Schepers 2000). A similar trend is likely here if the new strains establish.

Australia produced 1.3 million tonnes of potatoes in 2003-04 (*Source: Australian Bureau of Statistics*). In Italy, late blight has been estimated to cause 8% losses in production. If that percentage is used as a basis for estimating potential losses to Australian growers, annual production could be reduced by 104,000 tonnes.

The biggest impact will be felt in the district where an incursion is confirmed. A quarantine zone would be imposed and the adverse economic effects would be severe, particularly if it were a seed-producing district. In conclusion, should a new strain establish itself in Australia, the economic impact on both international and domestic trade added together with yield losses and extra costs of control would be significant at local, district, regional and national levels. Therefore the overall impact rating is significant.

Environmental Impact
Rating: Unknown

The impact of an exotic strain of *P. infestans* on native Australian flora is currently unknown. During the late blight epidemics of 1908-1911 when the old strain of the pathogen first established in Australia, McAlpine (1911) documented that Kangaroo apple (*S. laciniatum*) growing alongside infected potato crops was highly susceptible. However, there have been no new records of infection of this host for decades. The weed, black nightshade (*S. nigrum*), is immune to the strains currently present, yet is known to be susceptible to the new strains in Europe.

An important number of native Solanaceae that have evolved with the pathogen in South America are host to *P. infestans*. In Australia, 117 species of Solanaceae have been recorded. Many are native Solanaceae distributed all over Australia of which only kangaroo apple has been reported as host to *P. infestans*. Due to the uniqueness of Australia's flora, it is not possible to predict how the native Solanaceae and its relatives will react to the new strains if they were to establish in Australia. However, the flora of Australia and South America share a common ancestry through Gondwanaland. More studies on the potential host range of the old and new populations would help in determining a list of hosts that might act as reservoirs or potential pathways of infection.

Social Impact
Impact Score: C

Based on the experience of Potato Cyst Nematode, the social impact would be highly significant at the local level, significant at the district level, minor at the regional and unlikely to be discernible at the national level. Therefore the impact score is estimated to be C.

Overall Consequence Rating: High
The overall consequence rating is calculated based on Decision Rule 4: where one consequence is rated as 'E' and all others are not unanimously 'D', the overall consequence is considered to be 'high'.

Calculation of Overall Risk (Table 6)
Assessment of Likelihood

Entry Potential: Low
Establishment Potential: Moderate
Spread Potential Following Establishment: High
Overall likelihood: Low

Assessment of Consequences

Economic Impact: E
Environmental Impact: Unknown
Social Impact: C
Overall consequence: High

OVERALL RISK ESTIMATE: MODERATE

Although Australia has good border control and import restrictions, a moderate risk of impact to the potato industry exists.

Summary of Pest-Specific Contingency Plan for late blight of potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type).

Information sourced worldwide was summarised in order to increase our preparedness in the event of an incursion of these new strains. Differences in host range, distribution, features, biology and epidemiology of the new strains of *P. infestans* have been collated.

***Phytophthora infestans* distribution**

Table 9: Summary of the current knowledge of mating type and strain distribution of *P. infestans* worldwide.

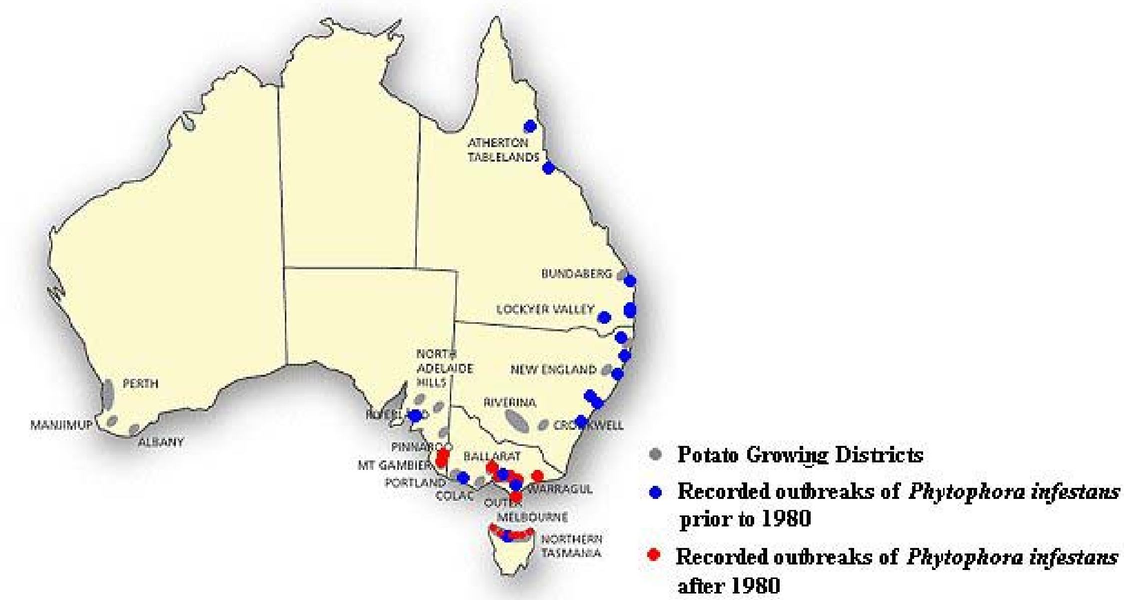
DISTRIBUTION OF A1 AND A2 MATING TYPES ACROSS THE WORLD		
Region	Country	Mating type , strains
Australasia	Australia	A1, old strains
	New Zealand	A1, old strains
	Papua New Guinea	Suspected A1 (unconfirmed), new strains
Africa	Ethiopia,	A1, new strains
	Kenya, Uganda	A1, old strains
	Egypt, Morocco	A1+ A2, new strains
	South Africa	A1, old strains
Asia	China, India, Japan, Korea, Nepal, Pakistan, Thailand	A1 + A2, new strains
	Bangladesh, Sri Lanka, Philippines, Taiwan, Vietnam	A1, new strains
	Indonesia	A1 + A2, new strains
	Russia	A1, new strains
Europe	Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Switzerland, UK-England and Wales	A1 + A2, new strains
	Finland, Hungary, Norway, Netherlands, Poland, Sweden, UK-Scotland	A1 + A2, new strains
	Spain	A1, new strains
	UK-Northern Ireland	A1 , new strains
Central America	Mexico	A1 + A2, new strains
	Colombia, Costa Rica, Honduras, Panama, Venezuela	A1, new strains
North America	USA	A1 + A2, new strains
	Canada	A1 + A2, new strains
South America	Argentina, Brazil, Paraguay, Uruguay	A1 + A2
	Bolivia	A2 only
	Chile, Ecuador, Peru,	A1

The Global Initiative on Late Blight (GILB) webpage, hosted by the International Potato Centre in Peru, regularly updates its country profiles on:
http://gilb.cip.cgiar.org/modules.php?name=News&file=article&sid=495

In most parts of the world where both mating types are present, including Asia, North America and western Europe, the local populations are very dynamic and the frequency of both mating types varies considerably from one year to the next. In some places, however, such as Northern Ireland, Spain, and eastern Europe, a single 'fitter' strain (either new A1 or A2) has become established, severely restricting further sexual recombination. To summarise, the present-day global resurgence of late blight is due to the displacement of "old" *P. infestans* populations by new, genetically more variable, aggressive, fit and fungicide resistant populations (Flier *et al.* 2002b, Fry and Goodwin 1997).

- Following migration events, variation detected in most countries outside Australia is on the increase.
- Asexual lineages dominate most *P. infestans* populations, but in some places they are associated with sexual recombinants (sexual events).
- Rapid changes in the frequency of sexual recombinant lineages occur from season to season. Recombinant lineages often disappear due to genetic drift.
- However, in many parts of Europe and America, genotypes of both mating types coexist and sexual reproduction occurs resulting in many long-lived oospores.

- In Australia (current distribution)

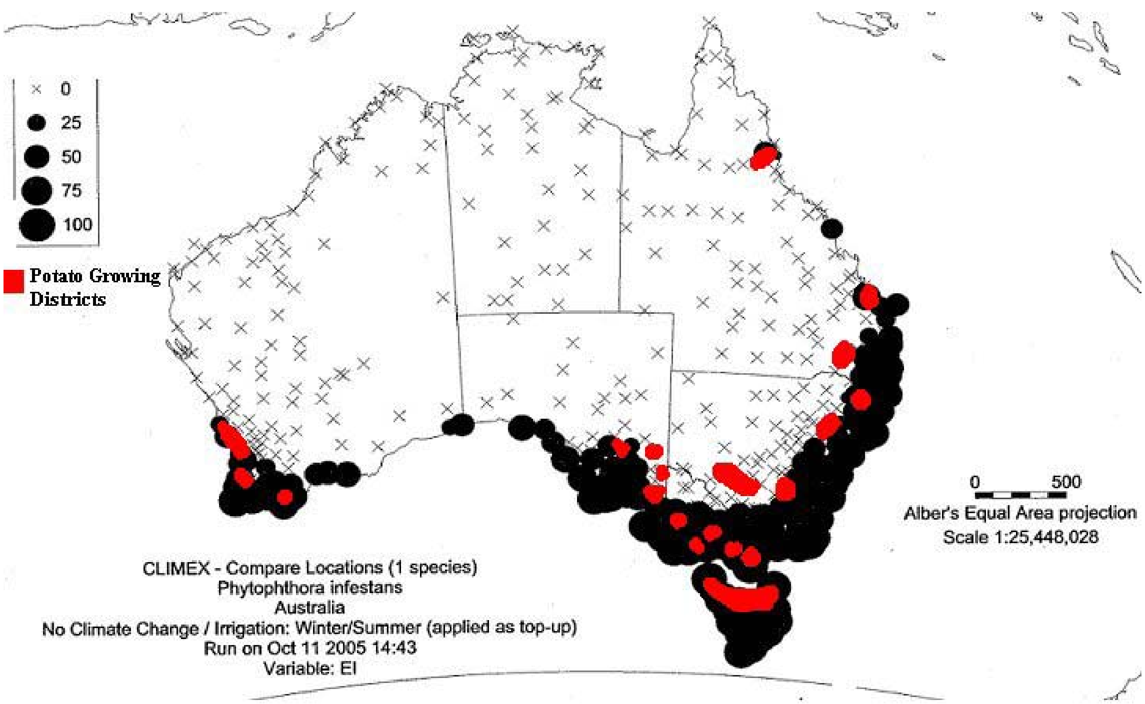


Map 1: Reported outbreaks of late blight (*P.infestans*) in relation to potato growing districts in Australia, based on herbaria records in the Australian Pest and Disease Database.

Although late blight has been observed in most potato growing regions of Australia (Map 1), more recent late blight outbreaks have generally been restricted to potato cropping districts on the north coast of Tasmania, Victoria (Gippsland, Central Highlands, The Otways), and in the past decade, around the Mt Gambier area of South Australia. Outbreaks are sporadic (not every year) and localised, being very weather dependent. The disease typically develops during periods of still, warm and humid weather conditions over mid January to late February. Late blight outbreaks are more common on the north coast of Tasmania, where these conditions occur every season. In the late blight prone areas of Victoria and South Australia, significant outbreaks may only occur in a few localised paddocks every few years. So far, late blight has not been a major threat to the potato industry and can be kept under control relatively easily.

A collection of Tasmanian isolates were demonstrated to be old strains of the A1 mating type. Isolates from other States were not characterised but all indications are that they are similar or identical to those characterised from Tasmania (Drenth *et al.* 2001)

-In Australia (potential distribution of new strains)
Late blight is very much a 'weather-driven' disease, dependent on two major climatic factors: moisture and temperature (Harrison 1992). The modelling package, Climex, developed by CSIRO, offers a means to predict where exotic organisms might establish in Australia by matching climates within Australia to other parts of the world where the organism is currently causing epidemics. When interpreting the output of this model, it must be cautioned that it is purely based on climatic data, and the presence or absence of a host is not taken into account. This model was run using information published overseas about the new strains of *P. infestans* to identify regions within Australia with matching climatic conditions where *P. infestans* could survive. The Climex prediction demonstrated that there are many locations in Australia with climates that match regions of the world where the new strains are currently established (Map 2). These showed that, in general, the new strains would establish in the same areas as the old strains. However, if there was a particularly wet season and a new metalaxyl-resistant strain was present somewhere in a potato crop, experience in all other parts of the world where new strains have established is that rapid spread would occur.



Map 2. Regions of Australia identified by Climex v2 to have climates that match the climatic conditions of regions in the world where the new strains of *P. infestans* have established. The figures in the legend indicate the closeness of the match eg 100 = 100% match, 50 = 50% match. The areas coloured red represent Australia's potato growing districts.

***Phytophthora infestans* host range**
Phytophthora infestans infects species from the plant family Solanaceae. The family Solanaceae contains 90 genera and up to 4,000 species, with considerable diversity in

morphology, ecology and distribution. In South America, the centre of origin of both *P. infestans* and Solanaceous plants, over a hundred wild and cultivated species of Solanaceae are susceptible to late blight. Due to the co-evolution of both host and pathogen in this region, many of the strains of *P. infestans* are specific to a particular host species. Broadly speaking, however, the strains fall into two categories: those that infect tuber-bearing Solanaceae (such as potato) and those that infect non-tuber bearing Solanaceae (such as tomato). All strains currently found outside the centre of origin are able to infect potato. Tomato is susceptible to some of these strains, but not all.

Primary hosts

- potato (*Solanum tuberosum* ssp. *tuberosum*)
- tomato (*Lycopersicon esculentum*).

Other domesticated Solanaceae species

- capsicum (*Capsicum annuum*)
- eggplant (*Solanum melongena*)
- pear melon (*S. muricatum*)
- tamarillo (*S. betaceum*)

P. infestans can also infect ornamental plants such as *Petunia, Nolana* and *Datura* species.
(Platt 1999, Flier *et al.* 2003b, Cooke *et al.* 2002, Sunita and Sen 1997, Turkensteen 1978, Abad *et al.* 1995)

Wild Solanaceae species:
There are many common weeds from the Solanaceae family in Australia. Of these, *P. infestans* is known to infect

- kangaroo apple (*S. laciniatum*)
- black nightshade (*S. nigrum*)
- woody nightshade (*S. dulcamara*)

(McAlpine 1911, Flier *et al.* 2003b, Cooke *et al.* 2002)

Infected kangaroo apples were observed growing in close proximity to infected potato plants during the late blight epidemics of 1909-11 (McAlpine 1911), but no further infections of this host have been reported. Black nightshade and woody nightshade are both immune to the old strains of *P. infestans,* but can host some of the new strains found in the UK and the Netherlands (Cooke *et al.* 2002, Flier *et al.* 2003b, Deahl *et al.* 2004).

Therefore, these three species should be considered useful indicator plants for the detection of incursions of the new strains into Australia. Any infection of these hosts in Australia would be a strong indication that a new strain has established in a nearby potato crop. Although these weeds can be infected by *P. infestans,* it must be stressed that they are much less susceptible than potato. Symptoms have only been observed on weeds growing in close proximity to infected potato plants, and it is believed that the infection spread from the potato to the weed, not *vice versa*.

According to herbarium records, kangaroo apple and black nightshade are widely distributed across potato-growing regions of Australia, and woody nightshade, although restricted to Tasmania, is also found in potato-growing regions.

Environmental conditions

Late blight epidemics are favoured by still conditions with high moisture and moderate temperatures for periods of several days (Harrison, 1992).

The pathogen requires free moisture on the leaves to germinate and infect, and the time required for this process to occur is called the 'leaf wetness period'. Studies have shown that at 15^{o}C, the 'old' strains of *P. infestans* required 8 hours of leaf wetness, but some new strains only require 4 hours (Flier *et al.* 2002a). The optimum temperature for disease development is 22^{o}C (Harrison 1992) and at this temperature, disease will spread rapidly if moisture requirements are right. However, disease can still occur at temperatures below or above this optimum (8-23^{o}C for 'old' strains, compared with 3-27^{o}C for 'new' strains (Forbes *et al.* 1998, Flier *et al.* 2002a)). For disease to effectively take hold, the temperature should be at least 10°C, with 12 hours of >90% relative humidity, followed by further rain within 7 to 15 hours. Night temperatures of 10-16°C and day temperatures of 15-20°C are most favourable for disease development.

Dispersal

Phytophthora infestans has been spread around the world through unwitting trade of infected potato tubers. The pathogen can be carried on tubers as dormant mycelium, and is very difficult to detect in this form. This is the main form of long-distance dispersal.

If both mating types are present and oospores have been formed, the pathogen can also be spread in contaminated soil on tubers and equipment, for example, in dirt trapped in tyre treads, or in the dust collected in transporters, etc.

The single major source of primary inoculum is considered to be infected tubers, as volunteers surviving over the winter, as newly planted seed tubers, or as discarded tubers stacked in cull piles (Andrivon 1995). It has been estimated that 1% of infected tubers develop into infected plants, and that a single infected potato per km^2 is enough to initiate a late blight epidemic if conditions are favourable (van der Zaag 1956). The infected potatoes develop lesions from which the secondary inoculum, sporangia, are produced. Under cool and wet conditions, late blight rapidly spreads to neighbouring plants via release of large numbers of wind-borne sporangia carried in moist air currents. A single lesion on a potato leaf can produce up to 100,000 sporangia (Legard *et al.* 1995), which are spread by wind and rain to healthy plants within the field. The disease can, therefore, become established and spread very quickly within a crop and be carried by wind to nearby crops. Sporangia can also be carried in irrigation water or splashed by rain onto nearby plants and exposed tubers (Erwin and Ribeiro, 1996). Due to their fragility, however, UV radiation and desiccation quickly destroy them, so they survive best when released during the night under cloudy conditions. If conditions are cool, cloudy and wet, sporangia can remain viable for up to 14 days (Sato, 1980; Andrivon *et al.* 1994).

Depending on environmental conditions, regeneration time can be very rapid and the entire infection cycle can be repeated within 3 days. Sporulation can begin within a day or two of lesions becoming visible and sporangia are produced within 8-12 h during favourable conditions. Researchers in the UK developed a model to predict how far sporangia travel based on wind speed and lesion position on the plant (Aylor 1986). Air sampled directly above an infected canopy contained 34,000 - 115,000 sporangia m^{-3}, decreasing rapidly with increasing height above the canopy (Aylor *et al.* 2001). Wind speeds of 20 – 40 km/h can potentially carry sporangia between 80 - 160 km in 4 hours. Bourke (1991) suggested that long-distance wind dispersal is possible in conditions of extreme wind, and Peters *et al.*

(1999) believe that sporangia have travelled up to 800 km in Canada in tropical storm systems. Sporangia can also be carried undetected on clothing or animal fur.

Tuber infection arises from sporangia that are washed down into the soil by rain and irrigation (Glass *et al.* 2001). The sporangia can infect tubers directly, or indirectly via swimming zoospores (Andrivon 1995). Infection can also occur at harvest through contact with blighted foliage. Intact mature tubers are infected through eyes, lenticels and wounds (Lacey 1967; Adams 1975). Potato tubers may rot in the ground before harvest, or later in storage. Dowley demonstrated that tuber-to-tuber spread could occur during in-storage handling if *P. infestans* was actively sporulating on tuber surfaces (Dowley and O'Sullivan 1991).

Guidelines for identification and diagnosis

A portfolio of symptom photos was compiled of late blight caused by both old and new strains of *P. infestans*. The severity of symptoms, however, is partly determined by environmental conditions, so confirmation of a new strain cannot be based on symptoms alone. Protocols for sample collection and handling have been detailed, along with media recipes, DNA extraction techniques, etc. Lists of State diagnostic laboratories, Australian potato disease experts and international *P. infestans* experts have been compiled.

Diagnostic capabilities available in Australia were examined and a list of State diagnostic laboratories was compiled. Currently in Australia, there is only one diagnostician with the capacity to distinguish old strains from new ie. Dr Andre Drenth in Queensland. However, the diagnostic tests available are not ideally suited for incursion purposes due to a turn-around time of at least two weeks for strain confirmation. Diagnostic protocols being developed and used at the Scottish Crops Research Institute have been identified as potentially more suitable for use in incursions, although they have not been developed specifically or tested for that purpose.

Quarantine and risk mitigation

Risk mitigation measures and movement controls were reviewed. At the State level, the high risk areas were identified as those potato regions that already experience late blight outbreaks. It was suggested that regular surveys be carried out whenever outbreaks occur. These pre-emptive surveys and regular crop inspections should be documented by the recognised and responsible authority for inclusion to support "unaffected" production areas of a State or Territory that can be measured against standards that require an area to be free of an exotic organism as demonstrated by scientific evidence. This valuable information would assist in the establishment of areas of pest free production particularly important to the seed industry if an outbreak did occur in Australia. In addition, the surveys would provide the opportunity for growers, third-party providers and diagnosticians to become proficient in accurate identification of *P. infestans.*

Proposed quarantine zones and survey protocols were determined for use during a suspected incursion of an exotic strain of *P. infestans*.

Incursion response

A response plan based on PlantPlan was drafted and contact details for relevant government agencies have been provided. The recommended actions are to guide and assist in the decisions that will need to be made if an incursion is suspected. They identify the issues, actions and responsibilities that may be required during the initial period following a notification of a potential outbreak of late blight caused by a new strain. It is vital that early containment occurs to minimise the spread of a potential outbreak and to maximise the opportunity for eradication. The plans have been arranged into:

- Stage 1 – Actions that take place while diagnosis is being carried out ie. pre-confirmation
- Stage 2 – Actions that take place once an exotic strain has been diagnosed ie. post-confirmation
- Stage 3 – Stand down phase

It must be stressed that these plans are a guide only, based on information and technologies available at the time of writing this contingency plan.

In the event of an incursion by a new strain of *P. infestans,* there are five important strategies that should be implemented immediately following a positive diagnosis (Merriman 2002):

- surveys and diagnosis of affected areas to map the extent of the disease
- pro-active control strategies including roguing and destruction of affected plants
- application of selected chemical treatments for control of the pathogen
- monitoring to check disease status of previously affected areas after treatments have been applied
- monitoring and surveillance to confirm ongoing area freedom status for unaffected areas

Chemical control options

More than one hundred (111) fungicide products currently available in Australia were compared with 198 overseas fungicide products, representing 28 active ingredients. Because of the localised and sporadic nature of potato late blight in Australia currently, agrochemical companies have little incentive in registering fungicide treatments specifically for this disease. Most of the current registrations were coupled with the registration of early blight treatments. It is advisable that additional products are registered, especially in the event that phenylamide-resistant strains are found.

- Short term - Fluazinam (Shirlan®, Syngenta Crop Protection) is a major late blight fungicide. The product is registered for late blight control in New Zealand but not in Australia. However, the product is available in Australia as a registered treatment for the control of club root in Brassica crops. An emergency use permit would be required to allow this product to be used on potato crops in an incursion management situation.

- Longer term alternatives to metalaxyl - Fungicides that are translaminar, locally systemic with curative properties and active against phenylamide resistant strains of *P. infestans* such as cymoxanil mixtures (Curzate®, DuPont), propamocarb-hydrochloride mixtures (Tattoo® and Merlin®, Bayer Crop Science). It should be noted that pathogen resistance to dimethomorph has been recorded, which is currently the only translaminar fungicide registered for late blight control in Australia.

Managing an outbreak of potato late blight caused by new strains of P. infestans

Spray schedule recommendations are listed in the Contingency Plan as a guide. Advice on the best options for managing a suspected incursion with fungicides must be sought from the major agrochemical companies. There must be strict adherence to hygiene protocols to minimise the risk of spread.

In Australia, the management of outbreaks of late blight from endemic strains of *P. infestans* is often reactive rather than preventative due to the sporadic and localised nature of the disease. As a result, the disease may be well established before an incursion is suspected. It is important to deal with outbreaks as quickly as possible. Late blight can spread rapidly through a crop when conditions are ideal.

Where only a few plants are affected, remove and destroy them. Where this is not practical, desiccate the infected patches using a fast-acting desiccant e.g. diquat. Blighted crops or parts of crops must not be irrigated as this increases the risk of tuber infection.

Suspected incursion - Pre-confirmation of new strain
In the event that an outbreak of potato late blight is suspected of being caused by a new strain or strains of *P. infestans* (pre-confirmation) the following spray schedule is recommended:

- At first sign of disease, spray the entire crop with a metalaxyl-based product eg. metaxyl + mancozeb (Ridomil Gold®). Use at the highest label rate.
- At 3-5 days (5 days maximum), spray crop with a dimethomorph-based product eg. dimethomorph + mancozeb (Acrobat®), tank mixed with fluazinam (Shirlan®). Apply a second spray 3-5 days later.
- Continue using a preventative spray program by applying alternating sprays of fluazinam and dimethomorph + mancozeb at 7-10 day intervals.

NB Sprays are best applied using field spray machinery, rather than aerial spraying. Attention to spray rates and water volumes is critical. Applying fungicides with high volumes of water can be counter-productive. High volumes of water can increase disease pressure, can help spread the pathogen throughout the crop and may result in dilution of actives, thereby reducing efficacy. Crops should not be sprayed immediately before heavy rain.

The use of fluazinam, which is available in Australia, is contingent on obtaining an emergency use permit through the Australian Pesticides and Veterinary Medicines Authority, or on an application to the APVMA for an extension to the label for Shirlan® to include potato late blight management treatments.

Preventative spray program for potato crops surrounding the field with the suspected incursion
Surrounding crops should be treated as per the suspect crop outlined above and closely monitored for signs of infection.

Destruction of affected crops
Where it is decreed that a crop affected with a new strain of *P. infestans* must be destroyed, the fungicide fluazinam can be mixed with the desiccant diquat to reduce the risk of tuber infection. Do not mow, slash or flail the crop as airborne spores will be released and dispersed. Once the crop is dead, it should be harvested and deep-buried at an approved burial site. Strict hygiene protocols must be followed.

Resistant cultivars
The National Potato Tissue Culture Collection (NPTCC) is held at DPI Victoria - Toolangi and contains more than 200 publicly and privately owned cultivars originating from Australia and overseas. The germplasm collection service is commercially available to those wanting to maintain pathogen-tested material in tissue culture. Each variety held in the collection is sub-cultured and tested for the presence of bacteria and fungi at least once a year and prior to being released to clients. The supply of tissue culture plantlets from the collection is subject to the importer/owner's permission, where applicable.

The list of cultivars held in the NPTCC was compared with cultivars listed by a variety of sources overseas (Eucablight, UK, the Netherlands, Canada, CIP) as having useful resistance

to foliar and tuber blight. The following are cultivars that are available through the NPTCC and have useful resistance to late blight:
Admiral, Atlantic, Charlotte, Innovator, Midas, Nooksack, Norland, Orla, Osprey, Sebago, Simcoe, Sini, Symfonia, Trent, Valentina and Victoria.

Technology Transfer

Appendices to the National Potato Industry Biosecurity Plan:

- Edwards J, Perrone ST, Dawson K., Gardner R., de Boer RF, Porter IJ (2006) Pest-Specific Contingency Plan for late blight of potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type). DPI Victoria 166 pp.
- Edwards J, Dawson K., Gardner R., Perrone ST, de Boer RF (2006) Pest Risk Analysis: Late blight of potato (*Phytophthora infestans* A2 mating type and exotic strains of A1 mating type). DPI Victoria 53 pp.

Grower fact sheets:

- Vegetable matters-of-fact. Late blight of potatoes. July 2006. DPI VegCheque.
- Vegetable matters-of-fact. Late blight of potatoes: exotic strains of *Phytophthora infestans*. July 2006. DPI VegCheque.
- Grower guide to late blight of potatoes: *Phytophthora infestans* A2 mating type and new strains of A1 mating type.

Grower field day in collaboration with VegCheque and the Processing Potato R&D Program, Ballarat, 25th May 2005 (20 growers and industry representatives (McCains) attended).

Industry articles:

- 'Late blight – the current state of play' Eyes on Potatoes, June 2005, Volume 25, 14-15.
- 'Potato late blight – being prepared!' Eyes on Potatoes, December 2005, Volume 26, p. 9.
- 'Late blight of potatoes' and 'Late blight of potatoes – exotic strains of *Phytophthora infestans*' Eyes on Potatoes, September 2006, Volume 29: in preparation.

Conference presentations:

- Perrone ST, de Boer RF, Dawson K, Edwards J, Wicks T (2005) Fungicide control of new strains of *Phytophthora infestans* – are we prepared? Potato 2005 Conference, 19th-21st September, Phillip Island
- Perrone ST, de Boer RF, Dawson K, Edwards J, Wicks T (2005) Fungicide control of new strains of *Phytophthora infestans* – are we prepared? 15th Australasian Plant Pathology Biennial Conference, 26-29 September, Geelong.

Recommendations

The National Potato industry should consider an industry—wide awareness program to ensure growers fully appreciate the importance of quarantine and on-farm biosecurity/hygiene programs, and to maximise the chance that new strains of *P infestans* are effectively diagnosed and controlled before causing economic damage to the industry. Consideration should be given to ensuring that approaches by major potato companies are standardised across the industry.

Diagnostic capability:

- There is an immediate need to improve the capability of State Diagnostic Services to ensure that appropriate skills are available in the rapid identification procedures required to identify specific 'new' strains of *P. infestans*.

- There is a need for testing and subsequent use of "in-field" *Phytophthora* test kits by the Agricultural Services Industries and other third party providers / growers for basic confirmation that the cause of symptoms is *P. infestans,* prior to submitting samples for diagnosis.

- There is also a need to update and standardise procedures for the identification of *P. infestans* strains into a National diagnostic protocol suitable for incursion purposes. To support this national initiative, consideration should be made for the overseas training of a suitable specialist in the isolation and identification of other strains of *P. infestans*, using methodologies with a more rapid turn-around time such as those developed at thhe Scottish Crops Research Institute.

Surveys:

Horticulture Australia Project No. PT98009 characterised Australian isolates of *P. infestans* in order to determine which strains are present (Drenth *et al.*, 2001). During that project, samples of diseased material were collected during the summers of 1998/99 and 1999/2000, but despite numerous samples being collected, only 20 were successfully characterised due to the need for and difficulties with isolating the pathogen into pure culture. Consequently, there is sparse information on the current distribution of *P. infestans* strains in Australia, which would be useful to determine pest free area status of districts in the event of an incursion.

- A surveillance program be conducted in areas where late blight is currently known to occur. Several Processing Companies have disease forecasting models which alert growers of potential late blight outbreaks. Using these late blight alerting systems already in place, samples of late blight should be collected whenever a disease outbreak occurs and sent to a designated laboratory for strain identification. The new diagnostic protocols recommended above should be used to offset the difficulties in pathogen isolation that were encountered during PT98009. These surveys would:
  (1) be a surveillance program that would enhance early detection of new strains
  (2) provide baseline data for determining pest free area status
  (3) provide the opportunity to refine new diagnostic methodologies so that they are rapid and robust enough for incursion purposes
  (4) train diagnosticians, third party providers and growers in the use of the diagnostic tests and kits, and in survey techniques in preparedness for an incursion.

Management and control:

- That industry consider applying for label extensions or registrations for additional products, especially in the event that phenylamide-resistant strains are found.

- That a review be carried out to determine whether eradication of oospores is possible using fumigants, long-term rotations, etc.

- Growers should choose the cultivar that is best suited to their purpose and to the type of late blight symptoms that predominate in their district.

It is recommended that the documents prepared for this project be reviewed and updated regularly as new information becomes available, and that a simulation exercise be performed to test the plan of action and determine its robustness in the event of an incursion.

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