Rice water weevil

COMMON NAME	Rice water weevil
SCIENTIFIC NAME	*Lissorhoptrus oryzophilus* Kuschel
SYNONYMS	None

Background

The Rice Water Weevil (RWW) is regarded as a serious threat to the Australian rice industry. RWW is native to North America, where it is distributed from Mexico through to Canada. It is a serious pest in both the warmer southern rice areas (Texas, Arkansas, Louisiana) and in California, where the climate closely parallels that in Australian rice growing areas. It is also known from Cuba, the Dominican Republic, Colombia, Suriname, and Venezuela, and has spread to other temperate rice producing areas including Japan, China and Korea, apparently having been introduced into Japan in imported Californian rice straw. The broad range of temperature tolerance shown by RWW indicates that this pest has the potential to survive in the eastern Australian rice growing areas, as well as throughout other parts of Australia where suitable foodplants are available.

Host range

PRIMARY HOST RANGE

Oryza sativa (rice), *Poaceae* (cereals)

THE FOLLOWING WILD HOSTS ARE KNOWN

Alopecurus aequalis (Dent foxtail), *Axonopus compressus* (carpet grass), *Cynodon dactylon* (Bahama grass), *Cyperus difformis* (small-flowered nutsedge), *Cyperus iria* (grasshopper's cyperus), *Cyperus serotinus*, *Echinochloa crus-galli* (barngrass), *Imperata cylindrica* (bedding grass), *Leersia hexandra* (southern cut grass), *Leersia oryzoides* (Rice cutgrass), *Panicum repens* (creeping panic), *Poa annua* (annual bluegrass (USA, Canada, South Africa)), *Saccharum officinarum* (sugarcane), *Zea mays* (maize).

It is highly likely that the known host range of RWW will expand considerably as new areas are invaded.

PART OF PLANT/COMMODITY AFFECTED

Rice roots and leaves.

Biology

Identification

Adult rice water weevils are about 3 to 4 mm in length, and are greyish brown in colour with a darker brown V-shaped marking dorsally (figure 1). The larvae, which feed on the plant roots, are between 0.8 and 4.7 mm long). The white, cylindrical eggs are less than 0.4 mm long. Adult weevils can be difficult to differentiate from native species that do not pose a threat to the rice crop.

A diagnostic standard for RWW has recently been prepared by Dr Rolf Oberprieler, CSIRO Division of Entomology, Canberra.

Symptoms

Adult rice water weevils attack the leaves of young rice plants, producing longitudinal feeding scars (Figure 1). Leaf scarring can kill young plants, however the damage is rarely sufficient to cause economic losses. Younger plants are more susceptible to adult feeding injury, and damage is exacerbated by fertilising with nitrogen. There have been reports of weevils attacking the flowering parts of rice plants, however the significance of this form of damage is not well understood.

Larvae are the principal cause of rice plant damage. The larvae feed on the roots of the rice plant below soil level, leading to reduced nutrient uptake that causes the plants to turn yellow. Plants that survive do not reach their normal height and produce less grain than unaffected plants. Grain weights are also reduced, which may affect product acceptance in some markets.

Life-history

Both male and female rice water weevils are found in the southern states of the USA, however in California the population is parthenogenetic (Way, 1990) – only females are present, and they can produce viable eggs without male fertilisation. Populations in Japan and the Dominican Republic are also parthenogenetic, indicating they are probably derived from the Californian population.

In the USA adult rice water weevils overwinter in grasses and leaf litter. They emerge from diapause in spring and invade rice fields to feed on the leaves of seedlings. Females deposit their eggs in the leaf sheath at or below the water line, and the first instar larvae initially feed in the leaf sheath before moving into the soil to feed on the roots. The larvae form oval cocoons attached to the roots and pupate inside. The pupal stage lasts for approximately one week, then the adults emerge and either fly to overwintering sites or invade other rice crops. The complete life cycle takes about 7 weeks to complete, but is heavily temperature-dependent.

Dispersal

Natural dispersal rates are variable, as adults only have functional flight muscles for a short period after initial emergence, and after emergence from diapause. During these periods, however, flight dispersal is rapid, and rice water weevil can rapidly expand its range. In late 1976 rice water weevil was present in 730 hectares of rice in Japan, but by late 1986 the affected area had grown to over a million hectares – approximately 46% of the Japanese rice growing area.

Estimate of economic impact on production, allied industries and native ecosystems

Rice Production

Establishment of RWW in southern Australia would have a major impact on rice production. Data from the USA indicates that at least 15 to 30% yield loss would occur if affected crops were not chemically treated. Most (but not all) of this potential yield loss could be recovered through the use of insecticides, however use of these treatments would severely reduce profitability for rice producers.

If not effectively controlled RWW would reduce rice production in Australia by 360,000 tonnes per annum, assuming an annual crop of 1.2 million tonnes. This equates to a loss of AUD 86 million ‘at the farm gate’. Implementation of effective chemical control could reduce this loss to around 60,000 tonnes per annum.

Pre-existing controls

Considerable effort has been directed towards identifying sources of host plant resistance to RWW, particularly in the USA, however these efforts have met with only limited success. Whilst some American commercial rice cultivars are considered tolerant to RWW, none has sufficient resistance to RWW to be grown without the use of chemical controls (Way, 1990; Pathak and Khan, 1994; M.Stout, Louisiana State University, pers. comm. 2004). No commercial Australian rice cultivars have any resistance to RWW.

In Australian rice production systems routine control of established RWW populations would rely almost entirely on synthetic insecticides, particularly fipronil seed treatments (at substantially higher application rates than currently used against rice bloodworm) and the synthetic pyrethroids lambda-cyhalothrin (Karete® Z) and zeta-cypermethrin (Mustang Max®).

Eradication of a RWW outbreak would rely heavily on the use of synthetic pyrethroid compounds for adult weevil control, combined with crop destruction to eliminate eggs, larvae, and pupae. Preliminary discussions with APVMA suggest that obtaining emergency use patterns for these compounds (particularly lambda-cyhalothrin) should pose little difficulty, as both materials have crop use registrations in Australia.

Cost of routine control

Chemical control can reduce RWW populations to levels where they have minimal impact on rice crop yield, however 2 chemical applications person season would be required. The costs associated with routine RWW control could be in the vicinity of AUD 100 to 160 per hectare per season, which would have a profound effect on profitability.

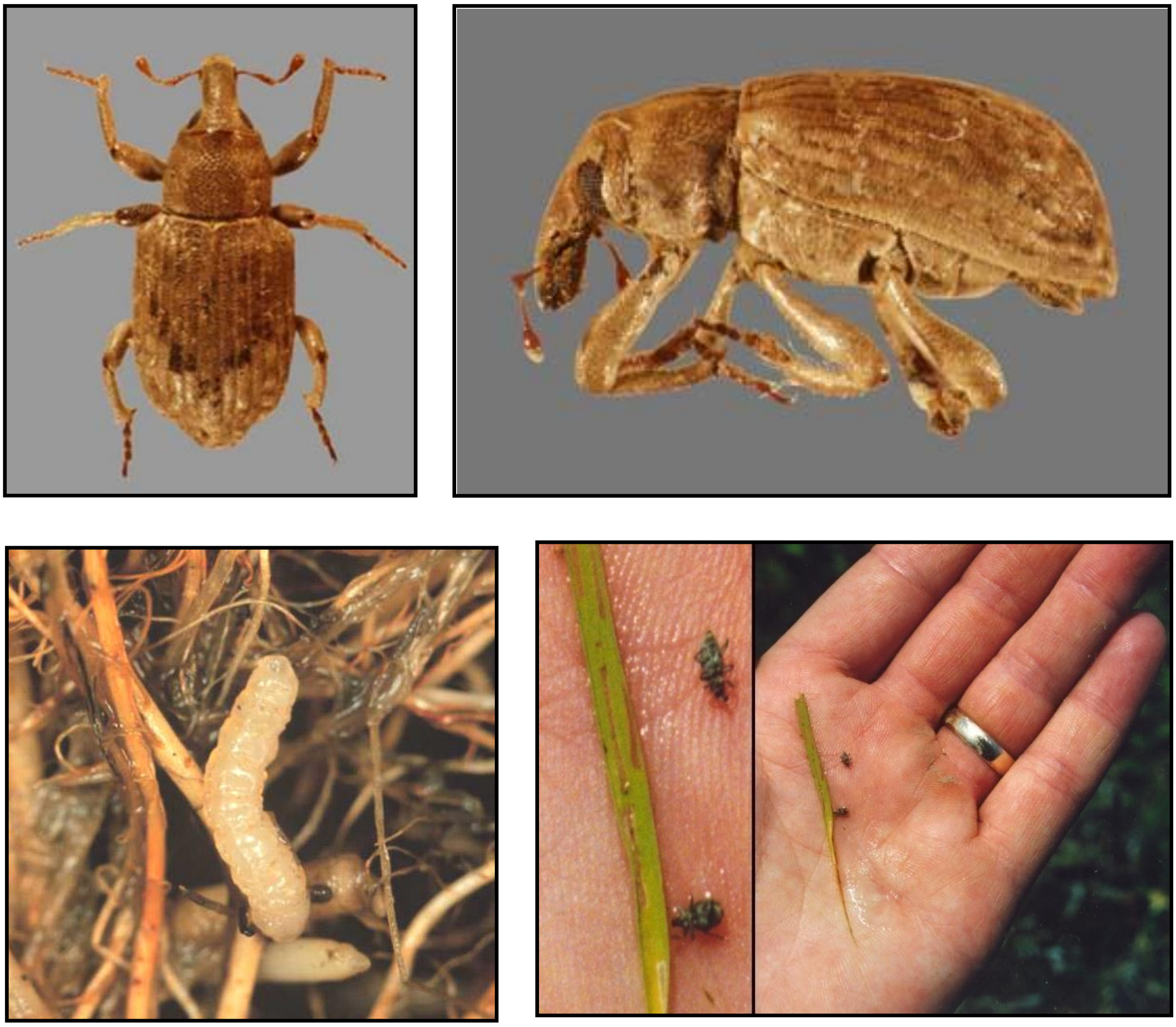
Trade implications

Whilst the routine control of established RWW populations in Australia would have a severe effect on grower profitability, it would be unlikely to substantially affect trade in milled grain. RWW is unlikely to significantly contaminate grain at harvest, and any grain contamination would be effectively removed during milling. RWW damage can affect grain weights, which may affect access to some markets, however effective chemical control would minimise this effect. Access to potential export markets for rice straw (particularly Japan) would be severely reduced by the establishment of RWW in Australia.

Environmental impact

Although RWW has a wide host range in terms of species attacked, it appears to be limited to grasses and sedges. Although RWW could become widely distributed in Australia, its overall impact on the natural environment would be far more limited than, for example, Golden Apple Snail.

Figure 1. *Rice water weevil. Clockwise from top left: adult (dorsal view), adult (lateral view), larva on rice roots, adults showing longitudinal feeding scars on rice leaves.*



Surveillance

General surveillance

The most realistic option for routine surveillance of rice growing areas in order to detect RWW infestations involves educating rice farmers and other industry professionals about the potential of RWW to damage their industry. Pictures and information on RWW have been distributed direct to rice producers (Stevens, 1997; Stevens et al., 2004), however this information has been within larger pest management publications, and preparation and distribution of a separate leaflet is justified to ensure the message reaches the target audience.

The difficulties associated with accurate identification of RWW and its anticipated low impact on areas outside the rice growing region suggest that awareness programs directed towards land managers in these areas may be of little overall benefit. Surveillance outside the rice growing area basically involves quarantine inspections of cargo at international points of entry. Whilst inspection of imported goods deserves the highest level of priority, surveillance of northern Australia is also important at RWW becomes more widespread in southern Asia. Surveillance in these areas is managed by AQIS under the Northern Australia Quarantine Strategy (NAQS).

Targeted surveillance

Targeted surveillance is defined here as particular actions that should be undertaken to minimise risks of RWW entering and establishing within Australia.

The primary responsibility for preventing the entry of RWW into Australia resides with AQIS. Whilst AQIS intercept 'weevils' on a regular basis, there have been no confirmed interceptions of RWW, which reflects the taxonomic difficulties associated with weevil identification. RWW may have been intercepted in quarantine, but not have been recognised. Whilst the diagnostic protocol for RWW may allow a greater level of taxonomic resolution for intercepted weevils, this assumes the resources are available within AQIS to apply the protocol on a regular basis. Development of a DNA-based diagnostic protocol for RWW may help in this regard.

The spread of RWW through northern Asia appears to have been a consequence of an initial introduction into Japan in Californian rice straw, with subsequent dispersal to Korea and China either through flight or contaminated rice straw or straw products. In strong contrast to the situation with Golden Apple Snail, deliberate movement of the organism by humans does not appear to be a significant factor.

Correspondingly, the main emphasis of targeted surveillance should be on imported products, and on potential incursions from Asia. Any material containing rice or grass straw imported from infested areas should be fumigated appropriately. Rice straw products are currently banned from entering the rice quarantine area in southern NSW, and this legislation should be extended to cover all imported products containing any form of grass straw.

Detection of incursions from Asia will prove difficult because of the absence of sentinel rice crops in northern Australia. RWW could enter northern Australia and establish in grassland areas without its presence being noticed. As mentioned previously, DNA-based identification protocols may facilitate faster recognition of a RWW incursion into northern Australia, provided resources are available for the screening of samples.

Exotic pest survey

Survey method

INTRODUCTION

Surveying for RWW requires a different approach to that used for Golden Apple Snail, since RWW are not as heavily dependent on the aquatic environment, and are capable of dispersing by air during part of their adult life. There are no pheromone-based trapping systems currently available for RRW.

Trapping of RWW adults can best be achieved through the use of a combination of light traps and aquatic barrier traps. Barrier traps, as described by Hix et al. (2000, 2001) will catch adult weevil active in the water regardless of whether they have functional flight muscles. Light traps will only catch adult RWW during the period when they are capable of flight. Care also must be taken with the use of light traps, since if they are positioned outside a control area but within line-of-sight, they may actually stimulate flights outward from the infestation zone, contributing to pest dispersal.

In the event of an RWW outbreak it will not be immediately apparent whether the population consists of flight-capable or flightless individuals, or a combination of both. Until this is determined manual surveys and barrier traps should form the basis of defining the infestation area.

1. DEFINING THE OUTBREAK ZONE AND PREVENTING DOWNSTREAM MOVEMENT

There are three main ways by which a RWW infestation may spread from a localised area, such as an individual rice crop.

- Dispersal by flight, if adults have functional flight muscles.
- Downstream movement (primarily of adults) in flowing water.
- Movement of all developmental stages in contaminated soil or plant materials attached to vehicles, boots, or machinery.

Once RWW has been confirmed from a point location it is essential to stop all flowing water from leaving the area. In a rice field, water inflow should be maintained, but only to the extent of maintaining water levels to compensate for evaporation. If RWW is located in vegetation along a drainage channel, or in crops leading to a drainage channel, then that channel should be blocked 300 metres downstream and inflows into the channel should be minimised. It is important to maintain water in the fields/channel until adulticides have been applied, as drying out the environment may encourage flight-capable adults to leave the area in search of more favourable environments.

2. DISTRIBUTION SURVEY AND DEFINING BOUNDARIES OF THE AQUATIC ZONE

Once the drainage has been blocked, a further 300 m downstream from the blockage point should be manually searched for RWW, walking upstream so as not to muddy the area being sampled. Searching should be done by examining grass and sedge vegetation in the area for evidence of weevils or their longitudinal feeding scars, and by taking 10 cm diameter soil cores (10 cm deep) from around the base of aquatic vegetation and wet sieving the samples to locate any larvae present. Soil cores should be taken in groups of 3 every 30 metres.

If suspect RWW are found in any part of the drainage channel the blockage needs to be re-established 300 m further downstream from the boundary of the infestation, and the survey repeated until a 300 m section is recognised as being clear of RWW. Tributaries entering the drainage system and their boundaries also need to be surveyed. Any tributary entering the drainage area needs to be surveyed for 200 metres upstream from its junction with the drainage channel, with the boundary being extended in response to any detection. The drain upstream from the rice field inflow and its tributaries needs to be surveyed in the same manner. It is important to retain surface water in the drains until adulticides have been applied. A 200 metre zone is appropriate for these areas because upstream movement of RWW adults is likely to be much slower than downstream movement.

Suspect weevils and weevil larvae collected should be placed in jars of water, with a separate sample being isolated and labelled for each 50 metre stretch of channel. At the end of the day the weevils should be transferred to tubes of 70% ethanol and then sorted by a diagnostician competent in separating RWW from other weevil species.

Within the rice fields themselves, all contiguous areas of rice (eg, all bays within a block) will need to be treated in response to a positive identification of RWW within any part of the crop. Whilst a systematic survey of all rice bays within an infested block may shed useful information on the age structure and flight capability of populations, the level of human activity required for such a survey may facilitate the spread of the pest and delay control activities. Once RWW is confirmed within a rice block, the whole area should be chemically treated prior to extensive within-block surveys.

Supply channels feeding the infested fields also need to be surveyed upstream of the fields. An initial 200 metre area should be surveyed, with water levels being reduced to the minimum feasible for maintaining water levels in the receiving fields. Any detection of RWW will result in the survey area being extended 200 m further upstream from the detection point. **Note that if there is a supply junction within this 200 m area leading to downward flow (away from the infested area), then the downstream section needs to be treated in the same way as a drainage channel because of the risk of downstream movement of adult RWW with the water flow.** Any supply lines coming from the defined area of the supply channel (including pressurised pipes, drip systems etc) will need to included in the infestation area and chemically treated. Areas receiving water from these systems, including dams and seepage areas will also need to be surveyed using these protocols. Any standing water body (farm dams, etc.) within 1 km of the infestation area will require inspection for RWW that may be associated with aquatic grass and sedge vegetation.

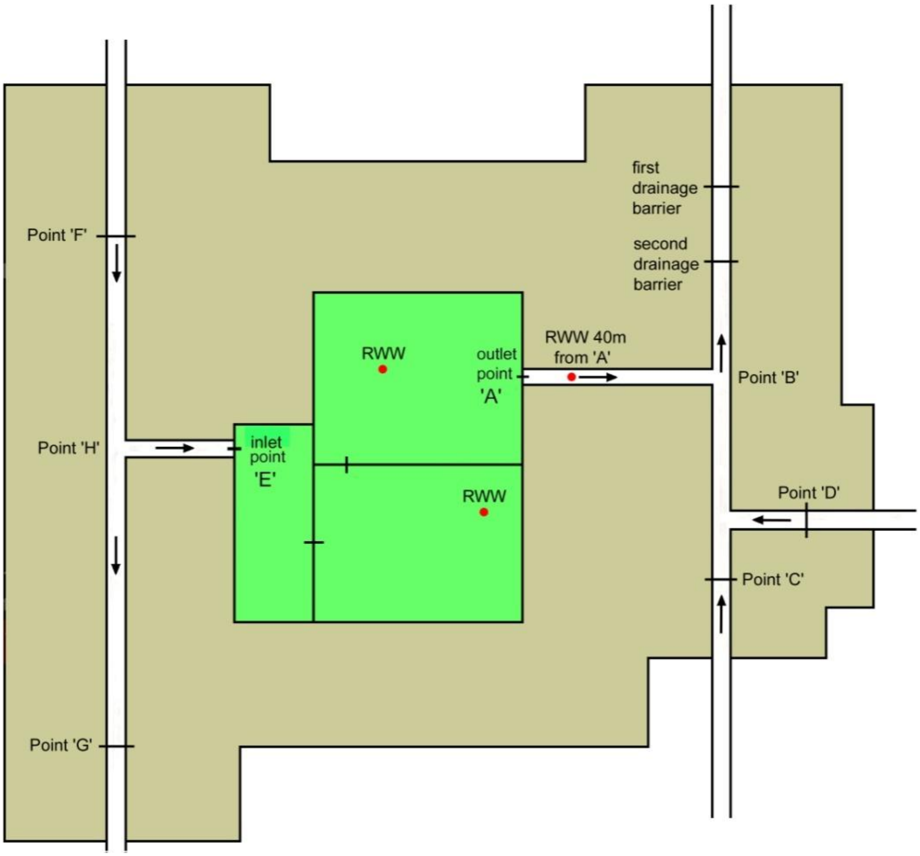
3. DEFINING BOUNDARIES OF ADJOINING TERRESTRIAL ZONES

RWW can survive in grasses outside the boundaries of rice fields, and unlike Golden Apple Snails, they are capable of moving considerable distances away from fields, particularly if they have functional wings. Accordingly, it is appropriate to set a fixed terrestrial boundary around infested aquatic areas and treat it with adulticides at the same time the aquatic areas are treated. The terrestrial area should extend 300 metres from the crop boundary and from any point in the defined aquatic zone. This area should be considered fixed and not dependent on any actual detections.

This initial survey will result in the area of infestation being defined, with the following boundaries:

- The infested block of contiguous rice bays, plus a dryland boundary area around the block 300 metres wide.
- The drainage channel (including any recirculation storages) for at least 300 metres downstream of the block, or for the infested area of the drainage, plus a 300 metre 'clear' zone, plus a dryland boundary of 300 metres.
- Upstream and downstream tributaries to the drainage channel to a point 200 m from any RWW detection, plus a dryland boundary area of 300 m (this includes the drainage channel itself upstream from the point where flow from the infested area enters)
- The supply channel feeding the infested rice fields to a point 200 m upstream from any RWW detection, plus a dryland boundary area of 300m. An example of the application of this protocol is shown in Figure 2.

Figure 2. *Application of the protocol for determining the extent of a RWW infestation in rice. Direction of normal water movement indicated by arrows. The pale brown zone (alternate host area) ends 300 metres from the infested bays and 300 m from the drainage and supply areas, with an extension of the area in response to any detection outside the bays. Distance from outlet 'A' to first barrier 300 m; distance from outlet 'A' to second barrier 340 m (furthest identified downstream RWW position plus 300 m); distance from drainage junction (point 'B') to points 'C' and 'D' 200 m. Distance from inlet point 'E' to point 'F' 200 m; distance from point 'H' to supply barrier (point 'G') 300 m (since junction at point 'H' allowing downstream movement occurs within 200 m of point 'E').*



Monitoring of adjacent rice crops

Any rice crop within 3 km of the infestation area needs to be monitored for RWW for the duration of the rice season. These crops should be subjected to sweep netting for adult weevils every 2 weeks, and an initial series of soil cores should also be taken to check for RWW larvae. Adult RWW interception traps (Hix et al., 2000, 2001) should be installed (minimum of 2 traps per bay) and monitored every 2 days. Since adult RWW are readily attracted to light (Rice Pest Management Alliance, 2000) one light trap should also be placed in each crop, provided the trap is not within line-of-sight of the infestation area.

Diagnostics and laboratories

Preservation of samples being sent for specialist identification

Suspected RWW (adults and larvae) being sent for identification should be carefully cleaned of any mud or debris and placed in small, tightly sealed vials containing 70% ethanol.

Diagnostic laboratories

The following researchers should be consulted for diagnosis of suspected RWW:

IN AUSTRALIA

Dr Mark Stevens
NSW Department of Primary Industries
Yanco Agricultural Institute
Private Mail Bag
YANCO NSW 2703
Telephone: 02 6951 2611
Email: mark.stevens@dpi.nsw.gov.au

Dr Rolf Oberpreiler
CSIRO Division of Entomology
GPO Box 1700
CANBERRA ACT 2601
Telephone: 02 6246 4001
Email: Rolf.Oberpreiler@csiro.au

Management/control options

Quarantine and containment

Once the initial infestation area has been defined, it will be necessary to establish a quarantine zone around that area during the eradication phase of the operation. This quarantine area should extend for 500 metres around the defined infestation area, and all movements of people, vehicles and machinery need to be controlled until the eradication attempt has been declared successful.

Transport of RWW adults, larvae, pupae, and eggs on passenger vehicles is a distinct possibility, and vehicle tyres and undercarriages need to be disinfested prior to moving from the outbreak area into the quarantine zone, and also when leaving the quarantine zone. Ideally operational vehicles should stay in the quarantine zone until eradication has been confirmed.

Boots and waders worn by survey and control personnel similarly need to be disinfested, and if possible should not be moved out of the quarantine zone until eradication is confirmed.

Farm machinery that has been used in the outbreak area and quarantine zone during the preceding 6 months needs to be cleaned of any plant and soil debris then steam-cleaned and sprayed in situ. Similar cleaning protocols need to be followed when operational machinery is moved from the defined outbreak area into the quarantine zone, and again when leaving the quarantine zone.

Cleaning / disinfestation treatments for vehicles and machinery are discussed under 'Destruction / Eradication'.

Research and development

Because of the significance of RWW to the rice industry in the USA, extensive research has been undertaken on the biology and control of this pest. Numerous web sites associated with research and extension services are available that provide details of this research, and there is little work that can be profitably conducted in Australia to increase our capacity to successfully respond to a RWW incursion.

The development of new diagnostic tools, however, would facilitate early detection of a RWW incursion. DNA-based testing protocols would allow rapid identification of weevil larvae without requiring them to complete development, and such a test, if routinely applied, would allow AQIS to determine in any of the numerous weevil interceptions that occur each year involve RWW, rather than other species.

Destruction/eradication

Destruction of a RWW infestation will rely heavily on both chemical control and modification of land use patterns for a two year period after chemical control.

Chemical control

An established rice water weevil infestation in rice would be characterized by adult weevils on plant foliage, larvae and pupae in the soil attached to plant roots, and viable eggs within submerged leaf sheaths. The greatest initial priority is to control the adults because of their greater dispersal ability. Synthetic pyrethroids are currently favoured for adult RWW control in the USA, with widely used compounds including lambda-cyhalothrin (Karate® Z) and zeta-cypermethrin (Mustang Max®). Current rates for these compounds in the USA are 0.025 - 0.04 lb active.acre-1 and 0.02 - 0.025 lb active.acre^{-1} respectively (LSU AgCenter Research and Extension, 2003; Texas Agricultural Experiment Station, 2004), which correspond to 28 - 45 g active.ha^{-1} and 23 – 28 g active.ha^{-1}. Higher rates suitable for an eradication campaign would be 60 g active.ha^{-1} for lambda-cyhalothrin and 40 g active.ha^{-1} for zeta-cypermethrin. The entire infestation area should be treated by air as soon as possible after it has been defined using the preceding protocol.

After an adulticide has been applied any water inflow into the system should be stopped. The crop and all low vegetation in the infestation area should immediately be sprayed with gyphosate by air and standing water in the crop and drainage/supply areas should be allowed to evaporate until the ground is suitable for machinery access. During this period additional adulticide applications should be made at 2 day intervals to destroy any adults emerging from pupae within the soil. Larvae and pupae cannot be reliably controlled with chemicals within a flooded rice crop. These supplementary adulticide applications only need to be made to the affected crops and supply and drainage areas, rather than to the dryland boundary areas included in the initial treatment.

Chemical disinfestation of machinery, vehicles, etc.

Disinfestation of machinery and vehicles could be achieved through chemical or heat treatment. High pressure steam cleaning is the optimum approach for machinery cleaning, and should be applied before any motor vehicle leaves the quarantine zone. Particular care should be taken to clean around the axles and wheel arches of passenger vehicles, and any other areas of the vehicle where vegetation contaminated by RWW may have been caught. Any plant trash removed from vehicles should be either burned or buried within the quarantine zone. Rubber boots worn by operational staff should also be steam-cleaned externally before being removed from the site.

Spraying machinery surfaces with lambda-cyhalothrin at a concentration of 0.05 – 0.1 $g.L^{-1}$ offers an alternative disinfestation technique for situations where steam cleaning may not be appropriate, however steam cleaning should be considered the preferred option wherever possible.

Land use after chemical control

As soon as practical after glyphosate application the crop and all low vegetation in the infestation area should be cultivated into the soil as thoroughly as possible. Dense crops may need to be burned before residue incorporation can be attempted.

Flight-capable adult populations should be monitored using light traps positioned within the infestation area during the eradication process. This will provide information on the success or otherwise of the eradication attempt. Light traps should not be used outside the infestation area and within line-of-sight of the area, as they may contribute to dispersal of adults beyond the treatment zone. Use of lights within line-of-sight (houses, sheds etc.) should be minimised during the eradication period for the same reason.

If there are no adults collected in light traps within the infestation area during a one week period, the light trapping grid should be progressively extended into the bordering quarantine area.

The available data suggests that destruction of grasses in the infestation area and dry soil cultivation should result in the death of RWW eggs, larvae, and pupae within a relatively short period of time. However, to ensure eradication no crops should be grown in the infestation area for a minimum of 2 years, and only then after further intensive cultivation. The infestation area will need to regularly resprayed with glyphosate during this period to keep the soil as bare as possible. The use of impact soil compaction machines on the affected land prior to future rice production is strongly recommended.

Documentation to establish area freedom

The biology of RWW is such that confirmation of eradication cannot be effectively made until rice is re-established within the infestation zone. After the quarantine period has been observed, rice should then be grown over the area of the previously infested fields, with all drainage water entering a defined recirculation system, rather than being allowed to enter regional drainage systems.

Adult RWW interception traps (Hix et al., 2000, 2001) should be installed (minimum of 3 traps per bay) at crop flooding and monitored every 2 days during the season. A minimum of one light trap per 5 ha of crop (overall minimum 3 traps) should also be installed at flooding and monitored weekly. Manual and sweep net inspections for adults should also be conducted every 2 weeks for the first 3 months of crop growth.

Any rice crop within 3 km of the former infestation area needs to be monitored for RWW for the duration of the rice season. Adult RWW interception traps (Hix et al., 2000, 2001) should be installed (minimum of 2 traps per bay) and monitored every 2 days. One light trap should also be placed in each crop, provided the trap is not within line-of-sight of the infestation area. No RWW recoveries by harvest in any of the crops indicates area freedom.

Stand down procedures

In addition to the preparation of an appropriate debriefing report in relation to operational issues, the following technical issues need to be evaluated in the event of an eradication attempt being unsuccessful.

1. Containment of an infestation. Long-term containment of an established RWW infestation is unlikely to be feasible due to the dispersal ability of the adults. If the outbreak is limited to one relatively isolated part of the rice producing area, however, movement controls may substantially delay spread of the infestation to other regions. Options for containment should be thoroughly examined, taking into consideration the area of the infestation, its isolation (or otherwise) from other rice areas, and the practicality of enforcing any State legislation enacted to facilitate containment.
2. Research on control options. Routine control of established RWW populations will rely heavily on agrochemicals. The rice industry in the USA has invested heavily in research on both chemical and non-chemical RWW control, and the advice of researchers from Texas, Louisiana, Arkansas, and California should be sought to determine the most appropriate areas for research on RWW management in Australia. The Rural Industries Research and Development Corporation should be approached to fund such research.

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