INDUSTRY BIOSECURITY PLAN

FOR THE GRAINS INDUSTRY

Threat Specific Contingency Plan

Russian wheat aphid

Diuraphis noxia

Prepared by

Plant Health Australia

August 2012

Plant Health Australia
Grains Research & Development Corporation
CRC PLANT biosecurity

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1 Purpose and background 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 Russian wheat aphid (RWA; *Diuraphis noxia*). It provides guidelines and options for steps to be undertaken and considered when developing a Response Plan for incursion of RWA. 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.

The information for this plan has been primarily obtained from documents as cited in the reference section as well as from an earlier version of this contingency plan developed for Plant Health Australia (PHA) in 2005 by O Edwards and S Miguiand, and a Pest Datasheet/Pest Risk Review developed for PHA in 2008 by M Moir, A Szito, J Botha and M Grimm. Information on background, life cycle, host range, distribution and symptoms of RWA are given, but the emphasis of this document on the response options in the event of an incursion in Australia.

2 Australian grains industry

The grains industry is the largest plant industry in Australia and grain crops are grown in all states and territories. The grains industry is primarily situated in a narrow crescent running through the mainland states, known as the grain belt. This area stretches from central Queensland, through New South Wales, Victoria and southern South Australia. In Western Australia, the grain belt covers the south-west corner of the state. Wheat (Figure 1) and barley (Figure 2) production take place in similar areas all over the grain belt, with wheat being the most widely planted crop.

In 2010-2011, over 50 million tonnes of grain was produced in Australia with a gross value of approximately $11 billion. On average wheat is grown on 12.9 million hectares each year (ABARES 2011) making it Australia's most widely planted crop. Barley is Australia's second most important crop (after wheat) and the average area planted in the last five years was approximately 4.5 million hectares and Australia's 2011 barley production is expected to be 9.3 million tonnes (ABARES 2011).

The Australian grains industry encompasses 25 leviable crops, though RWA is predominantly a threat only to barley and wheat crops. Rye and triticale are moderately resistant, and oats is resistant, but all three act as a harbour and a food source for the aphid (i.e. they are non-symptomatic) and should be considered as hosts for the purpose of eradication preparedness.

Due to Australia's relatively small population and domestic demand, export markets are essential for the viability of Australian grain farms and as a result, Australia is one of the world's largest grain exporters (Table 1). Therefore, maintaining our current pest status through effective biosecurity measures is essential in retaining access to markets and the resulting viability of the industry.

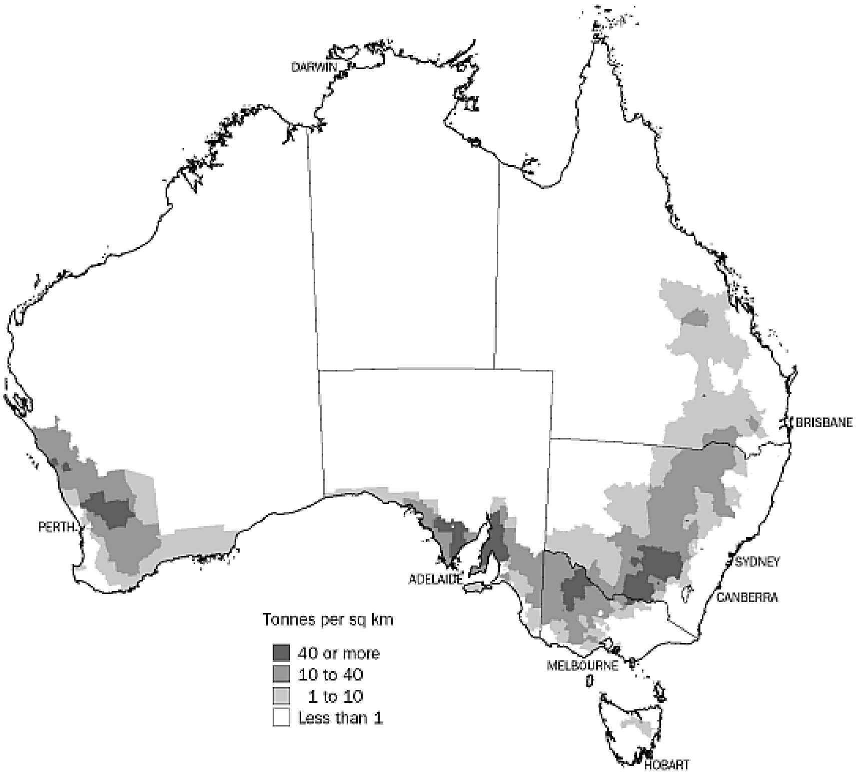

Figure 1. *Wheat producing regions in Australia (Source ABS 2007)*

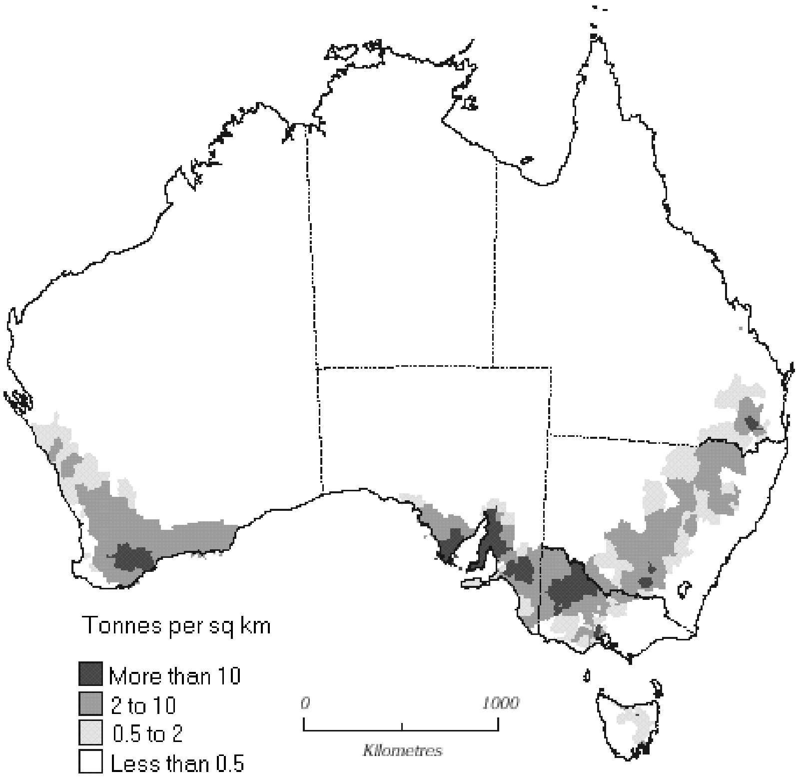

Figure 2. *Barley producing regions in Australia (Source: ABS 2003)*

Table 1. *Top grain exporting countries in the world (Source: ABARES, 2010)*

Country	Wheat exported 2009-2010 (million tonnes)	Barley exports 2009-2010 (million tonnes)
United States of America	23.5	0.01
European Union	22.8	1.1
Canada	17.8	1.3
Russia	18.7	2.7
Australia	13.7	4.5
Ukraine	9.3	6.2
Kazakhstan	8.0	No data
Argentina	4.5	No data
Turkey	4.0	No data
China	0.04	No data

2.1 Notification process for the reporting of suspect pests

Early detection and reporting may prevent or minimise the long-term impact of an incursion into Australia of RWA. The notification process is described in Figure 3.

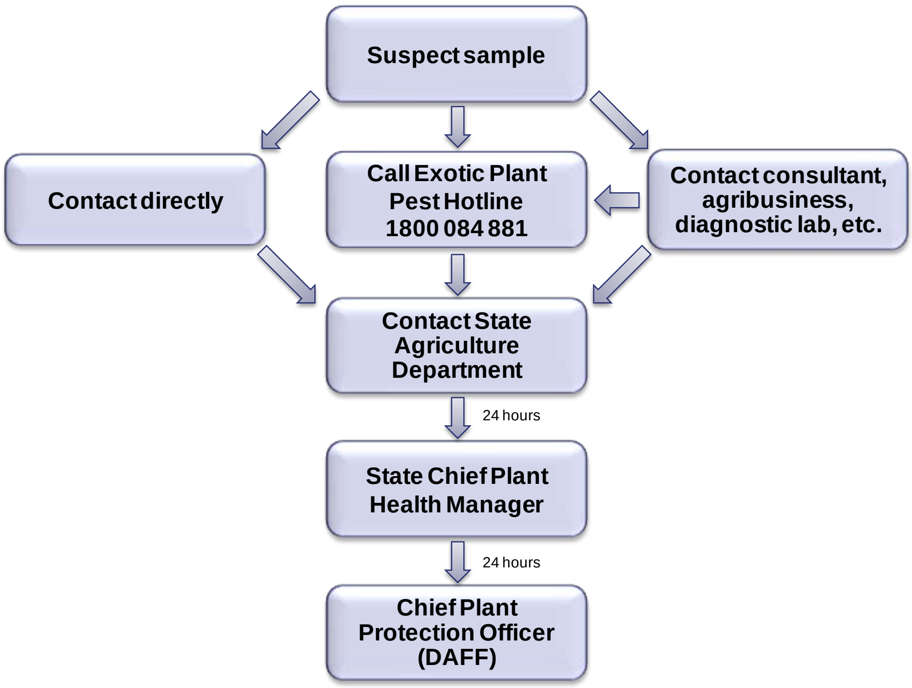

Figure 3. *Notification process for the reporting of suspect pests*

3 Eradication or containment decision matrix

The decision to eradicate should be based on the potential economic impact of host damage resulting from RWA, the cost of eradication and technical feasibility. Eradication costs must factor in long term surveys to prove the success of the eradication program. A minimum of 3 years with no detection of RWA may be necessary before pest free status can be declared.

No specific eradication matrix has been determined for RWA, however the general decision process as outlined in Figure 4 and Table 2 should be followed in determining if an incursion of this pest will result in eradication or management/containment. The final decision between eradication and management will be made through the National Management Group.

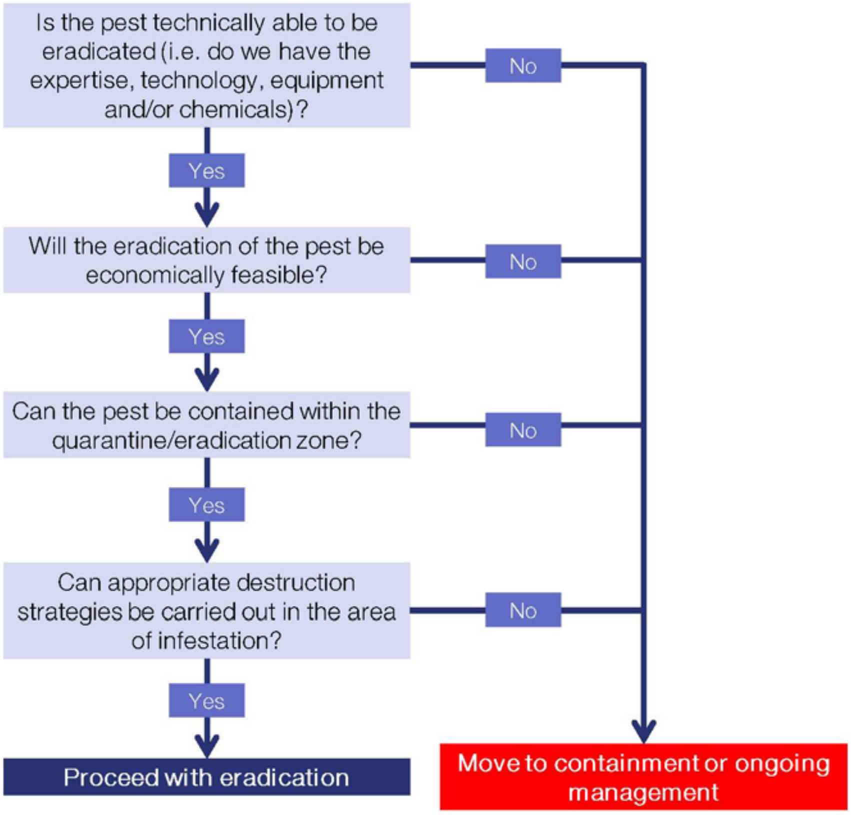

Figure 4. *Decision outline for the response to an exotic pest incursion*

Table 2. *Factors considered in determining whether eradication or alternative action will be taken for an Emergency Plant Pest (EPP) Incident (taken from Table 2; Section 4.16 of PLANTPLAN)*

Factors favouring eradication	Factors favouring alternative action
• Cost/benefit analysis shows significant economic loss to industry or the community if the organism established.	• Cost/benefit analysis shows relatively low economic or environmental impact if the organism establishes.
• Physical barriers and/or discontinuity of host between production districts.	• Major areas of continuous production of host plants.
• The generation time, population dynamics and dispersal of the organism favour more restricted spread and distribution.	• Short generation times, potential for rapid population growth and long distance dispersal lead to rapid establishment and spread.
• Vectors discontinuous in distribution and can be effectively controlled.	• Vectors unknown, continuous in distribution or difficult to control.
• Outbreaks few and confined.	• Outbreaks numerous and widely dispersed.
• Trace back information indicates few opportunities for secondary spread.	• Trace back information indicates extensive opportunities for secondary spread.
• Weather records show unfavourable conditions for pest development.	• Weather records show optimum conditions for pest development.
• Ease of access to outbreak site and location of alternate hosts.	• Terrain difficult and/or problems accessing and locating host plants.
• Pathways for reintroduction from international trade closed.	• Pathways for reintroduction from international trade open.

4 Pest information/status

4.1 Pest details

Scientific name	*Diuraphis noxia*
Synonyms	*Brachycolus noxia; Brachycolus noxius; Brachysiphoniella noxius; Cavahyalopterus graminearium; Cavahyalopterus noxius; Cuernavaca noxia; Cuernavaca noxius; Diuraphis noxius; Holcaphis noxius; Quernavaea noxia*
Common names	Russian wheat aphid ; Barley aphid; Russian grain aphid; Toxic wheat aphid
Taxonomic position	Kingdom: Animalia; Phylum: Arthropoda; Class: Insecta; Order: Hemiptera; Family: Aphididae; Subfamily: Aphidinae

4.1.1 General information

Diuraphis noxia is an aphid that affects cereal crops throughout the world, primarily barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*) (Miller *et al.* 2001). RWA is indigenous to central Asia and southern Russia. It was first reported as a pest in 1901 (Tolmay 2006), but it was considered minor until it was reported in South Africa in 1978 where it became a major pest of wheat (Robinson 1994). In the last 30 years it spread to other parts of the world including North and South America, reaching

Mexico in 1980 (Gilchrist *et al*. 1984), the USA in 1986 (Stoetzel 1987) and Chile in 1988 (Clua *et al*. 2004). Australia is one of the last major grain producing countries to remain free of the pest.

RWA is a small insect, 1.5–1.8 mm in length. The body is light green in colour, and an elongated spindle-shape (as opposed to more globular body of most aphids). They have short antennae (about one-quarter of body length), and a distinctive double-tailed (cauda) appearance when viewed from the side (Figure 5).They also lack the visible siphunculi (special tubes or pores in the abdomen of aphids for extruding waxy defensive fluids), which are present on other cereal aphids (Figure 6). This characteristic distinguishes RWA from other cereal aphids. Instars look similar to apterous adults but do not develop the characteristic caudal features until the fourth and fifth instars. This species also has alate (winged) adult morphs (Aalbersberg *et al.* 1987) (Figure 7).

RWA spend their entire life on cereals and grasses, and have the ability to reproduce both sexually and asexually. Yet, RWA is only known to reproduce sexually in Russia and central Asia, and male aphids have not been observed in many parts of the world (Tolmay 2006).

RWA feeding produces strong plant symptoms due to the injection of saliva into the plant during feeding. Symptoms include rolled leaves, chlorotic spots, leaf streaking, trapped awns giving a hooked appearance and a stunted appearance under heavy infestation.

Figure 5. *Wingless adult RWA, showing the presence of a "double tail" and no obvious siphunculi. Source Frank Peairs, Colorado State University, Bugwood.org*

Figure 6. *Oat aphid (Rhopalosiphum padi) showing siphunculi (darker brown parts protruding from abdomen) and single tail. Source SARDI.*

Figure 7. *Alate (winged) adult form of the RWA. Source Frank Peairs, Colorado State University, Bugwood.org*

4.1.2 Life cycle

RWA can complete its lifecycle through sexual or asexual reproduction. Sexual reproduction has been observed only in limited areas (e.g. Russia and central Asia), while in others RWA has only been observed completing the lifecycle through asexual reproduction (e.g. USA, South Africa and other countries outside the aphids native range). Sexual reproduction allows the aphids to overwinter as eggs, in contrast to areas where asexual reproduction occurs that requires the aphid to continue to feed over the winter period.

All invasive populations of RWA outside of its natural range are parthenogenetic (i.e. reproduce asexually). As a result, in most countries the RWA individuals are clones (although slight mutations can occur).

4.1.2.1 ASEXUAL REPRODUCTION OF RUSSIAN WHEAT APHIDS

Asexually reproducing populations of RWA are all female and adults give birth to live nymphs. After the fourth moult, aphids develop into either wingless (apterous) or winged (alate) adults. Wingless adults have a higher reproductive capacity and can produce 4-5 nymphs per day for a 3-4 week period. Reproduction rates increase as the temperature increases with generation times becoming shorter and more young produced by each female (Carver 2009). In general, maturation is completed within 7-10 days.

Reproduction continues to occur over winter, albeit at a reduced rate, with aphids remaining active and continuing to feed. During this period they are vulnerable to severe weather conditions, but Australia's wheat growing regions do not get cold enough to cause severe impacts, as RWA are known to survive at temperatures down to -25°C (Harvey and Martin 1988; Hodgson and Karren 2008; Michaud 2010).

4.1.2.2 SEXUAL REPRODUCTION OF RUSSIAN WHEAT APHIDS

In their native range, RWA are holocyclic, and therefore they can reproduce both sexually (usually for overwintering as eggs) and asexually (mostly during the warmer months). Where winter conditions are severe, RWA will over-winter as eggs. After mating, females lay 8-10 eggs on young cereal plants and die a few days afterwards. The eggs hatch in early spring and aphid population increases rapidly by parthenogenetic reproduction.

4.1.3 Dispersal

The RWA can be spread in a variety of ways including:

- On contaminated plant material.
- On machinery and other equipment.
    - Most likely to occur through the movement of eggs (in those areas where sexual reproduction occurs)
- Dispersal of winged adults over large distances by wind assisted flight. For example, it has been suggested that winds blew RWA to the USA from Mexico (Stoetzel 1987).

Contaminated plant material is the most likely pathway for the pest to enter the country, although wind assisted dispersal could occur if RWA becomes established in areas closer to Australia.

4.2 Affected hosts

4.2.1 Host range

4.2.1.1 PRIMARY HOSTS

Primary hosts for RWA support the entire life cycle and allow for reproduction to occur. All instars and adults can feed on these plants. The hosts that are most severely affected are barley (*Hordeum vulgare*) and wheat (*Triticum aestivum*). Other primary hosts include durum wheat (*Triticum durum*), field broom grass (*Bromus arvensis*), *Elymus* sp. and jointed goatgrass (*Triticum cylindricum*). See Section 9.5 Appendix 5 for a more complete list.

4.2.1.2 SECONDARY HOSTS

Secondary hosts are plants that only support adults and final instars. They allow the aphid to survive but not reproduce. This category also includes species on which the RWA has been observed but no further details are known.

Secondary hosts include cereal rye (*Secale cereale),* triticale (*Triticum aestivum x Secale cereale*) and various grasses in the Poaceae family, such as oats (*Avena satvia*), tall wheat grass (*Agropyron elongatum*) and Indian rice grass (*Oryzopsis hymenoides*). A full list is provided in Section 9.5 Appendix 5.

4.2.2 Geographic distribution

RWA is currently distributed in most wheat producing countries around the world (Table 3 and Figure 8). In general, RWA occurs in areas with low rainfall and has the ability to survive harsh winters.

Table 3. *Countries where RWA is known to occur*

Continent	Country
Asia	Afghanistan, China, Iran, Iraq Israel, Kazakhstan, Kyrgyzstan, Pakistan, Saudi Arabia, Syria, Turkey, Uzbekistan, Yemen
Europe	Bulgaria, Croatia, Czech Republic, France, Germany, Greece, Hungary, Italy, Macedonia, Moldova, Portugal, Russia, Slovakia, Spain, Ukraine, Yugoslavia,
Africa	Algeria, Egypt, Ethiopia, Kenya, Libya, Morocco, South Africa, Zimbabwe
North America	Canada, Mexico, USA
South America	Argentina, Chile

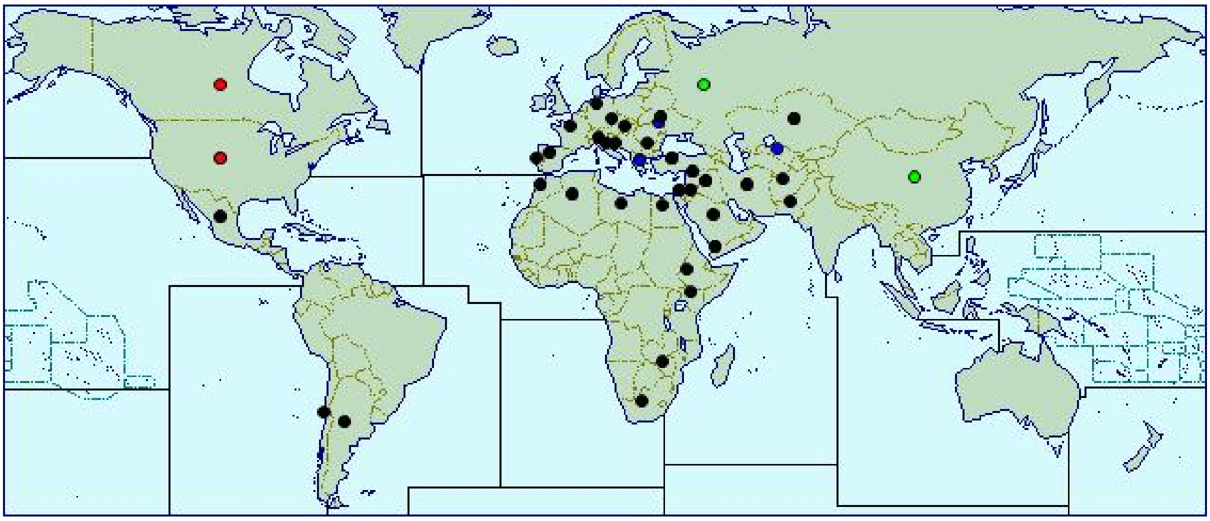

***Figure 8**. Distribution of RWA (dots mark countries where it is known to occur). Source: CAB International 2011*

4.2.3 Potential distribution in Australia

Should RWA enter and establish in Australia, it has the potential to establish throughout most of the wheat and barley producing areas of the country (Figure 9), based on known climatic requirements (Hughes and Maywald 1990).

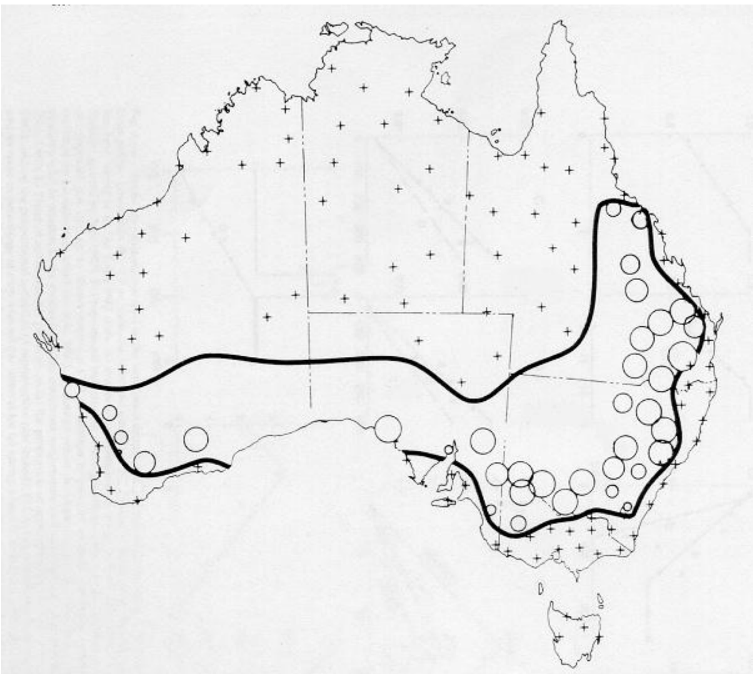

***Figure 9.** Potential distribution in Australia of the RWA in Australia based on the growth and stress parameters and resultant Ecoclimatic index in CLIMEX (Sutherst and Maywald, 1985) (Modified from: Hughes and Maywald 1990). Dot size represents suitability of climate and the wheat and barley production zone is outlined.*

4.2.4 Symptoms

4.2.4.1 SYMPTOMS OF RUSSIAN WHEAT APHID

RWAs feeding on cereals cause a range of symptoms, including:

- Rolled leaves. Feeding causes the leaves to roll along their length creating a hollow tube (similar to an onion leaf).
- Yellow, white and or purple streaks often occur along the length of the leaves of plants (Figure 10) as a result of toxic saliva being injected during feeding.
- Stunted crop growth (Figure 11).
- Wheat awns become trapped by the rolled leaves leading to miss-shapen growth. This often results in hook shaped growth and bleaching (Figure 12 and Figure 13).
- Reduced yields. There are reports of yield losses between 30-60% (Webster *et al.* 1987) and 92% (Robinson 1994).
- RWA can act as a vector for viruses, including Barley yellow dwarf virus and Barley stripe mosaic virus (Elsidaig and Zwer 1992; Kazemi *et al.* 2001).

Figure 10. *Colony of RWA. Note yellow and white streaks along the leaf surface. Source: Frank Peairs, Colorado State University, Bugwood.org*

Figure 11. *Symptoms on wheat. Note stunted growth, rolled and discoloured leaves. Source: Frank Peairs, Colorado State University, Bugwood.org*

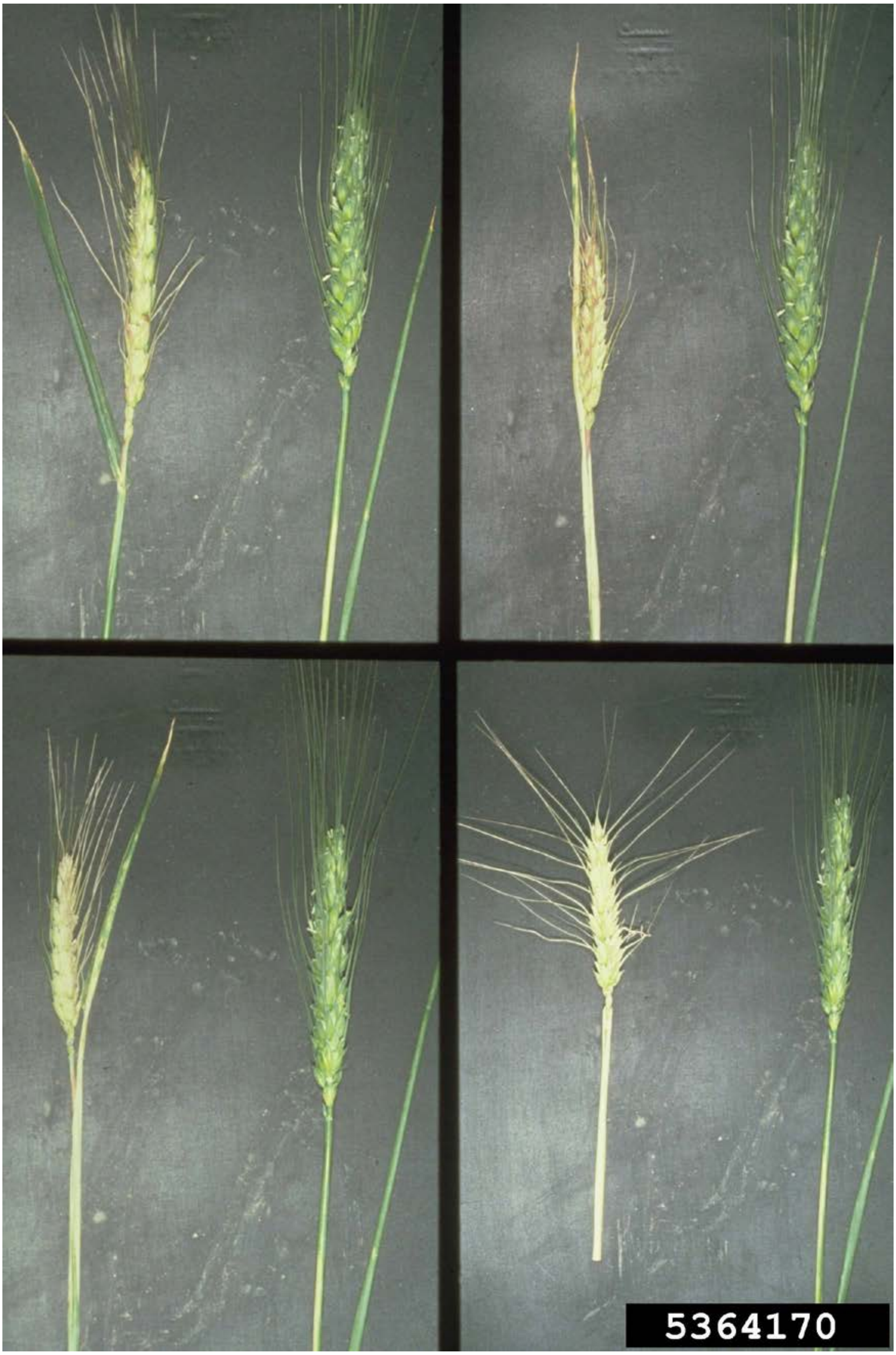

Figure 12. *Bleached awns (left) caused by RWA. Green awns (right) from healthy plant. Source Frank Peairs, Colorado State University, Bugwood.org*

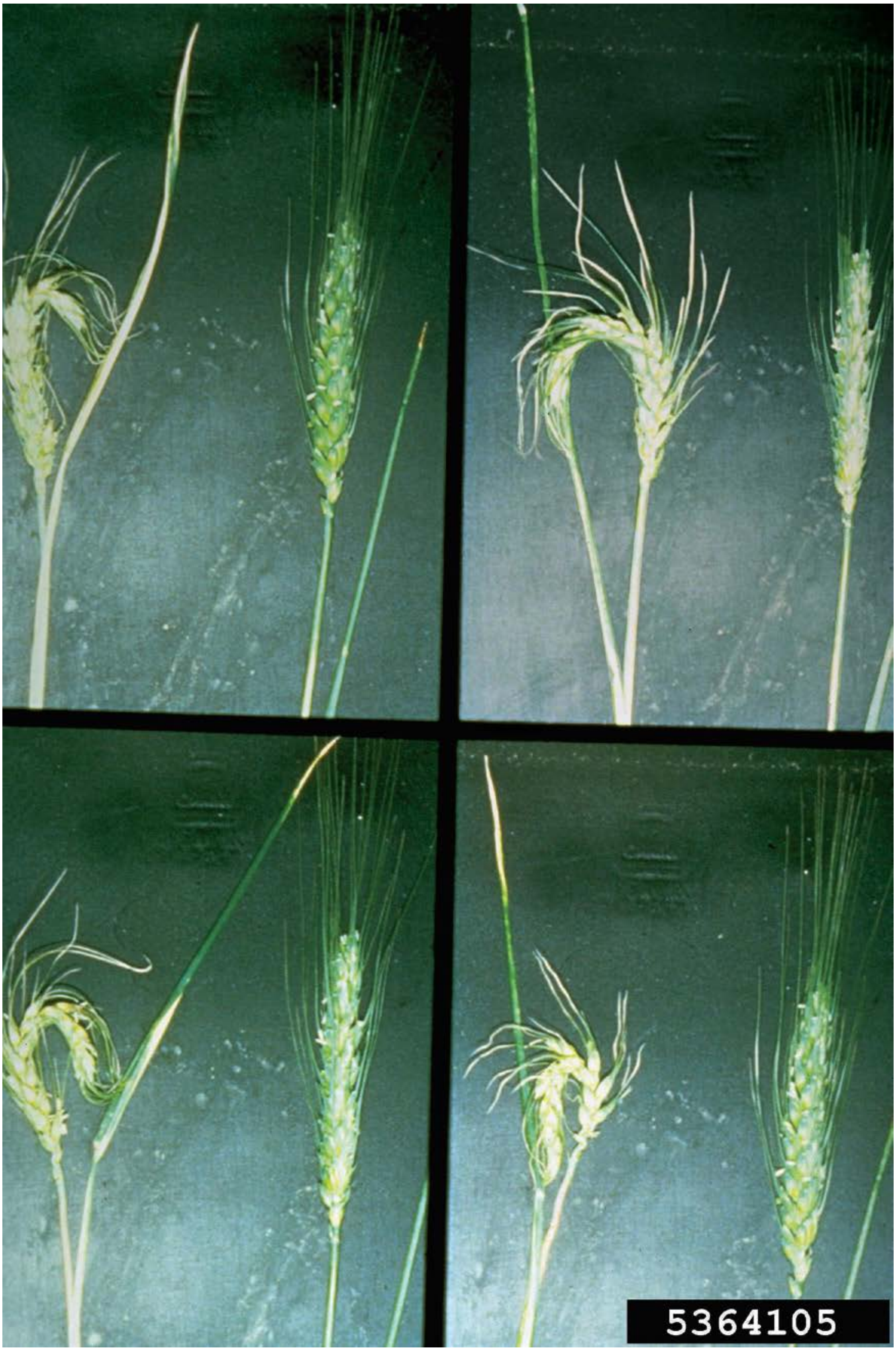

Figure 13. *Tapered, bleached and hook shaped awns (left) caused by RWA, with healthy awns on the right. Source Frank Peairs, Colorado State University, Bugwood.org*

4.3 Entry, establishment and spread

RWA is not known to be present in Australia. Within this contingency plan, a pest risk analysis has been carried out on this pest, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 4 with full descriptions provided below. Based on this information, RWA is considered to be a **High** overall risk to the Australian grain industry.

Table 4. *Pest risk ratings for RWA*

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	High
Environmental impact	Low
Overall risk	**High**

4.3.1 Entry potential

Rating: Medium

Long distance movement of RWA occurs through contaminated plant material, machinery, equipment and via wind assisted flight. Adults and nymphs do not survive long without access to a food source (living plants). As a result, eggs may be a more likely way for the RWA to enter the country, as they are very small and difficult to detect.

Grain imports are not likely to carry adult aphids, as there is no food source (growing leaf material) and they usually leave the crop before harvest. In addition, while eggs may be imported with grain imports, they are generally laid on leaves rather than the grains and therefore should not remain in the harvested grain.

Imported cereal hay is another possible, but low risk, pathway for entry. Hay is usually cut in spring, before eggs are laid, and hay is unlikely to serve as a suitable food source for adult aphids. Further, Australia does not import significant amounts of cereal hay from overseas.

Wind-assisted flight was the suspected pathway of RWA into Mexico from the USA (Stoetzel 1987), and provides a potential for entry into Australia. However, prevailing winds in Australia come from the west and it is unlikely that RWA can travel the distances from infected African countries, such as South Africa. Should RWA become established in countries closer to Australia, the likelihood of wind-borne entry would increase.

Based on this information the entry potential of RWA into Australia is considered as **Medium**.

4.3.2 Establishment potential

Rating: High

The majority of Australia's grain belt provides suitable climatic conditions and an abundance of host plant species to allow RWA to establish (see Section 4.2.3). RWA has also demonstrated an ability to spread rapidly and establish in quickly in new areas and countries. The short generation time and ability to produce large numbers of offspring suggests it can establish quickly in suitable environments.

Based on the aphids ability to reproduce and the suitability of Australia's climate the establishment potential of RWA in Australia is considered to be **High**.

4.3.3 Spread potential

Rating: High

RWA has a **High** spread potential because:

- The climate is suitable for the RWA (Hughes and Maywald 1990; see Figure 9).
- A wide distribution of host plants, providing an almost continuous breeding environment across Australia (see Figure 9)
- Previous examples of RWA rapidly spreading following establishment in other countries. For example RWA was found in Mexico in 1980 (Gilchrist *et al.* 1984) and six years later the USA (Stoetzel 1987; Clua *et al.* 2004) and within two years it had spread across western USA and into Canada (Shufran *et al.* 2007).
- The wide host range (see Section 9.5 Appendix 5), including non-crop species and volunteer plants.
- The ability to hitch-hike on vehicles and equipment.

Therefore the pest has a **High** potential to spread should it reach Australia and become established.

4.3.4 Economic impact

Rating: High

If RWA entered Australia it is likely to have a significant economic impact through lost markets, yield losses and additional control costs. There is also likely to be a need for increased surveillance to maintain area freedom status in some areas.

In other countries the economic impact of RWA depends largely on the suitability of the climate. For example, in Morocco during 1996 and 1997 the RWA infected 100% of barley fields at high altitudes (Lhaloui *et al.* 2000). Hughes and Maywald (1990) predicted that a 25-50% reduction in cereal crops could occur in Australia if the RWA became established.

As most major grain producing countries already have RWA there is unlikely to be market access restrictions placed internationally (see Section 9.4 Appendix 4), and therefore the major costs will be through loss of production and control methods.

This suggests that the economic impact it likely to be **High**.

4.3.5 Overall risk

Rating: High

The overall risk was calculated by combining the entry potential, establishment potential, spread potential and economic impact using the risk analysis framework applied in the Industry Biosecurity Plan. The overall risk of RWA to Australia is considered to be **High**.

5 Diagnostic information

5.1 Diagnostic protocol

RWA can be identified based on morphology alone, but there is also a molecular based test. Initial in field diagnosis generally utilises the host plant symptoms in conjunction with the presence of aphids.

For a series of guidelines for the diagnostic identification refer to the pest datasheet/ pest risk review of Moir et al (2008) and papers by Blackman and Eastop (2000) and Olsen et al (1993) for descriptions and key to assist identification of RWA. A key diagnostic feature is the double tailed appearance of *D. noxia* and the lack of obvious siphunculi, which is unlike other cereal aphids which have obvious siphunculi (see Figure 5 and Figure 6).

An expert with a good knowledge and understanding of aphids would be required to identify the pest. The identification may need to be confirmed by taxonomists overseas.

5.1.1 Molecular diagnosis

PCR tests can also be used to confirm a morphological diagnosis. Shufran and Payton (2009) used PCR techniques to look at the genetic variation that exists in the USA and these methods may be useful to identify aphids.

6 Pest management

6.1 Response checklist

The following checklist (Table 5) provides a summary of generic requirements to be identified and implemented within a Response Plan for an incursion of a new aphid transmitted virus into Australia.

Table 5. *Checklist of requirements to be identified in a Response Plan*

Checklist item	Further information
Destruction methods for plant material, soil and disposable items	Section 7.1.1
Disposal procedures	Section 7.1.5
Quarantine restrictions and movement controls	Section 7.3
Decontamination and property cleanup procedures	Section 7.5

Checklist item	Further information
Diagnostic protocols and laboratories	Section 5.1, 9.1
Protocols for delimiting, intensive and ongoing surveillance	Section 6.2, 7.6
Zoning	Section 7.4
Reporting and communication strategy	Section 9.3

A range of specifically designed procedures for the emergency response to a pest incursion and a general communication strategy refer to PLANTPLAN (Plant Health Australia 2013). Additional information is provided by Merriman and McKirdy (2005)[1] in the Technical Guidelines for Development of Pest Specific Response Plans.

6.2 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of the crop that are showing symptoms of the pest (Figure 10 to Figure 13) and careful examination of the plants may be required to detect the aphids. The normal procedure is to collect symptomatic plants and to get a laboratory, or suitably qualified person, to examine the plant and confirm the presence of RWA. 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.

Trace-back of machinery and personnel will indicate how many properties will need to be tested. Because the RWA is able to be wind dispersed, properties downwind of infected properties will also need to be checked. Delimiting surveys should be conducted at each site to determine the distribution of the pest.

6.2.1 Sampling method

Once initial samples have been received and preliminary diagnosis made, follow up samples to confirm identification of the pest will be necessary. Ideally this will involve sampling directly from the infested crop, and sampling crops over a larger area to determine the extent of pest distribution. A system of sample identification should be 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.

Samples should be initially collected over a representative area of the infected crop to determine the pest distribution. All personnel involved in crop sampling and inspections must take precautions to minimise the risk of spread between crops by decontaminating between paddocks.

Any personnel collecting samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis. General protocols for collecting and dispatching samples are provided in the Standard Operating Procedure (SOP) for *Collection and transport of Emergency Plant Pests (EPPs)* available as a supporting document of

[1] Available on the PHA website (**www.planthealthaustralia.com.au/biosecurity/risk-mitigation**)

PLANTPLAN (Plant Health Australia, 2013) (**www.planthealthaustralia.com.au/wp-content/uploads/2013/12/SOP-Collection-and-transport-of-EPPs.pdf**)

All plants should be assessed for the presence of the RWA symptoms with symptoms varying depending on the stage of infection (see Section 4.2.4 for full details and further information from Moir *et al.* 2008 and Edwards and Miguiand 2005).

Samples should be initially collected over a representative area of the infected crop to determine the pest distribution. It is important to note the distribution of pest in the initial crop, as this may indicate how the pest entered, for example, whether it was carried on trash from adjacent paddocks, originated from contaminated machinery or human movement or flight.

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.

All diagnoses of suspected exotic and emergency pests 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.
- Where possible diagnosis is confirmed by a second method.

6.2.1.1 HOW TO COLLECT SAMPLES

Consult with the laboratory on the appropriate methodologies for the collection of, and the later dispatch of samples for identification purposes.

Samples can be collected from plants showing symptoms, or by the use of suction traps, yellow pan traps and sticky traps (Robert *et al.* 1988; French and Taylor 1965). However wingless adults and nymphs will be only rarely captured in suction, yellow pan or sticky traps. Therefore sampling plants is the preferred way of collecting aphid samples.

Samples should be treated in a manner that allows them to arrive at the laboratory in a well-preserved state. An esky with ice packs or portable fridge should be carried when sampling crops. Leaf samples should be wrapped in damp newspaper, bundled into a plastic bag and clearly labelled. For appropriate labelling and packaging procedures for suspect EPPs consult PLANTPLAN (Plant Health Australia, 2013).

6.2.1.2 COLLECTION, KILLING AND PRESERVATION

- For detailed methodologies see Moir et al (2008).
- Live adults, nymphs or eggs must not be transported, unless essential for diagnosis and directed by the diagnostic facility. Any transport of specimens must use approved biosecure packaging and opened only in an approved containment facilities (see PLANTPLAN (Plant Health Australia, 2013) for further details).
- Specimens for morphological analysis should be killed by standard methods (Moir et al 2008).
- Usually identification requires material of wingless adults. Specimens for DNA analysis should be collected directly into absolute ethanol (adults or larvae).

6.2.2 Epidemiological study

There are many factors that affect the development of RWA in the field. These include the susceptibility of the crop varieties and climatic conditions. The number of infested plants within a crop will depend on the population of aphids and whether environmental conditions have been favourable for the pest 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 transport of hay or straw (especially from cereals and other hosts) onto or off the infested property.
- The proximity of host crops to the initial infected crop, both in the current growing season and previous season. Alternate host crops should also be considered as these crops can also harbour the pest in some instances. This will include the growers own crops, crops on neighbouring properties and feral plants (e.g. wheat plants growing on roadsides, volunteer plants in crops etc.).
- Machinery or vehicle movements (e.g. have contractors been employed recently). Especially the possible movement of contaminated plant material or soil on machinery.
- 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.
- Direction of the prevailing wind as winged adults can be blown to new areas by the wind.

6.2.3 Models of spread potential

There are a number of mechanisms of RWA spread, including wind assisted flight (which is thought to have spread RWA from Mexico to the USA (Stoetzel 1987)) and human assisted movement (probably responsible for the entry of RWA in to South Africa). However, there are no specific models of spread potential for RWA.

6.2.4 Pest Free Area guidelines

Determination of Pest Free Areas (PFAs) should be completed in accordance with the International Standards for Phytosanitary Measures (ISPMs) 8 and 10 (IPPC 1998a, 1999).The establishment and maintenance of PFAs would be a resource-intensive process. Prior to development of a PFA consideration should be given to alternative methods (e.g. treatments or enclosed quarantine) that achieve an equivalent biosecurity outcome to a PFA. A benefit-cost analysis is useful for this purpose.

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 PFAs as a risk management option for phytosanitary certification of plants and plant products. Establishment and maintenance of a PFA can vary according 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).

Points to consider are:

- Design of a statistical delimiting field survey for symptoms on host plants (See 6.2.1 for points to consider in the design).

- Plant sampling should be based on at least 100 plants taken at random per crop. The exact number will depend on a number of factors including how accurate the detection of the pest needs to be (i.e. the confidence interval required).
- Preliminary diagnosis can be based on the plants symptoms and must be followed up with diagnosis based on the morphology of the aphids.
- Surveys should also consider alternative host plants (see Section 4.2.1 and Section 9.5 Appendix 5).

6.3 Availability of control methods

6.3.1 General procedures for control

- Keep traffic out of affected areas and minimise movement in adjacent areas.
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.
- After surveys are completed, destruction of the infected crops may be required to eradicate the pest.
- On-going surveillance of infected paddocks to ensure the pest is eradicated.

6.3.2 Control if small areas are affected

If RWA is detected in a small area it may be controlled by spraying with a suitable pesticide (see Section 6.3.6). Particular care must be taken to minimize the transfer of infested material from the area.

6.3.3 Control if large areas are affected

Using suitable pesticides (see Section 6.3.6) on the affected and surrounding paddocks is the preferred control option. Pesticides, especially those with a fast knockdown, are preferred as such chemicals may be able to suppress the infestation before it can spread to new areas.

All equipment used on the site should be thoroughly cleaned down, with products such as a farm degreaser or a 1% bleach solution and washed down with a pressure cleaner on the affected farm. The clean down procedure should be carried out on hard standing or preferably a designated wash-down area to avoid mud being recollected from the affected site onto the machine.

6.3.4 Cultural control

Cultural control methods can be very effective at controlling and reducing the spread of RWA should it enter the country. There are a number of cultural control options. These include:

- The use of RWA resistant cultivars (see Section 6.3.5).
- Crop rotations that alternate between host and non-host species or do not include a susceptible summer crop (i.e. the paddock may be planted with a non-host crop such as

cotton (*Gossypium hirsutum*) or left fallow over summer) will be useful to stop the aphid populations from being able to survive on one paddock for years.

- Removal of host plants removes the aphids food source, and if the population is pathogenic, RWA will not be able to over-winter as eggs.
- Changing the time of planting can reduce the severity of RWA impact (Smith *et al.* 2004; Hammon *et al.* 1996).

6.3.5 Host plant resistance

The use of resistant crop cultivars is a method for control of RWA. Most resistant varieties available still act as a food source but show little to no reduction in yields. Several resistant wheat varieties exist from Russia and Iran and were used successfully in South Africa (Robinson 1994).

A substantial amount of research on controlling RWA by developing resistant varieties of cereal crop plants has been undertaken (Webster *et al.* 1987; Al-Ayied 2004; Lage and Skovmand 2004; Smith 2004; Basky 2004). Resistant varieties of wheat have received the majority of the attention as a number of RWA resistance genes are known, such as *Dn1* to *Dn9* and *Dnx* (Liu *et al.* 2005). Some, such as *Dn1*, were discovered in wheat while others, such as *Dn7*, were discovered in other species and transferred to wheat (Liu *et al.* 2005).

Work is also being carried out on finding RWA resistance in barley (Kindler and Springer 1990; Webster *et al.* 1991; Nieto-Lopaz and Blake 1993; Puterka *et al.* 2006). Similarly the International Maize and Wheat Improvement Centre (CIMMYT) carried out research to find resistant triticale and rye varieties (Robinson 1994).

Given that there are different biotypes of RWA (Basky *et al.* 2001), crops may not be resistant to all biotypes (Puterka *et al.* 2006). This highlights the necessity of trials to identify the varieties resistant to the biotype(s) present in an area.

6.3.6 Chemical control

Applications of pesticides can also help to control RWA although their habit of living in rolled leaves can make it difficult for chemicals to reach the aphids. Both foliar and seed treatments have had some success. Foliar treatments are often used, although Imidacloprid has potential as a seed treatment to control RWA in wheat (Pike *et al.* 1993). Applying a combination of Disulfuton and Phorate with a liquid fertilizer at planting time also demonstrated control of RWA (Armstrong *et al.* 1993).

Table 6 details some of the chemical control options that have shown some success in controlling RWA overseas. These chemicals would need to be approved by the Australian Pesticides and Veterinary Medicines Authority (APVMA) before they can be used to control RWA in Australia. Some chemicals (for example Carbofuran) are under review by the APVMA as they may pose human health issues (APVMA 2009). Similarly Parathion-methyl will be removed from the market in July 2013 (APVMA 2011).

Table 6. *Some of the chemical controls for RWA used overseas*

Chemical	Reference
Acephate[2]	Bayoun *et al.* (1995), Riedell *et al.* (2007)
Parathion-methyl[3]	Flickinger *et al.* (1991)
Malathion	Girma *et al.* (1993)
Imidacloprid[4]	Pike *et al.* (1993); Robinson (1994)
Thiamethoxam[4]	Tolmay (2006)
Dimethoate	Hill *et al.* (1993); Bregitzer *et al.* (2003) ; Tolmay 2006
Disulfoton[5]	Armstrong *et al.* (1993)
Phorate[5]	Armstrong *et al*. (1993)
Carbofuran[5 6]	Armstrong *et al.* (1993)
Demeton-S-methyl[7]	Tolmay (2006)
Chlorpyrifos[8]	Brewer and Kaltenbach (1995); Hammon *et al.* (1996); Hill *et al.* (1993)
Furadan	Hammon *et al.* (1998); Armstrong *et al.* (1993)

6.3.7 Mechanical control

Mechanical controls for the eradication of the RWA should be used in conjunction with other control actions, such as restricting the use of host plants in crop rotations, application of suitable pesticides and possibly the use of biological controls. Crop destruction removes food sources of the pest, but the movement potential of the winged adults may make this approach ineffective.

6.3.8 Biological control

There is a number of biological control approaches used against RWA in countries currently impacted by this pest. The predominant biological controls for RWA are other insects, such as hoverflies, lacewings and ladybirds (Carver 1989; Bernal *et al.* 1993; Hughes *et al.* 1994). However, fungi have also shown the potential as a biological control agent for RWA (Hatting *et al.* 1999).

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[2] Bayoun *et al.* (1995) suggests that Acephate is highly toxic to Russian wheat Aphids but not to the aphid's parasites and predators, making this chemical very useful as part of an control regime

[3] Flickinger *et al.* (1991) found that Parathion methyl caused the death of a number of Canada geese (*Branta canadensis*). Consideration should be given to the impact that this chemical has on native fauna before it is widely used. Recently APVMA stated that Parathion-methyl will be removed from the market in July 2013 (APVMA 2011)

[4] Seed treatment

[5] Applied at sowing directly into rip lines

[6] APVMA is reviewing this chemical due to human health concerns (APVMA 2009)

[7] No Demeton-S-methyl chemicals have been registered in Australia since 1998 and APVMA has concerns about the human health impacts of the chemical

[8] Hill *et al.* (1993) suggested that this chemical doesn't provide any sort of long term protection but may be useful as a knock down treatment.

There may also be a requirement to use a suite of biological control agents to achieve effective reductions in RWA populations. For example, twenty four different exotic species of predators and parasites were released in Texas to control the RWA (Michels *et al.* 1994).

Exotic parasitoids of aphids have already been released in Australia and have successfully controlled other aphid pests (Carver 1989). A parasitoid wasp, *Aphelinus varipes,* has previously been released into Australia as a pre-emptive measure against RWA (Hughes *et al.* 1994), but there is currently no evidence that *A. varipes* became established.

Table 7. *Biological control agents used to control RWA overseas*

Species	Common name/description	Reference
Adalia bipunctata	Ladybird	Robinson (1994)
Allograpta exotica	Hover fly	Robinson (1994)
Allograpta obliqua	Hover fly	Robinson (1994)
Alloxysta fascicornis	Hyper parasitoid Parasitic wasp	Robinson (1994)
Aphelinus albipodus	Parasitoid wasp	Brewer *et al.* (1999)
Aphelinus asychis	Parasitoid wasp	Michels and Whitaker-Deerberg (1993); Brewer *et al.* (1999)
Aphelinus hordei	Parasitoid wasp	Zhu *et al.* (2000)
Aphelinus sp.	Parasitoid wasp	Robinson (1994)
Aphelinus varipes	Parasitoid wasp	Hughes *et al.* (1994)
Aphidiines.	Parasitic wasp	Robinson (1994)
Aphidius colemani	Parasitoid wasp	Zhu *et al.* (2000)
Aphidius ervi	Parasitic wasp	Robinson (1994)
Aprostocetus sp.	Parasitic wasp	Robinson (1994)
Asaphes sp.	Parasitic wasp	Robinson (1994)
Beauveria bassiana	Fungus	Vandenberg *et al.* (2001)
Chrysopa carnea	Lacewing	Robinson (1994)
Chrysoperla plorabunda	Lacewing	Messina and Sorenson (2001); and Messina *et al.* (1997)
Coccinella californica	Ladybird	Bernal *et al.* (1993)
Coccinella nugatoria	Ladybird	Robinson (1994)
Conidiobolus sp.	Fungus	Hatting *et al.* (1999)
Cycloneda sanguinea	Ladybird	Robinson (1994)
Dendrocerus sp.	Parasitic wasp	Robinson (1994)
Diaeretiella rapae	Parasitic wasp	Robinson (1994); Wraight *et al.* (1993); Brewer *et al.* (1999)
Diomus sp.	Ladybird	Robinson (1994)
Eupeodes volucris	Hover fly	Robinson (1994)
Hemerobius pacificus	Lacewing	Robinson (1994)

Species	Common name/description	Reference
Hippodamia convergens	Lady bird	Robinson (1994); Brewer and Elliott (2004); Bernal *et al.* (1993)
Hippodamia quinquesignata ambigua	Ladybird	Bernal *et al.* (1993)
Micromus variolosus	Lacewing	Robinson (1994)
Olla-v-nigrum	Ladybird	Robinson (1994)
Orius tristicolor	Pirate bug	Robinson (1994)
Pachyneuron siphonophorae	Parasitic wasp	Robinson (1994)
Paecilomyces fumosoroseus	Fungus	Vandenberg *et al.* (2001)
Pandora neoaphidis	Fungus	Hatting *et al.* (1999)
Paranaemia vittigera	Ladybird	Robinson (1994)
Platycheirus (Carposcalis) sp.	Hover fly	Robinson (1994)
Propylea quatuordecimpunctata	Ladybird	Messina *et al.* (1997)
Scymnus (Pullus) loewii	Ladybird	Robinson (1994)
Scymus frontalis	Lladybird	Naranjo *et al.* (1990)
Sympherobius angustus	Lacewing	Robinson (1994)
Syrphidae sp.	Hoverfly	Robinson (1994); Bernal *et al.* (1993)

7 Course of action – eradication methods

Additional information is provided by the IPPC (1998b) 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.

Note: Eradication is unlikely unless the pest is detected while still contained within a small or isolated area, given the dispersal capabilities of the pest and the widespread availability of host plants in agricultural, natural, and populated areas.

7.1 Destruction strategy

7.1.1 Destruction protocols

- Infested crops should be sprayed with a fast knockdown insecticide to kill the aphids before they have a chance to spread.
- Crops should then be destroyed by burning and/or ploughing to ensure the destruction of any eggs or missed aphids.

- Disposable equipment, infected plant material or soil should be disposed of by autoclaving, high temperature incineration or deep burial.
- Any equipment removed from the site for disposal should be double-bagged, to avoid spreading the pest to other non-affected areas.
- All vehicles and farm machinery that enter the infected field should be thoroughly washed, preferably using a detergent, farm degreaser or a 1% (available chlorine) bleach solution.

7.1.2 Decontamination protocols

If decontamination procedures are required, machinery, equipment and 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% bleach solution in a designated wash down area. *Disinfection and decontamination* guidelines are available as a supporting document of PLANTPLAN (Plant Health Australia, 2013) (**www.planthealthaustralia.com.au/wp-content/uploads/2013/12/Guidelines-Disinfection-and-decontamination.pdf**. 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.
- Located away from hazards such as power lines.
- Waste water, soil or plant residues should be contained.
- 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.

7.1.3 Priorities

- Confirm the presence of the pest.
- Limit the movement of people and prevent the movement of vehicles and equipment through affected areas.
- Stop the movement of any plant material that may be infested with the pest.
- Determine a strategy for the eradication/decontamination of infested host material.
- Determine the extent of infestation through surveys and plant material trace-back/trace-forward.

7.1.4 Plants, by-products and waste processing

- Any plant material or soil removed from the infected site should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial (in a non-cropping area).
- As the pest can be spread mechanically, plant debris from the destruction zone must be carefully handled and transported for destruction.
- Infested paddocks should remain free of susceptible host plants (see Section 4.2.1) until the area has been shown to be free from RWA. Given that cereals are susceptible to RWA, while canola, legumes and other crops are not, it may be possible that crop rotations which do not incorporate susceptible crops could be a control strategy to allow the farmer to produce a crop off infected paddocks. Although careful monitoring of crops for the presence of volunteer plants or the pest itself will need to be carried out until decided otherwise by the relevant authority.

7.1.5 Disposal issues

- Particular care must be taken to minimise the transfer of infested plant material or pests from the area.
- Host material should be collected and incinerated or double bagged and deep buried in an approved site (preferably away from host plants).

7.2 Containment strategies

For some exotic pest incursions where eradication is considered impractical, containment of the pest may be attempted to prevent or minimise its spread and impact on other areas. The decision to eradicate or contain the pest will be made by the National Management Group based on scientific and economic advice.

7.3 Quarantine and movement controls

Consult PLANTPLAN (Plant Health Australia 2013) for administrative details and procedures.

7.3.1 Quarantine priorities

- Plant material (including seed, straw and hay) and soil at the site of infection to be subject to movement restrictions.
- Machinery, equipment, vehicles and disposable equipment in contact with infested plant material or soil to be subject to movement restrictions.

7.3.2 Movement control for people, plant material and machinery

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

Movement of people, vehicles and machinery, from and to affected farms, must be controlled to ensure that infected plant material or soil is not moved off-farm on clothing, footwear, vehicles or machinery. This can be achieved through:

- 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 infested 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 re-collected from the affected site onto the machine.
- Hay, stubble or trash should not be removed from the site.

7.4 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. The details will be determined by the National Management Group during the production of the Response Plan. Further information on quarantine zones in an EPP incursion can be found in Section 4.1.4 of PLANTPLAN (Plant Health Australia 2013). These zones are outlined below and in Figure 14.

7.4.1 Establishing Quarantine Zones

Delimiting surveillance will inform the establishment of quarantine zones and identify the Restricted Area(s) (RA), Control Area (CA) and Pest Free Area (PFA). The size of each quarantine zone will be determined by a number of factors including location of the incursion, climatic conditions, pest biology and proximity of an Infected Premises (IP) to other IPs.

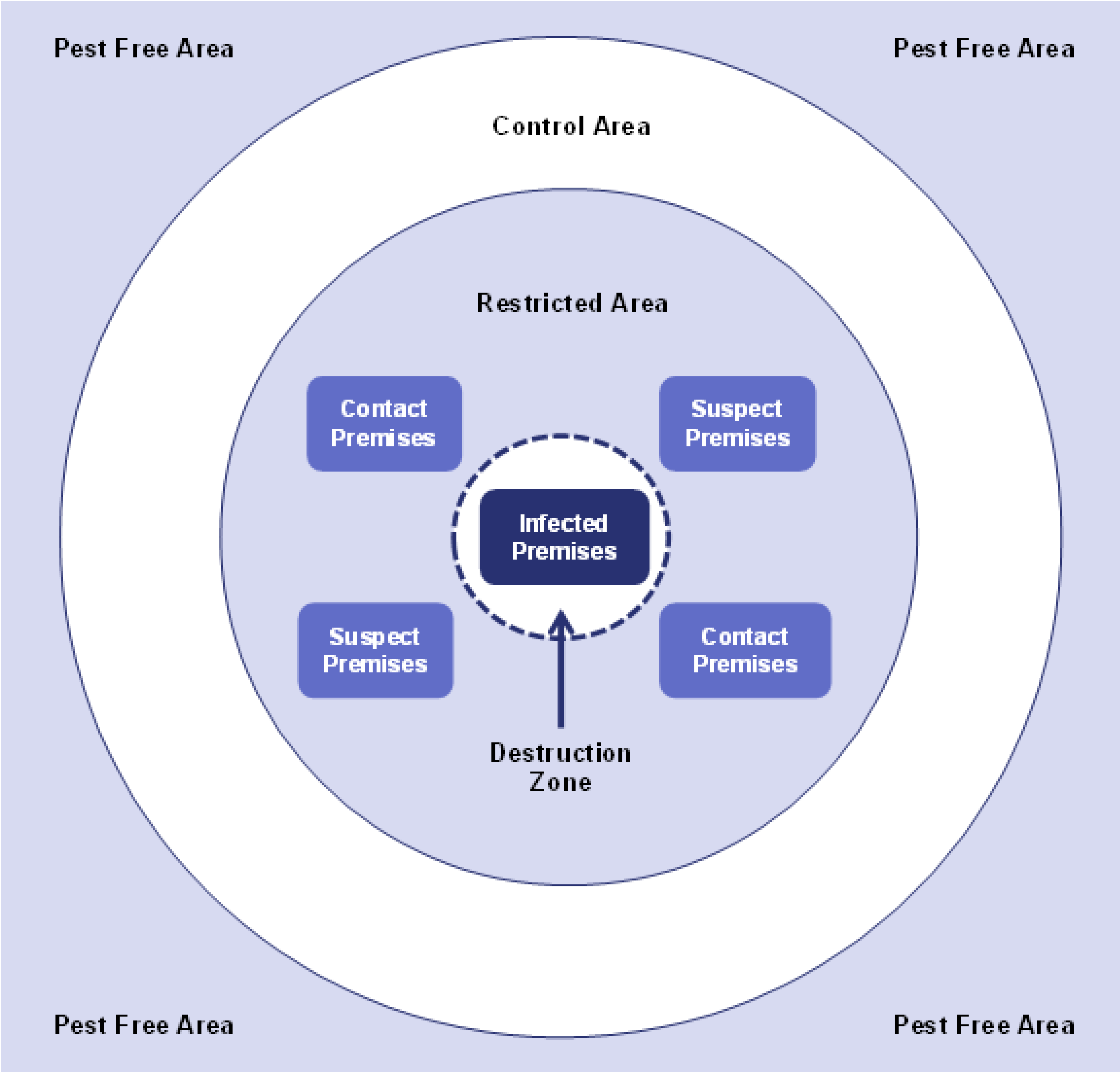

***Figure 14** Schematic diagram of quarantine zones used during an EPP incursion (not drawn to scale)*

7.4.2 Destruction Zone

The size of the Destruction Zone (i.e. zone in which the pest and all host material is destroyed) will depend on, distribution of the pest (as determined by delimiting surveys), ability of the pest to spread, factors which may contribute to the pest spreading and the time of season.

All host plants 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. If spread is likely to have occurred prior to detection, the Destruction Zone may include contiguous areas that have been in contact with, or are associated with the same management practices as, the infected area Particular care needs to be taken to ensure that plant material and soil are not moved into surrounding areas that are not showing symptoms of the pest. Where possible, destruction should take place in dry conditions to limit mud being spread within the field on boots and protective clothing.

7.4.3 Restricted Area

Data collected from surveys and tracing (trace back and trace forward) will be used to define the RA, which comprises all properties where the pest has been confirmed (Infected Premises or IP), properties which have come into direct or indirect contact with an IP or infected plants (Contact Premises or CP) and properties which may have been exposed to the pest (Suspect Premises or SP). The RA will be subject to intense surveillance and movement control, with movement out of the RA to be prohibited and movement into the RA to occur by permit only.

7.4.4 Control Area

A CA is established around a RA to control the movement of susceptible hosts and other regulated materials until the extent of the incursion is determined. There may be multiple RAs within one CA. When the extent of the EPP Incident has been confidently defined, the RA and CA boundaries and movement controls may need to be modified, and where possible reduced in size commensurate with appropriate controls.

Additional zones can be utilised as required for operational purposes.

7.5 Decontamination and farm clean up

Decontamination practices are aimed at eliminating the pest thus preventing its spread to other areas.

7.5.1 Decontamination procedures

General guidelines for decontamination and clean up:

- Keep traffic out of affected area and minimise it in adjacent areas.
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.
- 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, a farm degreaser or a 1% bleach solution in a designated wash down area as described in Section 7.1.2.
- Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label.
- Plant material should be destroyed by high temperature incineration, autoclaving or deep burial (in a non-cropping area away from susceptible host species).

For further information, refer to *Disinfection and decontamination* guidelines available as a supporting document of PLANTPLAN (Plant Health Australia, 2013) (**www.planthealthaustralia.com.au/wp-content/uploads/2013/12/Guidelines-Disinfection-and-decontamination.pdf**).

7.5.2 General safety precautions

For any chemicals used in the decontamination, follow all safety procedures listed within each Material Safety Data Sheet (MSDS).

7.6 Surveillance and tracing

7.6.1 Surveillance

Detection and delimiting surveys are required to delimit the extent of the outbreak, ensuring areas free of the pest retain market access and appropriate Quarantine Zones are established.

Initial surveillance priorities include the following:

- Surveying all host growing properties in the quarantine area.
- Surveying all properties identified in trace-forward or trace-back 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 RWA presence.
- Surveying other host growing properties.

7.6.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 7.4), 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 8 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 8. *Phases to be covered in a survey plan*

Phase 1	• Identify properties that fall within the buffer zone around the infected 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 infected 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 pest. 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-borne dispersal of the pest during these weather events.
Phase 5	• Surveillance of nurseries, gardens and public land where plants known to be hosts of pest are being grown.
Phase 6	• Agreed area freedom maintenance, post-control and containment.

7.6.3 Post-eradication surveillance

The period of pest freedom sufficient to indicate that eradication of the pest has been achieved will be determined by a number of factors, including cropping conditions, the previous level of infection and the control measures applied. As a guide, the following activities should be carried out following the eradication of the pest:

- Establishment of sentinel plants at the site of infection.
- Maintain good sanitation and hygiene practices throughout the year.
- Sentinel plants should remain in place and inspected on a fortnightly basis for a further 6 weeks and then on a monthly basis.
- Surveys comprising of plant and soil sampling for use in testing for RWA to be undertaken for a period of time as determined by decisions from the CCEPP and NMG committees.

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9 Appendices

9.1 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**).

9.2 Appendix 2. Resources and facilities

The following table provide lists of diagnostic facilities (Table 9) for use in professional diagnosis and advisory services in the case of an incursion.

Table 9. *Diagnostic service facilities in Australia*

Facility	State	Details
CSIRO Entomology, Centre for Environment and Life Sciences	WA	Floreat, Private bag 5 Wembley WA 6913 Ph: 08 9333 6000
CSIRO Entomology Black Mountain Laboratories	ACT	Clunies Ross St Canberra ACT 2601 Ph: 02 6246 4001
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
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
SARDI Plant Research Centre Waite Research Precinct	SA	Hartley Grove Urrbrae 5064 South Australia Ph: (08) 8303 9400 Fax: (08) 8303 9403

Facility	State	Details
Grow Help Australia	Qld	Grow Help Australia DEEDI Level 2C West Ecosciences Precinct B 3 Joe Baker Street Dutton Park Qld 4102 Ph: (07) 32554365 Fax: (07) 3846 2387
DPIPWE Tasmania	Tas	Plant pathology 13 St Johns Avenue NEW TOWN TAS 7008 Phone: 03 6233 6833/6804 Fax: 03 6228 5123

9.3 Appendix 3. Communications strategy

A general Communications Strategy is provided in Section 4.1.5 of PLANTPLAN (Plant Health Australia, 2013).

9.4 Appendix 4. Market access impacts

Within the AQIS PHYTO database (**www.aqis.gov.au/phyto**), no countries were found to have restrictions on importing commodities. Should *D. noxia* be detected or become established in Australia, there will be little in the way of repercussions for trade to other countries. Latest information can be found within PHYTO, using an Advanced search "Search all text" for *Diuraphis noxia.*

9.5 Appendix 5. Host plants

The following species (Table 10 and Table 11) can all act as hosts to the RWA. Table 10 lists primary hosts, which are hosts that the aphid can complete its lifecycle in full, whereas Table 11 lists the secondary hosts, which are hosts on which the final instar and adults can feed but other instars are not known to feed. This category also includes species on which the Russian wheat aphid has been observed but no further details are known. For example Stoetzel (1987) describes rice (*Oryza sativa*) as a host of RWA but it is not known if the Russian wheat aphid can reproduce of even feed on rice.

Both primary and secondary hosts should be considered in any eradication or control strategies as they can act as a source of infection/reinfection. Of these species barley, wheat, durum, oats, rye and triticale are the most widespread host species in Australia.

Table 10 *Primary host plants of RWA*

Scientific name	Common name	Reference
Hordeum vulgare	Barley	Stoetzel (1987); Kindler and Springer (1989)
Triticum aestivum	Wheat	Stoetzel (1987); Kindler and Springer (1989)
Triticum turgidum (durum)	Durum wheat	Hughes (1988)
Triticum cylindricum	Jointed goatgrass	Kindler and Springer (1989)
Bromus mollis	Blando bromegrass	Kindler and Springer (1989)
Vulpia myuros	Rattail fescue	Kindler and Springer (1989)
Elymus arenarius	European dunegrass	Kindler and Springer (1989)
Elymus canadensis	Canada wildrye	Armstrong *et al.* (1991)
Hordeum pusillum	Little barley	Kindler and Springer (1989)
Bromus arvensis	Field bromegrass	Kindler and Springer (1989)
Agropyron intermedium	Intermediate wheatgrass	Kindler and Springer (1989)
Agropyron cristatum	Creased wheatgrass	Armstrong *et al.* (1991)

Table 11 *Secondary hosts of RWA*

Scientific name	Common name	Reference
Avena sativa	Oat	Kindler and Springer (1989)
Secale cereale	Rye	Kindler and Springer (1989)
Agropyron elongatum	Tall wheatgrass	Kindler and Springer (1989)
Elymus triticoides	Beardless wildrye	Kindler and Springer (1989)
Oryzopsis hymenoides	Indian ricegrass	Kindler and Springer (1989)
Cynodon dactylon	Bermuda grass	Kindler and Springer (1989)
Phalaris canariensis[9]	Canary grass	Stoetzel (1987)
Phleum pratense[9]	Timothy grass	Stoetzel (1987)
Hordeum murinum[9]	Wall barley	Stoetzel (1987)
Bromus madritensis[9]	Spanish broom	Stoetzel (1987)

[9] *D. noxia* has been observed on these species but no further details are available regarding different life stages ability to survive on the plant.

Scientific name	Common name	Reference
Oryza sativa[9]	*Rice*	Stoetzel (1987)
Triticum aestivum X Secale cereale	*Triticale*	Robinson (1994)
Sorghum bicolor[9,10]	Sorghum	Harvey and Kofoid (1993)

[10] *S. bicolor* is not usually considered as a host, but some varieties have been shown to be susceptible in laboratory conditions in the USA (Harvey and Kofoid 1993). It is therefore a possibility that sorghum could act as a host in some conditions, and should be included in surveys etc.