INDUSTRY BIOSECURITY PLAN

FOR THE GRAINS INDUSTRY

Threat Specific Contingency Plan

Field pea and lentil rusts

Uromyces pisi, Uromyces viciae-fabae

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and

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Plant Health AUSTRALIA

GRDC Grains Research & Development Corporation

CRC PLANT biosecurity

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1 Purpose of this Contingency Plan

This Contingency Plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of field pea and lentil rusts (*Uromyces pisi* and *U. viciae-fabae*). It provides guidelines for steps to be undertaken and considered when developing a Response Plan to this pest. Any Response Plan developed using information in whole or in part from this Contingency Plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation.

2 Pest information/status

2.1 Pest Details

Uromyces pisi ((Pers.) Liro, 1908))
Common name: Rust of field pea, pea rust, broad bean rust

Uromyces viciae-fabae ((Pers.) J. Schrot, 1875))
Common name: Rust of field pea; rust of broad bean, bean rust, lentil rust, vetch rust, pea rust

Uromyces viciae-fabae ((Pers.) J. Schrot, 1875))
Common name: Rust of lentil, rust of broad bean, bean rust, vetch rust, lentil rust

2.1.1 General information

Taxonomic position – Kingdom: Fungi; Phylum: Basidiomycota; Class: Urediniomycetes; Subclass: Incertae sedis; Order: Uredinales; Family: Pucciniaceae; Genus: *Uromyces*; Species: *viciae-fabae* and *pisi*

2.1.1.1 Uromyces pisi (rust of field pea)

Uromyces pisi is the causal agent of rust of pea in a number of pea producing countries worldwide. Compared to *U. viciae-fabae*, the distribution and potential hosts are limited. Reports of yield losses in host crops due to *U. pisi* are sporadic, but this pathogen should be considered a quarantine risk for Australia (Wiberg and Walker 1990).

Some evidence has been found of races within *U. pisi*. Guyot (1937) found an infected source of *Euphorbia cyparissias* from which the aecidiospores infected *Lathyrus pratensis*, but failed to infect *P. sativum*. (*E. cyparissias* or Cypress Spurge is a plant species recorded as present in South Australia and Tasmania). Guyot (1939) later distinguished three races of *U. pisi*:

1. Infecting *P. arvense* and *P. sativum* but not *Lathyrus* spp.; considered to be a weak parasite not forming teleutospores on *P. sativum.*
2. Infecting *L. pratensis* but not *P. sativum*.
3. Infecting *P. sativum, P. arvense* and *L. aphaca* but no other species; considered to be a vigorous parasite, causing severe deformation and producing numerous uredospores and teleutospores on *P. sativum*.

Gäumann (1959) suggested that there are as many as 11 "species" within the *U. pisi* complex that occur on *E. cyparissias*. All 11 species have a complete life cycle and are heteroecious (i.e. requires two hosts), alternating between *E. cyparissias* and species of Fabaceae. The taxonomy of the different species in the *U. pisi* complex is based on the availability of the Fabaceae host after successful fertilisation.

Taxonomy within the *U. pisi* species complex is based upon the choice of alternate host, a species of Fabaceae, in addition to teliospore morphology on the Fabaceae hosts. Morphological identification of the fungi on *E. cyparissias* is impossible (Pfunder and Roy 2000).

2.1.1.2 Uromyces viciae-fabae (rust of field pea)

Uromyces viciae-fabae is a causal agent of rust of field pea. This pathogen is present in Australia on other host crop species but has not been observed on field pea in the field, however, host specific pathotypes of *U. viciae-fabae* have been identified in field pea producing countries overseas. This suggests that certain races of the pathogen do not occur in Australia and therefore present a threat to the Australian field pea industry if they became established.

Uromyces viciae-fabae is regarded as a high economic threat because of potential yield losses through reduced production.

Under Australian conditions *U. viciae-fabae* is a common pathogen of faba bean (*Vicia fabae*) and vetch (*Vicia sativa*). The apparent lack of cross species infection within Australian isolates of *U. viciae-fabae* has not been widely investigated. Testing of Australian isolates of *U. viciae-fabae* in Spain found them to be very mild compared to strains from the Mediterranean area (J. van Leur personal communication).

It appears that degrees of host specialisation and pathogenic variability do exist within populations of *U. viciae-fabae* worldwide. Much research has been performed regarding race identification within *U. viciae-fabae* over many years with conflicting outcomes regarding the suggestion of forma speciales within the species.

Researchers have shown that *Uromyces viciae-fabae* is complex (Hiratsuka 1933; Singh and Sokhi 1980) and that a considerable degree of pathogenic variability exists within populations in Canada (Conner and Bernier 1982; Xue and Warkentin (2002) and India (Lal et al 2007). More recently a combination of morphological observations, molecular phylogenetic analyses and host inoculations have been used to group isolates of *U. viciae-fabae* from Japan (Chung et al 2004). Emeran et al. (2005) concluded that *U. viciae-fabae sensu lato* is a species complex and may be subdivided into populations with differential pathogenicity to *V. faba, V. sativa* or *L. culinaris*.

2.1.1.3 Uromyces viciae-fabae (rust of lentil)

Uromyces viciae-fabae is the causal agent of rust of lentil. It is considered the most serious foliar pathogen of lentil worldwide. This pathogen is present in Australia on other host crop species but has not been observed on lentil in the field, however, host specific pathotypes of *U. viciae-fabae* have been identified in lentil producing countries overseas. This suggests that certain races of the pathogen do not occur in Australia and therefore present a threat to the Australian lentil industry if they became established.

Uromyces viciae-fabae is regarded as a high economic threat because of potential yield losses through reduced production.

In terms of pathogen variability and host specification for *Uromyces viciae-fabae* (rust of lentil) see section 2.1.1.2 details for rust of field pea.

Host species distribution or specific climatic requirements may be responsible for the sporadic appearance of the disease under Australian conditions, particularly in southern cropping areas. The risk of a more aggressive race developing remains distinctly possible.

2.1.2 Life cycle

2.1.2.1 Uromyces pisi (rust of field pea)

U. pisi is a heteroecious rust pathogen, completing its life cycle on two host plant species (refer Figure 1). The sexual stages are completed on *Euphorbia cyparissias* (cypress spurge), while the asexual lifecycle stages are completed on leguminous crop hosts such as *Lathyrus, Orobus, Pisum* and *Vicia* spp. *Euphorbia cyparissias* is an erect, branching, rhizomatous perennial, which typically grows to 30 cm tall. It occurs on poor and mainly dry soils, along forest edges, and roadsides. Numerous tiny flowers appear in umbel-like clusters in spring.

The asexual stage commences with the release of aeciospores produced by *U. pisi* on *E. cyparissias*, which are wind dispersed and infect field pea crops. Infection by aeciospores results in the production of uredinia and subsequent urediniospores. As the host plant matures telia are produced resulting in the formation of teliospores. This leads to the formation of basidiospores, which are windborne and infect *Euphorbia cyparissias* before the onset of winter in the northern hemisphere.

The sexual stage occurs on the alternate host *Euphorbia cyparissias*. Under European conditions the rust fungus remains latent during the winter in the roots of *Euphorbia cyparissias*, and grows with the host as it shoots in the spring. Infection of *Euphorbia* is restricted to the underground rhizome buds and requires an incubation period of 1-year (Hartwich 1955). The infected host plants develop earlier in the season and are inhibited from flowering. The host plant is induced by the fungus to form pseudoflowers; yellow leaves that grow in a rosette on the top of stems and resemble true flowers in colour and shape (Pfunder and Roy 2000). In addition, sweet smelling nectar is produced by the fungus on the surface of the yellow leaves, giving the appearance of a true flower. The nectar contains fungal gametes (spermatia) that are transferred by nectar feeding insects (including bees and ants) from one fungal mating type to another (see Figure 1). Once fertilisation has occurred, aeciospores are released which infect leguminous host plants including field pea.

Uromyces pisi has been reported and confirmed in India (Bharti et al 1988), occurring on *Lathyrus sativus* without an alternate host life stage reported.

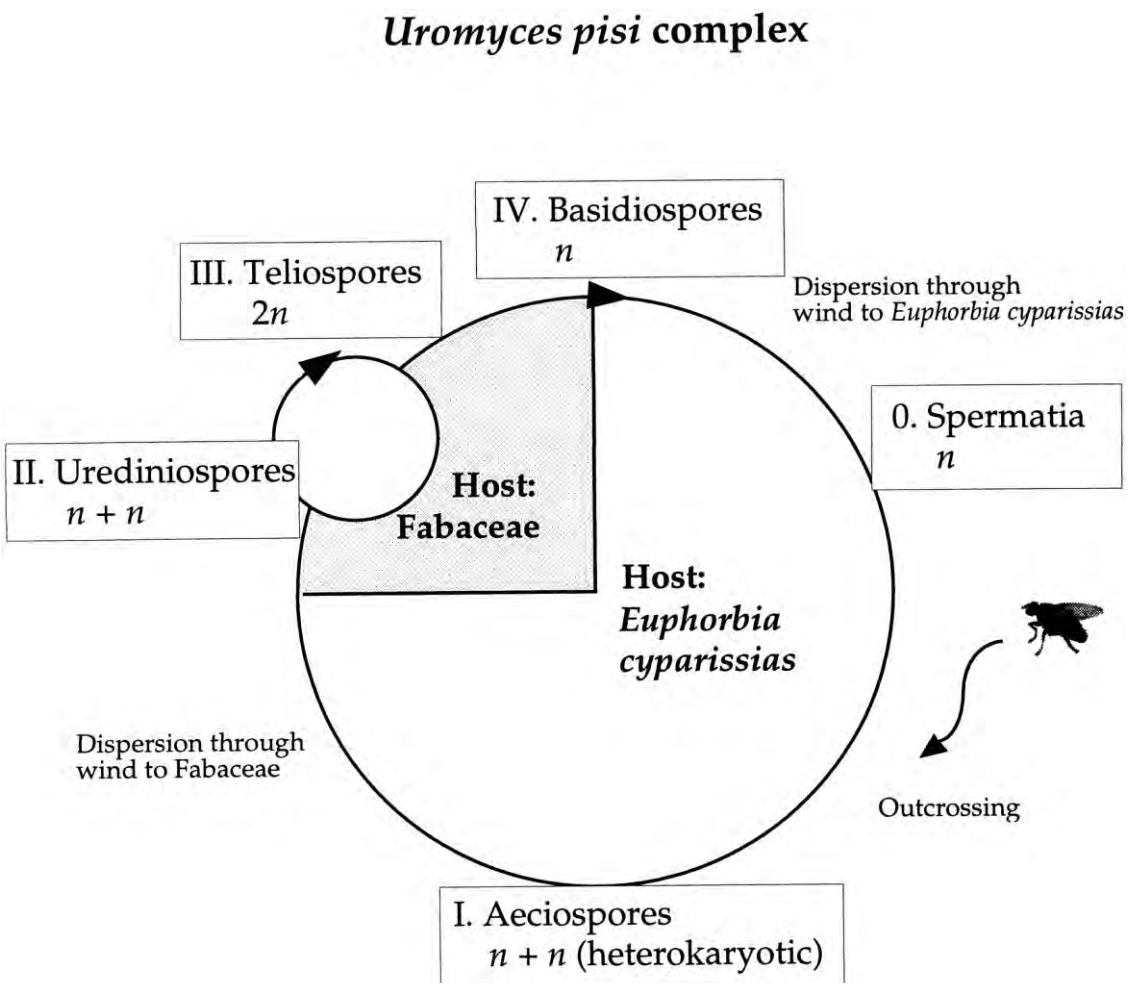

Figure 1. *Life cycle of rust fungi in the species complex of* Uromyces pisi*. These rusts alternate between two hosts (i.e. are heteroecious) and all species in the complex are macrocyclic, meaning that they proceed through all five possible spore stages of a rust fungus (spore stages with corresponding stage of nuclei in boxes). These fungi produce spermatia in spermogonia and aeciospores in aecia on* E. cyparissias*, then they switch to another host, this time a species in the Fabaceae. Each species of the* U. pisi *complex attacks one specific Fabaceae species (Pfunder and Roy 2000).*

2.1.2.2 Uromyces viciae-fabae (rust of field pea and rust of lentil)

Uromyces viciae-fabae is an autoecious fungus, completing its lifecycle on a single host. The disease generally starts from low-lying patches in the paddock and radiates towards the border (Bayaa and Erskine 1998). The resting stage (telia) survives in a semi-dormant stage over summer in crop residues both in the paddock and with seed. It can be carried with seed as concomitant contaminations. It may also perpetuate on weed hosts from where it may infect lentil or field pea crops by windborne spores. Teliospores produced on residues are blown by wind and infect volunteer plants and seedlings. Infection leads to the production of specialised fruiting bodies, aecia. Aecia produce aeciospores, which infect leaves and will spread the rust within the crop and to other crops. Aeciospores germinate at 17-22^{o}C and infect other plants forming either secondary aecia or uredia at 25^{o}C. In turn, this leads to the production of urediniospores, which can be carried long distances to produce new infections. Severe epidemics are caused by the production of several generations of urediniospores. Uridinia develop late in the season and are rapidly followed by telia (Beniwal et al

1993). Teliospores develop in late summer (Hall 2003) on stems and leaves. After harvest, aecia and uredia present on the plant die out, but teliospores are more persistent.

At lower temperatures, uredospores are probably an important means of survival in the absence of the host. Uredomycelium is, on the other hand, highly resistant to heat and sunlight and is probably important for continued development and survival of rust in hot, dry conditions.

Chauhan and Singh (1994) reported that the severity of infection by *U. viciae-fabae* on pea and the number of rust pustules/plant increased progressively with increases in the duration of leaf wetness up to 24 h, but did not increase further significantly. Both were high at 20°C under greenhouse and laboratory conditions. It was suggested that the observed relationship between severity of pea rust and duration of leaf wetness at 20°C might be useful in predicting disease outbreaks if initial inoculum is present. Negussie and Pretorius (2008) found that *U. viciae-fabae* was most damaging on lentil when infection occurred during pod setting and pod fill, reducing the size of seed. In addition, earlier infection by the rust at the flowering stage was found to affect the number of fertile flowers produced and hence, the number of pods formed.

2.1.3 Dispersal

2.1.3.1 Uromyces pisi (rust of field pea)

The fungus survives on debris and dispersal of inoculum can occur in several forms, namely infested debris, dust and sand. Aeciospores produced by *U. pisi* on *E. cyparissias* are dispersed by wind to infect field pea crops. Jørstad (1948) observed rust on field pea at a distance of 25 km from the nearest infected *Euphorbia cyparissias* source in Norway, suggesting long distance wind dispersal is possible. Infection by aeciospores results in the production of uredinia and subsequent urediniospores. The pathogen will spread by urediniospores from one field pea plant to another and from field pea crop to another crop. The primary source of urediniospores can be from volunteer field pea plants, infected earlier in the growing season, or spores carried long distances by wind. As the host plant matures telia are produced resulting in the formation of teliospores. This leads to the formation of basidiospores, which are windborne and infect *Euphorbia cyparissias* before the onset of winter in the northern hemisphere.

2.1.3.2 Uromyces viciae-fabae (rust of field pea and lentil)

Similarly, this fungus survives over summer in crop residues both in the paddock and with seed. The teliospores remaining on residues are dispersed by wind infecting volunteer plants and seedlings. Disease development is increased if high humidity and cloudy weather with temperatures 20-22^{o}C are present. Urediniospores are carried long distances to produce new infections. Severe epidemics are caused by the production of several generations of urediniospores.

It may also perpetuate on weed hosts from where it may infect crops by windborne spores. The predominant form of survival, therefore, varies with the environment and location (Bayaa and Erskine 1998). Severe epidemics are caused by the production of several generations of urediniospores. Teliospores develop in late summer (Hall 2003) on stems and leaves.

Infected inert plant debris mixed with seed can act as basic inoculum for the recurrence of the disease in most years (Khare 1981).

2.2 Affected hosts

2.2.1 Host range

2.2.1.1 Uromyces pisi (rust of field pea)

Strains of *U pisi* have been isolated from many hosts including *Euphorbia cyparissias* (cypress spurge), *Euphorbia esula* (leafy spurge), *Lathyrus latifolius* (perennial pea), *Lathyrus pratensis* (yellow vetchling), *Lathyrus sativus* (grasspea), *Lathyrus sphaericus, Lathyrus tuberosus* (tuberous vetchling), *Lathyrus vernus* (spring vetchling), *Lens culinaris* (lentil), *Lotus corniculatus* (birds foot trefoil), *Medicago sativa* (lucerne), *Pisum sativum* (field pea), *Vicia cracca* (tufted vetch), *Vicia lutea, Vicia sativa* (common vetch) (Parry and Freeman 2001).

2.2.1.2 Uromyces viciae-fabae (rust of field pea and rust of lentil)

Strains of *Uromyces viciae-fabae* have been isolated from *Cicer arietinum* (chickpea), *Lathyrus* spp, *Len culinaris* and *Lens esculenta, Pisum sativum, Rumex angustifolia, Vicia* spp (Parry and Freeman 2001).

2.2.2 Geographic distribution

2.2.2.1 Uromyces pisi (rust of field pea)

Reasonably wide distribution worldwide including (Africa) Canary Islands, Ethiopia, Libya, Morocco; (Asia) China, India, Iran, Pakistan Turkey, former USSR; (Europe) Austria, Belgium, Bulgaria, Corsica, Cyprus, Czechoslovakia, Denmark, Finland, France, Germany, Great Britain, Greece, Hungary, Italy, Malta, Netherlands, Norway, Poland, Portugal, Romania, Sicily, Spain, Sweden, Switzerland, former USSR, former Yugoslavia; (South America) Argentina, Chile (CABI 2005).

2.2.2.2 Uromyces viciae-fabae (rust of field pea and rust of lentil)

Widespread worldwide including (Asia) Afghanistan, Armenia, Azerbaijan, Bangladesh, Bhutan, China, Republic of Georgia, India, Iran, Iraq, Israel, Japan, Kazakhstan, Democratic Peoples Republic of Korea, Republic of Korea, Kyrgyzstan, Lebanon, Myanmar, Nepal, Pakistan, Sri Lanka, Thailand, Turkey, Yemen (Europe) Austria, Belgium, Bulgaria, Cyprus, Czechoslovakia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Malta, Netherlands, Norway, Poland, Portugal, Romania, Russian Federation, Serbia and Montenegro, Spain, Sweden, Switzerland, United Kingdom; (Africa) Algeria, Angolia, Egypt, Ethiopia, Kenya, Libya, Malawi, Morocco, Mozambique, Portugal, South Africa, Sudan, Tanzania, Tunisia, Uganda, Zambia, Zimbabwe; (North America) Bermuda, Canada, Mexico, United States of America; (Central America) Guatemala; (South America) Argentina, Bolivia Brazil, Chile, Colombia, Ecuador, Peru, Uruguay, Venezuela; (Oceania) Australia (but not found on field pea), New Zealand (CABI 2005).

2.2.3 Symptoms

2.2.3.1 Uromyces pisi (rust of field pea)

No published reports could be found describing the symptoms of *U. pisi* infection on field pea. But it can be assumed that the symptoms would be the same as infection by *U. viciae-fabae* (see following section)

2.2.3.2 Uromyces viciae-fabae (rust of field pea)

Initial symptoms of rust on peas are minute, whitish, slightly raised spots. These enlarge and rupture the epidermis to produce reddish brown, irregular pustules on the stems, pods and lower surface of leaves. At first the pustules contain abundant, powdery urediniospores, but eventually they turn dark brown to black when overwintering teliospores are produced (Xue 2003).

2.2.3.3 Uromyces viciae-fabae (rust of lentil)

Rust starts with the formation of yellowish-white pycnidia and aecial cups on leaflets and on pods, singly or in small groups in a circular form. Later, brown uredial pustules, oval to circular and up to 1 mm in diameter; develop on either surface of leaflets, branches stems and pods. They may coalesce to form larger pustules (Bayaa and Erskine 1998).

The telia, which are formed late in the season, are dark brown to black, elongated and present mainly on branches and stems.

In severe infections, the affected plant dries without forming any seeds in pods or with small shrivelled seeds. The plant has a dark brown to blackish appearance, visible in affected patches of the paddock or in the whole paddock if totally infected (Beniwal et al, 1993).

2.3 Entry, establishment and spread

2.3.1 Uromyces pisi (rust of field pea)

Entry potential: Low

It is currently unclear how *U. pisi* would behave under Australian conditions. While *Euphorbia cyparissias* is present in South Australia and Tasmania, its distribution is not widespread in cropping districts. It would be very rare therefore to find *Euphorbia cyparissias* in close proximity to field pea crops. By comparison, the lifecycle of leaf rust of wheat (caused by *Puccinia recondita* f. sp. *tritici*) and stem rust of wheat (caused by *Puccinia graminis* f. sp. *tritici*) use alternate hosts in the Northern Hemisphere, but such lifecycle stages are not known to occur in Australia. Despite this, both diseases are of economic importance and occur frequently in Australia without the alternate host present. Thus, in Australia it is not known if *U. pisi* would be a serious threat to field pea production. The absence of an alternate host would inhibit the completion of the sexual lifecycle stages by the pathogen and therefore inhibit or limit the amount of genetic variation within *U. pisi* populations. However, the asexual stage could still be potentially damaging to field pea production despite the inability of the pathogen to undergo sexual recombination.

Entry potential is considered to be Medium, but possible given the following factors:

- While seed is not directly infected by the pathogen, the pathogen can be transported with seed as a contaminant on infected segments of host plant debris. All above ground plant

parts can be infected by *U. pisi* infected debris from any of these plant parts could carry the pathogen.

- Seed is imported from countries known to have pea rust for sowing and human consumption. It is an AQIS requirement that seed consignments be free of plant material (including leaf and stem material). However, spores of the pathogen may adhere to seed.
- The pathogen would be very difficult to detect visually as spores adhering to seed. Any plant material present in the consignment may be undetected upon entry.
- The wide distribution of the pathogen worldwide and high frequency of air travel into Australia could allow *U. pisi* to enter Australia via the clothing and personal effects of passengers.

Establishment potential: Medium

Establishment potential is considered to be Medium, as:

- Most current commercial field pea cultivars in Australia are susceptible to pea rust.
- *U. pisi* of field pea may not be detected in the first year of introduction in the field.
- Climatic conditions in parts of the cropping belt could potentially be suitable for *U. pisi.*
- The alternate host *Euphorbia cyparissias* is already present in Australia in South Australia and Tasmania, but its distribution is not widespread.

Spread potential: Medium

Spread potential is considered to be Medium, given the following:

- Spores are wind dispersed over large distances.
- The host range of the pathogen is restricted to species of *Lathyrus, Pisum, Vicia* and *Euphorbia.* Most current commercial pea cultivars in Australia are susceptible to pea rust.
- Spores of the pathogen can be transported as a contaminant of seed over large distances, and in contaminated harvest machinery.
- Windblown plant debris could spread the pathogen over moderate distances following harvest into adjacent paddocks.

Economic impact: Medium

This disease is known to cause significant damage to *P. sativum* in Hungary (Füzi 1995). Sidenko (1960) reported that early sown vetchling to be liable to high levels of infection by *U. pisi* in the Ukrainian steppe, especially if sown in close proximity to alternate hosts.

This disease has the potential to disrupt the pea industry in Australia. An outbreak of pea rust would result in a reduction in the area of production for a short period, due to increased costs of production making field peas less competitive compared to other crops. Germplasm with improved resistance to the disease has been identified within the Australian Field Pea Breeding Program, but would be several years away from public release. Production of other pulse crops may also be affected depending on the host specificity of the pea rust pathogen.

Environmental impact: Negligible

There is no potential to degrade the environment or otherwise alter the ecosystem by affecting species composition or reducing the longevity or competitiveness of wild hosts.

Social impact: Low

The reduction in the value of production and increased production costs would be expected to have low social impact.

Overall risk: Medium

At present, by combining the likelihoods of entry, establishment, spread and economic impact the overall risk to the industry is Medium.

2.3.2 Uromyces viciae-fabae (rust of field pea and rust of lentil)

For both species the risks are considered similar with the only change being the actual host.

Entry potential: Medium

Entry potential is considered to be Medium, but possible given the following factors:

- While seed is not directly infected by the pathogen, the carry-over capacity of teliospores is very high as teliospores can easily be part of the dust and dirt in a seed sample. However for disease transmission to occur, teliospores would have to come into contact with a living host, for example as dust during transport coming into contact with a living host plant.
- Seed is imported for sowing and human consumption from countries known to have pea and/or lentil rust. It is an AQIS requirement that seed consignments be free of plant material (including leaf and stem material). However, spores of the pathogen may adhere to seed. Seed of host plant species entering Australia other than lentil has to be considered as a possible pathway of entry. This includes *Vicia* spp and *Lathyrus* spp.
- The pathogen would be very difficult to detect visually as spores adhering to seed. Any plant material present in the consignment may be undetected upon entry.
- The wide distribution of the pathogen worldwide and high frequency of air travel into Australia could allow *U. viciae-fabae* to enter Australia via the clothing and personal effects of passengers.

Establishment potential: High

Establishment potential is considered to be High, as:

- *U. viciae-fabae* is already widely established in Australia on other host grain legume species such as faba bean and vetch over a wide geographic and climatic area. This area includes Victoria and South Australia where lentils are most widely grown.
- All current commercial field pea cultivars and most lentil cultivars in Australia are susceptible to *U. viciae-fabae* rust.
- *U. viciae-fabae* of field pea and/or lentil may not be detected in the first year of introduction in the field.

Spread potential: High

Spread potential is considered to be High, given the following:

- Spores are wind dispersed. Under ideal conditions the pathogen can cycle every 8-10 days, producing a new generation of urediniospores.
- The host range of the pathogen potentially includes several pulse crop species including lentil, faba bean, field pea and chickpea. All current commercial field pea and most current commercial lentil cultivars in Australia are susceptible to *U. viciae-fabae* rust.
- Spores of the pathogen can be transported as a contaminant of seed over large distances, and in contaminated harvest machinery.
- Windblown plant debris could spread the pathogen over moderate distances following harvest into adjacent paddocks.

Economic impact: Medium

This disease has the potential to disrupt the field pea and/or lentil industry in Australia. An outbreak of *U. viciae-fabae* rust would result in a reduction in the area of production for a short period, due to increased costs of production making either host less competitive compared to other crops. Germplasm with improved resistance to the disease has been identified within the Australian Field Pea and Lentil Breeding Programs, but would be several years away from public release. Production of other pulse crops may also be affected depending on the host specificity of the *U. viciae-fabae* rust pathogen.

Rust is considered the most important foliar disease of lentil worldwide (Erskine et al 1994), with complete crop failure possible from an early infestation of the fungus (Khare and Agrawal, 1978; Negussie et al 2005). Yield losses within experimental plots can vary from 30 to 60% depending on the cultivar and disease severity (Beniwal et al 1993).

Environmental impact: Negligible

There is no potential to degrade the environment or otherwise alter the ecosystem by affecting species composition or reducing the longevity or competitiveness of wild hosts.

Social impact: Low

The reduction in the value of production and increased production costs would be expected to have low social impact.

Overall risk: Medium

At present, by combining the likelihoods of entry, establishment and spread the overall risk to the industry is medium.

2.4 Diagnostic information

2.4.1 Diagnostic protocol

There are several traditional methods of identifying rust species on lentil and field pea. These include:

- identification of the *Uromyces* species based on the morphology of telia, teliospores, uredinia and urediniospores.
- identification based on host species.

A molecular protocol for the identification of *U. pisi* and host specific isolates of *U. viciae-fabae* has not been published. However, Emeran et al (2008) found that comparison of different isolates of *Uromyces* spp, including *U. pisi* and host specific isolates of *U. viciae-fabae*, using RAPD markers revealed that isolates of *U. pisi* clustered differently to isolates of *U. viciae-fabae* and that within isolates of *U. viciae-fabae*, isolates from different host plants did cluster separately. The authors concluded that use of more powerful techniques for detecting molecular polymorphism may allow greater discrimination of isolates.

2.4.1.1 Identification based on morphology

Identification based on morphology can be done with direct visual examination of fungal spores recovered from infected plants. This type of identification is not entirely conclusive and should be done in conjunction with other identification methods. Identification is based on spore size, ornamentation and colour. It will not indicate host specificity. Spores have to be mounted onto slides and inspected using a microscope.

It is important that all diagnoses of suspected exotic and emergency pathogens are undertaken according to the following parameters:

- The laboratory diagnostician has expertise in this form of diagnosis
- The results are confirmed by diagnosis in another recognised laboratory or by another diagnostician and where possible diagnosis is confirmed by a second method.

Morphological description of *U. pisi* (from Laundon and Waterson 1965)

Pycnia mostly hypophyllous, scattered among the aecia. Aecia are hypophyllous, scattered over the entire leaf surface, often covering most leaves of the infected plant, cupulate, 0.3-0.4 mm diam. Aeciospores broadly ellipsoidal, 17-22 μm diam.; wall hyaline, finely verrucose, 1μm thick. Uredia mostly hypophyllous, irregularly scattered, cinnamon, up to 1 mm. diam. Urediospores broadly ellipsoidal, 22-28 X 19-24 μm; wall sienna, very finely echinulate, 1.5-2 μm thick; pores 3-6 scattered. *Telia* like uredia but chestnut. Teliospores broadly ellipsoidal, slightly bullate at the apex, 22-28 X 17-22 μm; wall sienna, paler over the pore, finely warted, 2-3 μm thick at the sides, 4-5 μm thick at the apex; pedicles almost hyaline, fragile, short.

Pycnia and aecia form on *Euphorbia*, uredia and telia form on *Lathyrus*, *Pisum* and *Vicia*.

U. viciae-fabae differs from *U. pisi* in having urediospores with equatorial pores and smooth teliospores with greatly thickened apical wall.

Morphological description of *U. viciae-fabae* (from Laundon and Waterson 1965)

U. viciae-fabae is an autoecious fungus, completing its life cycle on lentil or field pea. *Pycnia* amphigenous in small groups associated with the aecia. *Aecia* amphigenous or hyphyllous, usually in groups surrounding the pycnia or sometimes scattered, cupulate, 0.3-0.4 mm diam. *Aeciospores* are spheroidal, 18-26 μm diam.; wall hyaline, verrucose, 1 μm thick. *Uredia* are amphigenous and on the petioles and stems, scattered, cinnamon, 0.5-1 mm diam. *Uredospores* are ellipsoidal or obovoidal 22-28 x 19-22 μm; wall luteous to sienna, very finely echinulate, 1-2.5 μm thick; pores 3-4, equatorial or occasionally scattered on *Lathyrus*. *Telia* are like the uredia but black and larger: 1-2 mm diam. *Teliospores* are ellipsoidal, obovoidal or cylindrical, rounded or subacute above, 25-40 x 18-26 μm; wall chestnut, smooth, 1-2 μm thick at the sides, 5-12 μm thick above; pedicels sienna to luteous, up to 100 μm long.

2.4.1.2 Identification based on host species

Inoculation of the rust isolate onto a range of differential host species would indicate the host specificity of the isolate and hence whether the isolate is exotic.

A suggested set of differential plant species would include:

- Lentil (*Lens culinaris*) – widely grown commercial variety, all are susceptible
- Field pea (*Pisum sativum*) – variety selection is not important as all are susceptible
- Chickpea (*Cicer arietinum*) – variety selection not important
- Faba Bean (*Vicia faba*) – a rust susceptible variety (e.g. Farah, Fiesta VF, Fiord, Ascot, Barkool)
- Vetch (*Vicia sativa*) - a rust susceptible variety (e.g. Blanchefleur, Languedoc)

Clearly a pathogenic response on field pea and/or lentil would indicate that the isolate is exotic and poses a threat to these pulse industries. A pathogenic response on faba bean and/or vetch only would indicate that the isolate is endemic and poses no threat. A pathogenic response on chickpea may indicate an exotic threat. *Uromyces ciceris-arietini* is a host specific rust species that is pathogenic to chickpea and exotic to Australia, and exotic strains of *U. viciae-fabae* can also infect chickpea.

2.5 Response checklist

Guidelines for Response Checklists are still to be endorsed. The following checklist provides a summary of generic requirements to be identified and implemented within a Response Plan:

- Destruction methods for plant material, soil and disposable items
- Disposal procedures
- Quarantine restrictions and movement controls
- Decontamination and farm cleanup procedures
- Diagnostic protocols and laboratories
- Trace back and trace forward procedures
- Protocols for delimiting, intensive and ongoing surveillance
- Zoning

- Reporting and communication strategy

Additional information is provided by Merriman and McKirdy (2005) in the Technical Guidelines for Development of Pest Specific Response Plans.

2.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of poor growth. The normal procedure is to collect symptomatic plants and to test them to confirm the presence of *U. pisi or U. viciae-fabae*. If confirmed, plants taken at random from the same crop should be tested to enable an estimate to be made of the disease incidence. Surrounding crops would then be surveyed. The extent of the survey beyond the initial infected crop should be guided by the test results from surrounding crops. It should be noted that both *U. viciae-fabae* and *U. pisi* produce large numbers of air-borne spores on infected tissue. Once established the disease would be expected to spread quickly to susceptible host crops.

Containment of the pathogen will depend on:

- The density of field pea and lentil crops grown in the affected area
- The prevailing weather conditions
- The initial surveys being completed quickly

Seed trace-back will indicate how many seed lots and crops will need to be tested. While not seed borne, spores may contaminate harvested seed, therefore if the seed used has been sown at several sites, delimiting surveys should be conducted at each site. A further consideration should be given to crops that may have been cut for hay to feed livestock and pea stubble that may have been baled following harvest and sold has garden mulch in the previous season.

2.6.1 Sampling method

Once initial samples have been received and preliminary diagnosis made, follow up samples to confirm identification of the pathogen will be necessary. This will involve sampling directly from the infected crop, and sampling crops over a larger area to determine the extent of disease distribution. The total number of samples collected at this point may run into the hundreds or even thousands. It is vital that a system of sample identification is determined early in the procedure to allow for rapid sample processing and accurate recording of results. Follow up samples will be forwarded to the nominated diagnostic laboratories for processing.

General protocols for collecting and dispatching samples are available from PLANTPLAN, Appendix 3 (Plant Health Australia 2008).

2.6.1.1 Number of specimens to be collected

Samples should be initially collected over a representative area of the infected crop to determine the disease distribution. The disease may appear as „hotspots" or patches within the crop or may have developed to infect most of the crop given the nature of dispersal of the pathogen. Depending on the stage of infection the symptoms may appear as:

- Small patches of plants with rust pustules on leaves and pods
- Larger patches of plants with rust pustules on leaves, pods and stems
- Large patches of plants prematurely defoliated and dying within the crop

It is important to note the distribution of disease in the initial crop, as this will indicate whether the disease has been seed-borne, carried on trash or infected hay, or airborne spores from adjacent paddocks or originated from contaminated machinery or human movement.

It is vitally important that all personnel involved in crop sampling and inspections take all precautions to minimise the risk of disease spread between crops by decontaminating between paddocks.

It is important to record the precise location of all samples collected, preferably using GPS, or if this is not available, map references including longitude and latitude and road names should be recorded. Property and owners names should also be included where possible.

2.6.1.2 How to collect samples

All foliage can become infected by rust; this includes leaves, stems and pods. Samples should be collected that represent a range of symptoms observed in the infected crop. Preferably enough material should be collected to allow for immediate processing and retention of a portion that can be placed into long term storage as a reference.

2.6.1.3 How to transport samples

Samples should be treated in a manner that allows them to arrive at the laboratory well-preserved state. In this instance samples can be collected and transported between pieces of dry paper. The viability of the rust spores will not be compromised. In addition, in a dry state the sample is unlikely to become infected with saprophytic fungi and bacteria, which may render the sample unviable.

2.6.1.4 How to store samples

Samples should be processed as quickly as possible after sampling from the field. Infected plant tissue and rust spores to be used for PCR analysis can be placed in a –80^{o}C freezer and stored for an indefinite period without damaging fungal DNA.

Long term storage of isolates can occur as rust spores can be freeze dried for future reference (without loss of viability) or as deep frozen plant specimens maintained at –80^{o}C, which can be used to extract DNA.

2.6.2 Epidemiological study

The number of infected plants within a crop will depend on the source and amount of primary inoculum available and whether environmental conditions have been favourable for the disease to spread from initial foci.

Sampling of crops within a district and beyond will be based upon the origins of the initial suspect sample(s). Factors to consider will be:

- The source of seed used and how long that seed has been used by the grower.
- If any other field pea or lentil crops have been sown from the same seed source.
- The possibility that infected crops may have been cut for hay to feed livestock or field pea trash baled and sold for garden mulch. Nursery supply businesses may have to be consulted if garden mulch is a pathway of spread.
- That infected trash (either as hay or garden mulch) may have been bought onto the property from an outside source.
- The proximity of other pulse crops, to the initial infected crop, both in the current growing season and previous season. Faba bean and vetch crops should also be considered as these crops can also host the pathogen. This will include the growers own pulse crops and pulse crops on neighbouring properties.
- In the case of *U. pisi*, the proximity to any pastures or rangelands where *Euphorbia* spp. may be present.
- Machinery or vehicle movements into the infected crop.
- The extent of human movements into the infected crop. A possible link to recent overseas travel or visitors from other regions should also be considered.

2.6.3 Models of spread potential

No modelling data are available for the spread of *U. pisi* or *U. viciae-fabae* in broadacre cropping.

Spread may occur in the following ways:

- Movement of infected seed. The pathogen has the potential to be transmitted with seed. Small infected fragments can also be carried within infested seed lots.
- Mechanical transmission through movement on contaminated vehicles and machinery.
- Infected crops that may have been cut for hay to feed livestock or field pea trash baled and sold for garden mulch.
- Infected trash (either as hay or garden mulch) may have been bought onto the property from an outside source.
- Small fragments of pod, stem or leaf tissue carrying telia and teliospores can be blown into surrounding paddocks during harvesting and allow the pathogen to move considerable distances away from the infected crop. Telia and teliospores are a source of primary infection for following crops.
- Under ideal conditions several generations of urediniospores can be produced by the pathogens on infected plants, following primary infection. These secondary spores are air-borne and can be carried long distances to initiate new infections.

- Fungal spores that adhere to clothing, machinery or animals can be carried large distances into other lentil crops.
- Infected pea crops that may be unknowingly cut for hay and later fed to livestock. Hay may also be transported over large distances.
- Pea straw that may be baled following harvest and used as mulch for home gardens and transported over large distances.

2.6.4 Pest Free Area (PFA) guidelines

Pest free area guidelines relevant to this pest. Points to consider are:

- Design of a statistical delimiting field survey for symptoms on host plants (See 2.6 for points to consider in the design).
- Plant sampling should be based on at least 100 plants taken at random per crop.
- Seed sampling should be based on a minimum of 400 seeds, but preferably 1000 seeds should be tested. The author has been unable to find figures for the level of seed contamination in lentil or field pea.
- Surveys should also consider alternative host plants, in particular faba bean, vetch, chickpea and Euphorbia spp (for *U. pisi*).
- The use of aerial inspection or remote sensing may be possible, with suspect patches inspected and sampled to confirm or deny the presence of *U. viciae-fabae* and *U. pisi*.

Additional information is provided by the IPPC (1995) in Requirements for the Establishment of Pest Free Areas. This standard describes the requirements for the establishment and use of pest free areas as a risk management option for phytosanitary certification of plants and plant products. Establishment and maintenance of a PFA can vary according to the biology of the pest, pest survival potential, means of dispersal, availability of host plants, restrictions on movement of produce, as well as PFA characteristics (size, degree of isolation and ecological conditions).

2.7 Availability of control methods

Few attempts have been made to formulate control strategies for *U. pisi* (rust of field pea) as reports of serious yield losses to peas due to *U. pisi* are rare.

2.7.1 General procedures for control

- Keep traffic out of affected areas and minimize it in adjacent areas. Spores of the rust pathogens are easily transported through mechanical means (movement of vehicles and machinery, human movement)
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.

- Ensure seed production does not take place on affected farms and do not use lentil, field pea faba bean, chickpea or vetch seed from affected areas to plant new crops as this seed may be infected with *U. pisi* or *U. viciae-fabae.*
- If pastures in close proximity have *Euphorbia* spp. present, remove stock. The *Euphorbia* may also be infected by *U. pisi* and livestock may inadvertently spread spores from infected *Euphorbia* plants and spread the disease.
- After surveys are completed, destruction of infected crops and seed lots should be undertaken. Infected crops should be destroyed by burning and ploughing. Any infected seed lots should be incinerated or buried deeply (in a non-cropping area).
- Note: Depending on the density of field pea and lentil crops in the area, blanket spraying of these crops with foliar fungicides within a 10 km radius of the infected crop(s) may be necessary to prevent further spread.
- Ongoing surveillance of infected paddocks and adjacent paddocks should continue for several years.

2.7.2 Control if small areas are affected

As above.

2.7.3 Control if large areas are affected

A large area may become affected if:

- A large quantity of infected seed has been widely distributed.
- An infected field pea crop has unknowingly been cut for hay to feed livestock and the hay distributed over a large area.
- The disease has gone unnoticed for a number of years.
- Disease epidemic conditions occur and the disease is able to spread rapidly through the movement of air-borne spores and quickly become established in new crops.

Implementation of large area controls will depend on the ability to determine the original source and track/trace the spread. It will also depend on whether the source has come from contaminated seed or from another source e.g. contaminated clothing or machinery. If the disease is found to be confined to a single seed lot and only found in lentil or field pea crops, it may be possible to eradicate the disease by destroying all lentil or field pea crops in that region. However, for either pathogen, unless detected very early it is unlikely that disease eradication would be possible. The rust fungi are able to produce large amounts of air-borne spores that will spread the disease very quickly over a large area. Infected plant debris are also likely to be spread by wind over moderate distances.

If eradication was attempted, there would need to be ongoing monitoring of infected paddocks to ensure there was no opportunity for the pathogen to re-establish on self sown plants or alternate hosts.

2.7.4 Cultural control

Cultural control may be possible by growing non-host crops such as cereals and oilseeds as this would enable ongoing spraying with selective herbicides on any self-sown lentil, field pea or other legumes. This would remove any potential hosts of the pathogens. Surrounding pastures would have to be monitored for *Euphorbia* spp. and the plant eradicated if necessary.

2.7.5 Host plant resistance

2.7.5.1 Uromyces viciae-fabae (rust of field pea)

The use of host plant resistance is the best means of rust control (Bayaa and Erskine 1998). Genetic differences among genotypes and sources of resistance have been reported.

Screening of field pea germplasm under field conditions for resistance to rust has been reported in India (Singh et al. 1995). Several entries of both dwarf and tall types were found to exhibit a resistant reaction. Rathi et al. (1991) found no field pea lines to be completely free of rust infection, but did identify lines with reduced levels of infection. Currently field pea germplasm from the Australian Field Pea Breeding Program is sent to China for screening in the field for resistance to rust. Breeding lines have been identified which are less susceptible to the disease, but no lines have been identified with complete resistance. No current commercial field pea cultivars in Australia are resistant to rust of field pea.

Glasshouse screening in Canada of 93 field pea varieties found a large range of reactions to infection by three isolates of *Uromyces fabae* (*U vicia-fabae* was previously known as *U. fabae*) (Xue and Warkentin 2002). Four varieties were considered to be resistant (Tara, Century, Titan and Yellowhead), having a leaf area with symptoms (LAS) of less than 2%. The remaining varieties had LAS of 2-67% and were considered susceptible. However, no single variety was considered completely resistant when the variety X isolate interaction was taken into consideration. It was concluded that any screening for rust resistance performed under glasshouse conditions should use several different isolates of the pathogen, given the degree of variability within the pathogen population.

2.7.5.2 Uromyces viciae-fabae (rust of lentil)

Genetic differences among genotypes and several sources of resistance have been reported worldwide, with several rust resistant lines available. Resistance to rust has been reported to be monogenic and dominant (Sinha and Yadav 1989). Most recently Chahota et al. (2002) reported that resistance to rust in lentil is controlled by two duplicate, non-allelic and non-linked dominant genes. Breakdown of rust resistance in lentil has not been reported, but the likelihood of such an event in varieties with monogenic resistance cannot be ruled out (Negussie et al. 2005).

Screening activities for evaluation of rust resistance are performed under both natural epiphytotic conditions and artificially in the glasshouse. Field screening has been undertaken at several locations worldwide where infection occurs naturally, these include, Ishurdi in Bangladesh, Pantnagar in India and Akaki in Ethiopia (Erskine et al. 1994). More recently the Australian lentil breeding program has undertaken screening of Australian developed germplasm at Pellehue in Chile. Kramm and Tay (1984) developed a method of artificially screening germplasm in the glasshouse, which is a valuable method of confirming resistance observed in the field.

Studies of the factors influencing the mechanism of resistance to rust in lentil (Reddy and Khare 1984) reported that resistant cultivars contained more leaf surface wax, levels of P, K, S, Zn, Fe, Cu

and phenols and lower levels of amino acids, N, Mn, and sugars than susceptible cultivars. Structurally there were no significant differences found between resistant and susceptible cultivars.

2.7.6 Chemical control

2.7.6.1 Uromyces pisi (rust of field pea)

In Hungary, applications of foliar fungicides at budding and pod formation to control rust were found to increase pea yields by up to 78% (Füzi 1995). A mix of cyproconazole + carbendazim or epoxiconazole were both found to be effective. Early recommendations for fungicidal control of *U. pisi* in peas included spraying with Bordeaux (Deutelmoser 1926).

2.7.6.2 Uromyces viciae-fabae (rust of field pea)

Singh and Singh (1997) reported results of nine foliar fungicide treatments for the control of pea rust caused by *U. viciae-fabae* comprising a first spray of fungicide just after the appearance of symptoms, followed by two more sprays at 10-day intervals. Flutriafol was the most effective fungicide giving 74.7% disease control and increased the grain yield of pea. From the pooled data from two seasons it was concluded that three sprays of flutriafol, metalaxyl or tridemorph could be recommended for the management of pea rust.

2.7.6.3 Uromyces viciae-fabae (rust of lentil)

Seed treatments

Early studies on the control of lentil rust in India found seed treated with Agrosan (phenylmercury acetate) to control seed-borne inoculum (Prasada and Verma 1948). Singh (1985) found Vigil (diclobutrazole), applied as a seed dressing, to prevent the appearance of *U. viciae-fabae* up to 70 days following inoculation with uredospores 30 days post sowing. Bayleton (triadimefon) prevented disease appearance up to 40 days post inoculation. The untreated control was severely infected with rust 35 days after inoculation.

Foliar fungicides

Agarwal et al. (1976) found Hexaferb (Ferric dimethyldithiocarbamate) and Dithane M-45 to give the best control of *U. viciae-fabae* in experimental plots at Jabalpur, India. In addition Dithane M-45 also increased plot yield by 82% and grain weight by 24% when compared to the untreated control.

Currently in Australia there are a number of fungicides registered for the control of *U. viciae-fabae* on faba bean including products that contain mancozeb, chlorothalonil and copper, that could be used to effectively control the disease on field pea or lentil (Hawthorne et al. 2008).

Note: The use of foliar fungicides may be needed to control the disease after the initial discovery. This may include the recommendation to blanket spray large numbers of field pea and lentil crops within a 10-20km radius of the initial infected crop. Prophylactic spraying would assist in containment of the disease and prevent further infections developing.

2.7.7 Mechanical control

2.7.7.1 Uromyces pisi (rust of field pea)

Cultural control methods such as crop rotation, removal and burning of crop residues after harvest and eradication of neighbouring alternate hosts such as *Euphobia cyparissia* were recommended by Noffray (1924). Sidenko (1960) also recommended removal of field milkwort (*Euphorbia* spp.) and tuberous vetchling (*Lathyrus tuberosus*) when growing vetchling crops.

2.7.7.2 Uromyces viciae-fabae (rust of field pea)

The cultural control methods currently recommended in Australia for control of *U. viciae-fabae* on faba beans include the destruction of old crop residues either by grazing, burial or burning, control of volunteer plants over summer, and isolation of new season faba bean crops from old faba bean stubbles (MacLeod 1999). Despite these recommendations being based on faba bean, the approach to controlling *U. viciae-fabae* on field pea would be basically the same.

2.7.7.3 Uromyces viciae-fabae (rust of lentil)

Cultural control methods currently recommended in Australia for control of *U. viciae-fabae* on faba beans include; the destruction of old crop residues either by grazing, burial or burning; control of volunteer plants over summer; and isolation of new season faba bean crops from old faba bean stubbles (MacLeod 1999). Despite these recommendations being based on faba bean, the approach to controlling *U. viciae-fabae* on field pea would be basically the same. Prasada and Verma (1948) recognised the importance of old lentil crop residues as an inoculum source for the following season and recommended their destruction as part of a control strategy for lentil rust in India.

2.7.8 Biological control

No biological control agents are available to control *U.pisi* or *U. viciae-fabae*.

3 Course of action – eradication methods

Additional information is provided by the IPPC (1998) in Guidelines for Pest Eradication Programmes. This standard describes the components of a pest eradication programme which can lead to the establishment or re-establishment of pest absence in an area. A pest eradication programme may be developed as an emergency measure to prevent establishment and/or spread of a pest following its recent entry (re-establish a pest free area) or a measure to eliminate an established pest (establish a pest free area). The eradication process involves three main activities: surveillance, containment, and treatment and/or control measures.

3.1 Destruction strategy

3.1.1 Destruction protocols

- Infected crops should be destroyed by burning and ploughing. This will prevent aerial dispersal of the pathogen via infected crop residues. Teliospores or urediniospores may persist on crop residues until fully decomposed and the paddock should not be re-cropped to lentil, field pea, faba bean or vetch for at least three years.
- Any sources of infected field pea hay destroyed by burning or deep burial in a pit.
- The paddock may be cropped with cereals or oilseed crops for several years following the incursion and selective herbicides used to ensure the area remains free of lentil, field pea and other potential host plants.
- All vehicles and farm machinery that enter the infected field should be thoroughly washed, preferably using a detergent such as Decon 90.
- Any infected plant material or soil removed from the site should be incinerated, autoclaved or buried deeply (in a non-cropping area).
- Unless the pathogen is detected very early it is unlikely that the disease could be eradicated. It is able to produces large numbers of air-borne spores that can be carried large distances. The pathogen is also likely to be transported over long distances via the movement of infested seed and contaminated vehicles and machinery.

3.1.2 Decontamination protocols

If containment, eradication and/or best practice hygiene measures are implemented, machinery, equipment, vehicles in contact with infected plant material or soil or present within the Quarantine Area, should be washed to remove soil and plant material using high pressure water or scrubbing with products such as a farm degreaser or a 1% (available chlorine) bleach solution in a designated wash down area. General guidelines for wash down areas are as follows:

- Located away from crops or sensitive vegetation.
- Readily accessible with clear signage.
- Access to fresh water and power.
- Mud free, including entry and exit points, (e.g. gravel, concrete or rubber matting).
- Gently sloped to drain effluent away.
- Effluent must not enter water courses or water bodies.
- Allow adequate space to move larger vehicles.
- Away from hazards such as power lines.
- Waste water, soil or plant residues should be contained (see PLANTPLAN 2008 Appendix 18).
- Disposable overalls and rubber boots should be worn when handling infected soil or plant material in the field. Boots, clothes and shoes in contact with infected soil or plant material should be disinfected at the site or double-bagged to remove for cleaning.
- Skin and hair in contact with infested plant material or soil should be washed.

3.1.3 Priorities

Specific priorities for eradication:

- Confirm the presence of the pathogen.
- Prevent movement of vehicles and equipment through affected areas.
- Determine the extent of infection through survey and seed/hay/trash trace back.
- Priority of eradication/decontamination of infected host material.
- Inform all groups in the industry.
- Stop the movement of any seed that may be infected with *U.pisi* or *U. viciae-fabae*.

3.1.4 Plants, by-products and waste processing

- Seed harvested from infected plants and any infected soil or plant material removed from the paddock should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial (in a non-cropping area).
- Destruction of crops with herbicide is not suitable as the spores of the rust pathogen can still persist and be released from dead host plant tissue.
- Crops or stubble should be destroyed by burning and deep ploughing.
- Infested paddocks should remain free of host plants for at least three years.

3.1.5 Disposal issues

- Once introduced and established, lentil and field pea rust can be difficult to eradicate due to dispersal of air-borne spores.
- Particular care must be taken to minimize the transfer of infected trash from the area.
- Raking and burning infected crops is not an option as this procedure is likely to spread the pathogen greater distances during the raking phase.

3.2 Quarantine and movement controls

3.2.1 Quarantine priorities

- Plant material and soil at the site of infection to be subject to movement restrictions.
- Machinery, equipment, vehicles and disposable equipment in contact with infected plant material or soil to be subject to movement restrictions.
- Harvesting of rust infected crops should be prevented as the dust created during harvesting can spread the disease to neighbouring areas.
- Wind-borne inoculum can escape from rust infested crops; therefore the establishment of a quarantine area may be impractical.

3.2.2 Movement control for people, plant material and machinery

Once symptoms of rust are observed the pathogen is usually well established and eradication difficult. Therefore, any zoning, quarantine or movement controls will usually pertain to containment and management.

If Restricted or Quarantine Areas are practical, movement of equipment or machinery should be restricted and movement into the Area only occurs by permit. The industry affected will need to be informed of the location and extent of the disease occurrence.

Movement of people, vehicle and machinery, to and from affected farms, must be controlled to ensure that infected soil or plant debris is not moved off-farm on clothing, footwear, vehicles or machinery.

Examples of movement controls include:

- Signage to indicate quarantine area and/or restricted movement in these zones.
- Fenced, barricaded or locked entry to quarantine areas.
- Movement of equipment, machinery, plant material or soil by permit only.
- Clothing and footwear worn at the infected site should either be double-bagged prior to removal for decontamination or should not leave the farm until thoroughly disinfected, washed and cleaned.
- All machinery and equipment should be thoroughly cleaned down with a pressure cleaner prior to leaving the affected farm. The clean down procedure should be carried out on a hard surface, preferably a designated wash-down area, to avoid mud being recollected from the affected site onto the machine.
- Seed from the affected site should not be used for planting new crops, feeding stock or for human consumption. Hay, stubble or trash should not be removed from the site.

3.3 Zoning

The size of each quarantine area will be determined by a number of factors, including the location of the incursion, biology of the pest, climatic conditions and the proximity of the infected property to other infected properties.

3.3.1 Destruction zone

Destruction Zone may be defined as contiguous areas associated with the same management practices as the infected area (i.e. the entire trial, paddock or farm if spread could have occurred prior to the infection being identified).

The entire crop should be destroyed after the level of infection has been established. The delimiting survey will determine whether or not neighbouring host crops are infected and need to be destroyed.

The Destruction Zone will usually be the entire crop but may be the entire farm or contiguous areas of management if spread is likely to have occurred prior to detection.

The movement of air-borne inoculum to adjacent host crops will be likely; they will also need to be destroyed.

Particular care needs to be taken to ensure that soils and plant material are not moved into surrounding areas not showing symptoms of disease. Spores of the rust fungi will be readily disturbed with human and machinery movement, and movement should be minimised.

3.3.2 Quarantine zone

The Quarantine Zone is defined as the area where voluntary or compulsory restraints are in place for the affected property(ies). These restraints may include restrictions or movement control for removal of plants, people, soil or contaminated equipment from an infected property.

3.3.3 Buffer zone

A Buffer Zone may or may not be required depending on the incident. It is defined as the area in which the pest does not occur but where movement controls or restrictions for removal of plants, people, soil or equipment from this area are still deemed necessary. The Buffer Zone may enclose an infested area (and is therefore part of the Control Area) or may be adjacent to an infested area.

3.3.4 Restricted Area

The Restricted Area is defined as the zone immediately around the infected premises and suspected infected premises. The Restricted Area is established following initial surveys that confirm the presence of the pest. The Restricted Area will be subject to intense surveillance and movement control with movement out of the Restricted Area to be prohibited and movement into the Restricted Area to occur by permit only. Multiple Restricted Areas may be required within a Control Area.

3.3.5 Control Area

The Control Area is defined as all areas affected within the incursion. The Control Area comprises the Restricted Area, all infected premises and all suspected infected premises and will be defined as the minimum area necessary to prevent spread of the pest from the Quarantine Zone. The Control Area will also be used to regulate movement of all susceptible plant species to allow trace back, trace forward and epidemiological studies to be completed.

3.4 Decontamination and farm clean up

Decontaminant practices are aimed at eliminating the pathogen thus preventing its spread to other areas.

3.4.1 Decontamination procedures

General guidelines for decontamination and clean up

- Refer to PLANTPLAN (Plant Health Australia 2008) for further information.
- Keep traffic out of affected area and minimize it in adjacent areas.

- Adopt best-practice farm hygiene procedures to retard the spread of the pathogen between fields and adjacent farms.
- In additional to aerial dispersal, spores of the rust fungi can be transmitted by vehicle, machinery, human and stock movement.
- Machinery, equipment, vehicles in contact with infected plant material or soil or present within the Quarantine Area, should be washed to remove soil and plant material using high pressure water or scrubbing with products such as a detergent, farm degreaser or a 1% (available chlorine) bleach solution in a designated wash down area as described in 3.1.2.
- Only recommended materials should be used when conducting decontamination procedures, and should be applied according to the product label.
- Plant material should be destroyed by incineration or burial.

3.4.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each MSDS.

3.5 Surveillance and tracing

3.5.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pathogen retain market access and appropriate quarantine zones are established.

Initial surveillance priorities include the following:

- Surveying all properties in the quarantine area with known hosts.
- Surveying all properties identified in trace-back and trace-forward analysis as being at risk.
- Surveying all host growing properties that are reliant on trade with interstate or international markets which may be sensitive to lentil and field pea rust.
- Surveying commercial grain traders that may have held contaminated seed.

3.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 3.3), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these regions will either allow for the area to be declared pest free and maintain market access requirements or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out.

Steps outlined in Table 1 form a basis for a survey plan. Although categorised in stages, some stages may be undertaken concurrently based on available skill sets, resources and priorities.

Table 1. *Phases to be covered in a survey plan*

Phase 1	• Identify properties that fall within the buffer zone around the infested premise • Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action)
Phase 2	• Preliminary survey of host crops in properties in buffer zone establishing points of pest detection
Phase 3	• Surveillance of an intensive nature, to support control and containment activities around points of pest detection
Phase 4	• Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the disease. Pathways to be considered are: o Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment o The producer and retailer of infected material if this is suspected to be the source of the outbreak o Labour and other personnel that have moved from infected, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers) o Movement of plant material and soil from controlled and restricted areas o Storm and rain events and the direction of prevailing winds that result in air-born dispersal of the pathogen during these weather events
Phase 5	• Surveillance of nurseries, gardens and public land where plants known to be hosts of pathogen are being grown
Phase 6	• Agreed area freedom maintenance, pest control and containment

3.5.3 Post-eradication surveillance

Specific methods to confirm eradication of *U.pisi* or *U. viciae-fabae* may include:

- Monitoring of sentinel plants.
    - Sentinel plants are to be grown in pots or small plots at the affected site. Plants are to be grown *in situ* under quarantine conditions and monitored for symptoms of infection.
    - If symptoms are detected, samples are to be collected and stored and plants destroyed.
- Surveys comprising host plant sampling for *U. pisi* or *U. viciae-fabae* should be undertaken for a minimum of three years after eradication has been achieved.
- Alternate non-host crops should be grown on the site and any self-sown plants sprayed out with a selective herbicide.

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5 Appendices

Appendix 1. Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia"s PLANTPLAN (**www.planthealthaustralia.com.au/plantplan**).

Appendix 2. Experts, resources and facilities

The following tables provide lists of experts (Table 2) and diagnostic facilities (Table 3) for use in professional diagnosis and advisory services in the case of an incursion.

Table 2. *Experts who can be contacted for professional diagnostic and advisory services*

Expert	State	Details
Kurt Lindbeck	NSW	NSW Department of Primary Industries Wagga Wagga Agricultural Institute Private Bag Pine Gully Road Wagga Wagga NSW 2650 Ph: 02 6938 1999; Fax: 02 6938 1809
Joop van Leur	NSW	NSW Department of Primary Industries Tamworth Centre for Crop Improvement 4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222

Table 3. *Diagnostic service facilities in Australia*

Facility	State	Details
The University of Melbourne BioMarka	Vic	Faculty of Land and Food Resources The University of Melbourne VIC 3010 Ph: (03) 8344 9753; Fax: (03) 8344 9753
DPI Victoria Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222; Fax: (03) 9800 3521
DPI Victoria Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
DPI New South Wales Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809

Facility	State	Details
SARDI Plant Research Centre - Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae SA 5064 Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

Appendix 3. Communications strategy

A general Communications Strategy is provided in Appendix 6 of PLANTPLAN (2008, Version 1).

Appendix 4. Market access impacts

Within the AQIS PHYTO database, no countries appear to have a specific statement regarding area freedom from field pea (*U. pisi, U. viciae-fabae*) or lentil rusts (*U. viciae-fabae)* (January 2009). Should these field pea or lentil rusts be detected or become established in Australia, some countries may require specific declarations. Latest information can be found within PHYTO (**www.aqis.gov.au/phyo**), using an Advanced search “Search all text” for species names.