INDUSTRY BIOSECURITY PLAN FOR THE GRAINS INDUSTRY

THREAT SPECIFIC CONTINGENCY PLAN

SUNN PEST
EURYGASTER INTEGRICEPS

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CONTINGENCY PLAN
EURYGASTER INTEGRICEPS PUTON

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1 Pest information/status

1.1 Pest Details – *Eurygaster integriceps* Puton

1.1.1 General information

Taxonomic position – Class: Insecta; Order: Hemiptera; Family: Scutelleridae

Common names: Sunn Pest, Sunni Pest, Sunn pest, Sunn bug, cereal bug, Soun bug, Soune bug, Sunne pest, Suni pest, Senn bug, Sen pest, noxious pentatomid, wheat shield bug (additional names exist in other languages, *see* Crop Protection Compendium 2008)

Eurygaster integriceps is an insect pest that predominantly attacks grains, feeding on the leaves, stems and grains, reducing yield and injecting a toxin into the grains which adds a foul smell to the resulting flour, and substantially reduces the baking quality of the dough. In the absence of control measures, infestations can lead to 100% crop loss (http://www.fao.org/docrep/V9976E/v9976e07.htm).

E. integriceps is characterised by being of medium size (10-12 mm long) and with colour varying from grey to brown to reddish brown to black.

The symptoms of an infestation of *E. integriceps* are yellowing and dieback of the stem and leaves, and stunting of the growth of growing tips and buds. Feeding on other parts of the plant causes abnormal flower formation and discoloration. Cereal grains may be aborted if feeding occurs before grain development or, if feeding occurs after development, the grains are left shrivelled, discoloured (white) and/or empty.

E. integriceps is currently widely distributed in some parts of the near East and west Asia, is present in north Africa and has a limited distribution in other areas of the near East and west Asia. *E. integriceps* has not yet been recorded in Australia and entry potential is considered to be low.

Given the widespread distribution of cereal crops in Australia, a substantial food source exists for *E. integriceps*. Furthermore the pest is able to adapt to different circumstances. The Australian southern coastal forests and mountainous regions would provide suitable over-wintering sites and in those areas without dense forests and mountains, bushland surrounding cropping regions may be utilised instead. *E. integriceps* may also be capable of utilising native grasses. Most of the known primary and secondary host species are widespread in Australia, although the susceptibility of Australian cereal varieties is not known. Furthermore many genera of wild hosts utilised by *E. integriceps* have become established in Australia, though it is not known is the pest is able to complete a full developmental cycle on them.

1.1.2 Life cycle

E. integriceps has a single generation per year and individuals survive for up to one year. In the Northern Hemisphere in late summer/autumn (June-October), adult *E. integriceps* fly from the wheat fields at low altitudes (or other cereal based crops) to mountainous areas, to over-winter through sub-zero temperatures under low shrubs. In some regions the bugs can travel to altitudes as high as 2000 m above sea level (Critchley 1998). Other strains travel to forests, such as oak forests in Romania, to over-winter under the leaf-litter (Popov *et al.* 1996). In the mountainous regions there may be two stages of over-wintering. At the end of the first stage (aestivation) in mid-October, the bugs migrate to lower altitudes to escape the colder temperatures, and begin the second stage (Schuh and Slater 1995). *E. integriceps* adults over-winter for up to 9 months in total.

If over-wintering sites such as dense forest or mountainous regions are unavailable (e.g. around Baghdad, some regions of Syria and Ukraine), then *E. integriceps* can over-winter in the surrounding soil near fields (Brown 1965), and in weeds or litter under any available plant (Panafidin 1976). If established in Australia, *E. integriceps* may not migrate to over-wintering locations as these may be lacking in some localities (e.g. eastern and western Wheatbelts). In this case, the population size of the bug in a particular locality may depend, not upon dispersal of *E. integriceps*, but on weather conditions and proximity of crops to woodlands and grasslands (e.g. see Force *et al.* 1978).

Mating occurs at the end of over-wintering, usually requiring temperatures above 13^{0}C (Critchley 1998). The bugs migrate back to the cropping areas where they remain feeding from February to April (Javahery *et al.* 2000). The adults feed on crops and wild grasses (see Tables 2.1, 2.2 and 2.3) before seeds or grains develop. Eggs are deposited on the host-plant, weeds in the crop or even on pebbles on the ground. Females can lay an average of 200 eggs on wheat and 185 eggs on barley in their life time (Javahery 1996). Eggs hatch after 4-10 days depending on the climate (Talhouk 2002), during late May to July when seeds and grain are developing. During this time most remaining adults that have returned to the crops from over-wintering sites will die. Eggs are fragile and easily broken by mechanical damage.

There are 5 nymphal instars before *E. integriceps* reaches maturity. Each of the first four instars takes about 4-7 days to complete, with the final instar taking the longest time of 11 days. The development process from egg to adult is a minimum of 35-37 days but could be as long as 50-60 days depending on food availability and field conditions (Critchley 1998). Young instars feed on buds and leaves, hiding deep in the canopy of plants, presumably to avoid predation. Older instars and adults feed on the developing grain. If the grains finish maturing before *E. integriceps* individuals have reached maturity, then both adults and nymphs are capable of feeding on the dry grains, provided that moisture is available such as in the form of weeds, dew or rain (Banks *et al.* 1961; Brown 1962). Young adults will continue to feed until they have enough fat reserves for the over-wintering period. If cereals are harvested before *E. integriceps* has built up enough fat, then individuals migrate to surrounding fields and feed until they have enough reserves (Brown 1962). Densities on crops can reach up to 120 individuals per square metre in outbreak conditions (Popov *et al.* 1996), and have been as high as 1000 individuals per square metre in over-wintering sites (Critchley 1998).

E. integriceps can survive temperatures between –30°C to 45°C (Javahery 1996), and dies at about 49.5°C. In very hot conditions, *E. integriceps* populations will take refuge in cracks in the soil or beneath leaf litter at the base of plants (Banks *et al.* 1961).

After maturation, adults migrate to over-wintering sites. Not all individuals may migrate back to over-wintering and aestivation sites, some will remain in the fields. In situations where the last instars and young adults have failed to gain enough fat reserves to last throughout the aestivation and over-wintering period, they may not migrate at all (Brown 1965).

Adults survive for up to a year, depending on the minimum temperatures reached. The mortality rate is also influenced by the animal's fat reserves, which, if not adequate, will fail to support the bug throughout the entire aestivation and over-wintering period (Critchley 1998). The level of body fat also influences fertility, and thus, outbreaks of the species (Popov *et al*. 2004). When conditions are optimal, outbreaks of *E. integriceps* occur usually every 5-8 years (Javahery 2004). Outbreaks are most common when maturation of the grain and Sunn pest nymphs coincide, as the young adults can build up adequate fat reserves for over-wintering and the large majority will survive until the following spring (Skaf 1996).

A problem when assessing the risk potential of *E. integriceps* to Australia is the scarcity of information. Critchley (1998) noted that details of *E. integriceps* biology and ecology are limited by the majority of information being in the 'grey' literature such as unpublished reports. In addition, much of the literature is written in languages other than English. Unless this information is interpreted, future documentation of biology and ecology must rely on accounts of literature reviews conducted by other authors, and not on the original material.

1.1.3 Dispersal

Adult *E. integriceps* have functional wings that can allow longterm dispersal into new areas and new fields. Adult populations of some biotypes can migrate between 150-250 km. Wind borne dispersal is less likely and birds are not known to play a role. In areas of intensive cultivation or areas with a continuous presence (no more than 10 km gaps) of suitable hosts, adult insects may successfully disperse to adjacent cereal fields. The eggs and diapause stage of *E. integriceps* can survive for long periods without a host in cracks in soil, etc and can therefore be spread in machinery or equipment with soil contamination.

1.2 Affected Hosts

1.2.1 Host range

Avena, Secale, Sorghum, Triticum, Triticosecale, Hordeum. This cereal bug is found on several wild graminaceous plants such as *Agrostis, Bromous, Dactylis, Festuca, Lolium* and *Poa*. In the absence of these the insect can feed and develop on cultivated cereal plants, especially wheat. Gerini (1968) lists more than 15 species, of eight to nine families, of nongrain host plants. *E. integriceps* has also become adapted to a number of wild graminaceous species such as *Heteranthelium pliliferum*.

1.2.2 Geographic distribution

E. integriceps is widespread in Bulgaria, Greece, Romania, Southern Russia, Iran and Israel. It is present but with restricted distribution in Moldova, Western Siberia, Central and European Russia, Afghanistan, Iraq, Iran, Jordan, Lebanon, Pakistan, Syria and Turkey. It is also present in other European and Asian countries and in Algeria. *E. integriceps* has not been recorded in Australia to date.

1.2.3 Symptoms

Cereal crops infested with *E. integriceps* will display yellowing of the leaves and stems, with dead heart and subsequent dieback of whole plants. This first stage in crop damage is caused by adults after they exit the over-wintering stage. Wilting and death of new growth before the onset of flowering is also common. Nymphs emerge around seed onset and can cause abortion of the seed through feeding. This results in 'white ears' of wheat (Stamenkovic 1976). In these plants, the awns are characteristically perpendicular to the rachis and the grain is empty.

If seeds continue to develop, attack by *E. integriceps* can result in seeds that are shrivelled, discoloured (white) and eventually empty if feeding is constant. Often *E. integriceps* will continue to feed on seeds after they are harvested or drop to the ground. The grain in this condition is considered more nutritious than the younger grain, but *E. integriceps* can only feed on the dry grain if a water source is available, for example, in the presence of green weeds (Brown 1962). Feeding is indicated by a yellow (or opaque) spot with a black dot in the centre, which is the site of penetration (Stamenkovic 1976).

When bugs within the genera *Eurygaster* and *Aelia* (Hemiptera: Pentatomidae: *Aelia acuminata* L., *A. rostrata* Boheman and *A. klugi* Hahn) feed on grain, they produce saliva which assists in the penetration and begins pre-oral digestion of the grain contents. In New Zealand, the Lygaeidae bug *Nysius huttoni* Buchanan-White causes similar symptoms in wheat (Cressley *et al.* 1987). Both nymphs and adults are capable of feeding on grain. During digestion, degradation of the endosperm proteins by proteolytic enzymes in the saliva occurs (Sivri *et al.* 2004). These proteolytic enzymes remain in the grain after the bugs have finished feeding and continue to cause extensive damage to the endosperm proteins when the grain is milled (Hairiri *et al.* 2000). The attack on the endosperm proteins results in degraded gluten molecules and causes dough weakening (Cressey *et al.* 1987; Sivri *et al.* 2004). Dough is ruined for bread-making as it is weak and sticky, having lost its elasticity (Hairiri *et al.* 2000). The resulting bread has a reduced volume and an unusual heavy texture, as the dough does not rise in the oven and often burns. As little as 2-5% damaged grains can result in unacceptable dough (Hairiri *et al.* 2000; El Bouhssini *et al.* 2004).

1.3 Entry, establishment and spread

See Pest Risk Review for further information on the entry, establishment and spread potential and economic risk of *E. integriceps*. It should be noted that *E. maura* (L.) dominates *Eurygaster* populations in certain regions of Turkey and, as such, there is greater potential for this pest species to be imported with the commodities from these regions, rather than *E. integriceps*. However, such dominance may not continue in the future. In some regions *E. integriceps* has replaced other *Eurygaster* species in dominance over a period of 50 years or so (see Popov *et al.* 1996).

Entry potential: Medium

The probability of entry for *E. integriceps* is rated as **Medium** as natural introduction is considered unlikely given the current world distribution. Incursions through importation of commodities or through non-commodity pathways is unlikely for *E. integriceps*, given current quarantine procedures and lack of recorded incursions.

The most likely method of *E. integriceps* incursion into Australia is as a hitchhiker through the importation of commodities from the pest's host plants, and from regions in which *E. integriceps* is prevalent. The adults are relatively large and may be obvious in commodities. However, if individuals occur in low abundances in bulk cargo or bagged commodity, then detection may be difficult. Eggs and nymphs are much smaller and may escape unnoticed.

Establishment potential: Medium

The Australian climate is suitable for *E. integriceps* establishment and would promote regular outbreaks particularly in the cereal production areas of the eastern and western Wheatbelts, as the climate is comparable to *E. integriceps* current distribution and an abundance of primary host plants are available. In other countries, *E. integriceps* has continuously expanded its distribution with the cultivation of cereals and the species has displayed some plasticity in its ecology to accommodate establishment in new regions. The probability of establishment for *E. integriceps* is therefore **Medium**.

Spread potential*: *High

E. integriceps can migrate large distances as adults possess wings. One biotype of certain populations can migrate between 150 to 250 km (Brown 1965). However, given its current Northern Hemisphere distribution, it is highly unlikely that *E. integriceps* will enter Australia by wind dispersal. It is not transported by birds.

The climate of Australia is suitable for the spread of *E. integriceps* and coupled with the adults ability to fly, the probability of spread for *E. integriceps* is **High**

Economic impact: *Medium*

The impact on yield and cost of protection for *E. integriceps* is rated as **Medium** as, once established, *E. integriceps* may be impossible to eradicate and will require the implementation of Integrated Pest Management plans to contain outbreaks. The initial economic outlay in research, trials and implementation will be high. During this time, the loss of yield in cereal production regions due to *E. integriceps* may also be high. Historically, chemical control of *E. integriceps* has been expensive.

Overall risk: *Medium*

Specific action is required, generic risk treatment plans should be adopted as soon as possible in the interim.

1.4 Diagnostic information

1.4.1 Diagnostic protocol

Traditional taxonomic methods based on keys and descriptions are adequate for identification of *E. integriceps* adults. Nymphs will require rearing to adulthood for species determination. The descriptions in this pest data sheet are sufficient for identification of the pest, but only if examination of genitalia is performed for exact identification. Dorsal view image of *E. integriceps* is provided on http://www.invasive.org/images/768x512/5190030.jpg, and diagnostic images of other *Eurygaster* species on the Pest and Disease Image Library (PaDIL) web site (http://padil.museum.vic.gov.au)

Due to the variety of colour morphs, examination of a male specimen's genitalia is the only certain method of determination. Genitalia are only developed in the adult.

Egg characteristics are useful in distinguishing *Eurygaster* species, the eggs of *E. integriceps* are green, shiny, spherical, about 1 mm in diameter, and possess 16 – 23 micropylar processes.

1.4.2 Reference documents

- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

1.5 Response checklist

1.5.1 Checklist

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

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

1.5.2 Reference documents

- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

1.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of poor growth.

1.6.1 Sampling method

Field inspections should include a transect or track through a field that allows representative sampling of the entire field with, on average, one inspection site of 10 m^2 of plants per hectare. Plants should be assessed for the presence of insects and yellowing of the leaves and stems, with dead heart and subsequent dieback of whole plants.

The occurrence of the insects in cereal grain crops is usually recorded by routine inspection using a metric 50/50 cm frame or an entomological sweeping net. In countries where Sunn Pest is known to occur, wheat is assessed by inspecting 20-40 surfaces for insects on the plants. On the surface of the soil inspection is done using metric frames. In this way, the average density per square metre is established. Insect collection with sweeping net is more superficial, and leads to more approximate results because insects on the soil surface are not recorded.

For diagnostic purposes, adult and nymph *E. integriceps* can be hand collected into glass vials or vacuum collected either with vacuum sampler, or swept from foliage with a hand net. All life stages are normally found on the foliage. Mature nymphs for rearing to adults can be collected with plant material and kept in rearing cages in a constant temperature room for regular checking, if necessary plant material in rearing cages may need to be replaced with fresh material every few days.

Where possible it is advisable to collect a large number of specimens of all life stages. With adult stages collect a number of specimens of varying size and colour depicting variation in the morphology of the species. Collection of different life stages can assist in diagnosis. Also collect specimens in duplicate that are clean and in good condition i.e. that is complete with appendages such as antennae, wings and legs. Kill specimens by freezing for 24 hours. If live specimens need to be sent away for identification, carefully fold specimens in tissue paper and place in crush-proof plastic tube or container with several holes in the lid for ventilation. Label each sample clearly using an alcohol-proof marker. If possible retain and store a duplicate sample in a secure location.

1.6.2 Epidemiological study

In *E. integriceps,* fluctuations in population density from one year to another are related to the physiological conditions of the individuals as well as the biotic and abiotic ecological factors. Thus it is possible from a study of the physiological conditions of the internal organs to forecast the degree of abundance of Sunn pest during the forthcoming invasions of wheat fields. Survival of individual bugs depends on the quantity of food reserves from the time of migration to resting sites to the moment they return to the fields the following year in spring (Fedotov 1947-1960, Brown 1962, Popov et al. 1996). Changes in population density can also be observed by monitoring populations over consecutive years in cultivated fields and overwintering areas (Brown 1962, Martin et al. 1969, Javahery 1995).

The use of insecticides, and local movements after the main migration, may affect population densities, but in the overwintering areas the population densities are more constant (Brown 1962, Javahery 1995, Popov et al. 1996). This method was first used by Russian workers to forecast the population of *E. integriceps* (Fedotov 1947-1960). The estimates of population density in the overwintering areas appear to be more reliable than the data taken from fields. A long-term study of *E. ingegriceps* in two localities has provided valuable information on forecasting population densities and periodical outbreaks of this pest (Martin and Javahery 1968, Martin et al. 1969, Javahery 1995,1996).

1.6.3 Models of spread potential

There are no previously developed models / programs which depict spread potential given various factors.

1.6.4 Pest Free Area (PFA) guidelines

- Statistical field survey for symptoms on host plants.
- Plant and soil sampling using appropriate diagnostic tests.
- Survey around irrigation systems or waterways that may have transported insects as well as alternative host graminaceous plants such as *Agrostis, Bromous, Dactylis, Festuca, Lolium* and *Poa.*
- Aerial inspection or remote sensing should also be used where possible, with suspect patches inspected and sampled to confirm or deny the presence of the pest.

1.6.5 Reference documents

- *PLANTPLAN, Appendix 3: Sampling procedures and protocols for transport, diagnosis and confirmation of EPPs – Plant Health Australia (2006)*
- *Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.*

1.7 Availability of control methods

There are many different methods for controlling *E. integriceps* however, there is no attempt to eradicate *E. integriceps* in its current distribution, only to control outbreaks. The methods utilised for this purpose include chemical, biological, mechanical and cultural control.

In most countries where *E. integriceps* has regular outbreaks, the main control used is by chemicals as they are relatively cheap and easy to obtain and apply. The best sustainable Integrated Pest Management procedures include more sophisticated measures such as developing effective pheromone traps, mass releases of parasitoids, application of fungal and bacterial diseases and encouraging *E. integriceps* predators into affected regions.

Currently no holistic Integrated Pest Management procedure is conducted in cereal cropping regions of Australia. The methods listed above would fit into such an Integrated Pest Management strategy, however predators and parasites used to control *E. integriceps* in its current distribution could not be released into Australia without appropriate assessments, as these may target native fauna including Scutelleridae and Pentatomidae species. If possible, biological control species already present in Australia should be used to contain *E. integriceps*, such as native parasitic wasps and predatory Reduviidae species (e.g. Grundy and Maelzer 2000).

1.7.1 General procedures for control

- Keep traffic out of affected areas and minimize it in adjacent areas.
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms.
- Ensure that seed production does not take place on affected farms and do not use seed from these farms for human consumption.

1.7.2 Control if small areas are affected

In most countries where *E. integriceps* has regular outbreaks, the main control used is by chemical control of either insects or hosts. As the adults can fly, the response plan must consider the feasibility and practicality of removing host plants and will depend on results from delimiting surveys to assess the extent of establishment.

Other issues that need to be considered for controlling / managing the pest are minimising traffic movement through the infested area and adopting best practice hygiene to manage/control sources of inoculum (e.g soil, seed, wood, hay, stubble etc)

The best sustainable Integrated Pest Management procedures include more sophisticated measures such as developing effective pheromone traps, mass releases of parasitoids, application of fungal and bacterial diseases and encouraging *E. integriceps* predators into affected regions.

1.7.3 Control if large areas are affected

As above under section 1.7.2.

1.7.4 Cultural control

Other methods that are currently being developed for widespread use include cultural control methods such as planting crops early and planting cereal varieties which mature earlier (allowing grain harvest before the nymphs emerge) (El Bouhssini *et al.* 2004). Another method of decreasing the damage is to eliminate all weeds from fields with herbicides both before, and during, cereal crop growth, as green weeds are required to allow feeding on dry grains (Brown 1962; and see Section 5 – Biology, subsection "Symptoms of feeding damage"). In addition it may be able to use weeds as alternative hosts. Other management practices for the pest that have been effective overseas are: not leaving ripe, unharvested fields of wheat and barley left standing because of shortage of labour and of combine harvesters (Javahery 1995), and improved two-stage and quick (which takes only 5-7 days) harvesting method, which has proved to be a very effective and economic method of controlling this pests (Javahery 1995).

1.7.5 Host plant resistance

Recent results from experimental field studies in Iran have indicated varying levels of resistance to E. *integriceps* by certain wheat and barley varieties – some have high-level tolerance, some medium –level tolerance and others susceptible. Rezabeigi (1995) indicated that wheat varieties show less resistance to over wintering adults, nymphs and new adults.

Genetic manipulation of resistance in controlling *E. integriceps* is under investigation and early results are promising.

1.7.6 Chemical control

Chemical methods are the most widely used in countries with *E. integriceps* outbreaks. In total, approximately seven million hectares are treated chemically in affected regions each year (Popov 2004). Currently the pesticide Sumithion is used in many countries (e.g., Iran - Javahery 1996, Iraq – Zuwain and Al-Khafaji 1996), while organophosphates such as Trichlorfon based insecticides and synthetic pyrethroids are also used (e.g., Romania – Popov *et al.* 1996, Sheikh and Al Rahbi 1996). However, *E. integriceps* has been capable of developing resistance to each chemical used (Javahery 2004). For example *E. integriceps* developed resistance against DDT in 3 years, Lebaycid in 10 years, Sumithion after 12 years and Dipterex in 15 years (Javahery 1996). Most of these pesticides are still in use today, even though *E. integriceps* resistance reduces the effectiveness of control. The most commonly used pesticides in the last decade are synthetic pyrethroids, such as deltamethrin (Decis, Deltamethrin, Deltarin), because of their low mammalian toxicity and short persistence, thus allowing short intervals between spraying and harvesting (Critchley 1998). However, if *E. integriceps* populations remain below economic levels, then no chemical spraying is required (Mohyuddin 1996). This is the preferred option as insecticides reduce the populations of natural enemies, a situation that remains for several years (Rosca *et al.* 1996), and possibly promotes subsequent outbreaks of *E. integriceps*.

1.7.7 Mechanical control

Mechanical methods of control, such as harvesting eggs and adults from crops, or adults from over-wintering sites, would be labour intensive and costly in Australia, unlike in other regions of the world where such methods are practised because labour is cheap (e.g., Syria – Talhouk 2002). Burning the over-wintering sites is a more plausible solution in Australia given the evolutionary history native forest ecosystems have with fire. However, burning would not destroy the entire population and certain over-wintering sites would not permit burning, for example, mountainous regions. In addition, burning sites every year would change the natural vegetation composition and would not be a viable long-term solution.

1.7.8 Biological control

Much research has been directed at developing biological control agents, such as mass predator and parasitoid releases (see reviews by Voegelé 1996 and Rosca *et al.* 1996). To date only Iran practises biological control on a large scale due to their ability to collect copious *E. integriceps* individuals in hibernation and mass-produce eggs for rearing parasitoids (Skaf 1996). Another biological control agent, entomoparasitic fungi (*Beauveria bassiana*) has demonstrated potential as it kills bugs when other biological agents do not, i.e. during diapause (Parker *et al.* 2003; Bouhssini *et al.* 2004). Another control agent effective against *E. integriceps* is the microorganism *Bacillus thuringiensis.* Both *B. bassiana* and *B. thuringiensis* have been commercially prepared and applied for many years (e.g. Fedorinchik 1977).

1.7.9 Reference documents

- PLANTPLAN – Plant Health Australia (2006).
- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

2 Course of Action – Eradication Methods

2. 1 Destruction strategy

2.1.1 Destruction protocols

If containment, eradication and/or best practice hygiene measures are implemented, disposable equipment, infected plant material or soil should be disposed of by autoclaving, high temperature incineration or deep burial. Equipment removed from the site for disposal should be double-bagged. Other methods such as use of methyl bromide and phosphine may be suitable for destroying this pest however little international data exists on specific rates and treatments for Sunn Pest.

2.1.2 Decontamination protocols

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

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Mud free, including entry and exit points, (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as powerlines
- Waste water, soil or plant residues should be contained (see PLANTPLAN Appendix 18).
- Disposable overalls and rubber boots should be worn when handling infected soil or plant material in the field. Boots, clothes and shoes in contact with infected soil or plant material should be disinfected at the site or double-bagged to remove for cleaning.
- Skin and hair in contact with infested plant material or soil should be washed.
- Specific chemicals or treatments used to decontaminate equipment or personnel are provided in Section 3.4.6.

2.1.3 Priorities

- Confirm the presence of the pathogen.
- Prevent movement of vehicles and equipment through affected areas.
- Priority of eradication/decontamination of infected host material.
- Management of water flows through infected area.

2.1.4 Plants, by-products and waste processing

- Seed harvested from infected plants and infected plant material should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial (in a non-cropping area).
- Hay, straw or stubble should be destroyed by burning as eggs and occasionally overwintering / aestivating adults will survive for long periods in dry straw.

2.1.5 Disposal issues

- Particular care must be taken to minimize the transfer of infected soil from the area.
- Raking and burning infected crops is not an option as this procedure is likely to spread the pathogen greater distances.

2.1.6 Reference documents

- PLANTPLAN, Appendix 18: Disinfection and decontamination – Plant Health Australia (2006).
- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

2.2 Quarantine and movement controls

2.2.1 Quarantine priorities

- Plant material and soil at the site of infection to be subject to movement restrictions.
- Machinery, equipment, vehicles and disposable equipment in contact with infected plant material or soil to be subject to movement restrictions.
- Insects have wings and can move long distances, possibly making establishment of quarantine impractical.

2.2.2 Movement control for people, plant material and machinery

Movement controls are usually put in place for flightless pests/pathogens i.e. those that are principally moved as a result of contamination in plant material or soil.

If Restricted or Quarantine Areas are required, movement of equipment or machinery is to be restricted and movement into the Area is to occur by permit only. The industry affected will need to be informed of the location and extent of the disease occurrence. People, vehicle and machinery movements, from and to affected farms, will need to be controlled to ensure that infected soil or plant debris is not moved off-farm on clothing, footwear, vehicles or machinery. Clothing and footwear worn at the infected site should not leave the farm or they are thoroughly disinfected, washed and cleaned before wearing off-farm.

- While *E. integriceps* is a large insect, and therefore reasonably easily seen, adults and nymphs may still be present on vehicles and machinery used on the site. 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 hard standing or preferably a designated wash-down area to avoid mud being recollected from the affected site onto the machine. Any crop seed from the affected site should not be used for for planting new crops, feeding stock or for human consumption.

- Hay must not be removed from the site or used for feeding stock due to the risk of moving adults, nymphs or eggs.
- Insects have wings and can move long distances, making establishment of quarantine impractical.

2.2.3 Reference documents

- PLANTPLAN – Plant Health Australia (2006)
- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

2.3 Zoning

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

2.3.1 Destruction zone

The size of the destruction zone (i.e. zone in which the pest and all host material is destroyed) will depend on the ability of the pest to spread, distribution of the pest (as determined by delimiting surveys), time of season (and part of the pest life cycle being targeted) and factors which may contribute to the pest spreading. *E. integriceps* is a mobile pest and adults are known to fly long distances, hence strong fliers, hence establishment of a destruction zone would depend on distribution being believed to be restricted.

If destruction zones are established, all host plants within initial site of infection should be destroyed to reduce food source and/or refuge for Sunn Pest. In addition or alternatively, the Destruction Zone may be defined as contiguous areas associated with the same management practices as the infected area (i.e. the entire trial, paddock or farm if spread could have occurred prior to the infection being identified).

2.3.2 Quarantine zone

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

2.3.3 Buffer zone

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

2.3.4 Restricted Area

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

2.3.5 Control Area

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

2.3.6 Reference documents

- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.
- PLANTPLAN
- International Standards for Phytosanitary Measures No 1: Phytosanitary principles for the protection of plants and the application of phytosanitary measures in international trade (2006).

2.4 Decontamination and farm clean up

Decontaminant practices are aimed at restricting the movement of, and destruction of insects from growing media, equipment, tools or any media.

2.4.1 Decontamination procedures

2.4.1.1 General guidelines for decontamination and clean up

- Refer to PLANTPLAN Appendix 18 for further information.
- Keep traffic out of affected area and minimize it in adjacent areas.
- A list of best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms
- Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label.

2.4.2 General safety precautions

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

2.4.3 Reference documents

- PLANTPLAN, Appendix 18: Disinfection and decontamination – Plant Health Australia (2006).
- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

2.5 Surveillance and tracing

2.5.1 Surveillance

For diagnostics to determine Sunn Pest damage in harvested grain for trace-back, trace-forward or food safety purposes it may be possible to assess affected grain by taking and assessing subsamples from silos or farms to determine if feeding by Sunn Pest had occurred. In some cultivars, there is a tendency for gluten index volume to decrease with higher insect damage (Kostyukovsky and Zohar 2004) although this would need to be assessed in Australian cultivars. The *E. integriceps* damaged wheat seed has more water-soluble nitrogen (because of a decrease in glutenin and gladin), and this nitrogen has higher enzymatic activity than occurs in normal grain.

No known molecular tests for assessing grain affected by Sunn Pest were available at the time of document preparation.

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

Initial surveillance priorities include the following:

- surveying all properties/land with suitable hosts in the pest quarantine area;
- surveying properties identified in trace forward analysis as being at risk;
- surveying other host growing properties and backyards;
- surveying host growing properties that are reliant on trade with interstate or international markets which are sensitive to Sunn pest presence.

2.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (section 2.3), and prioritised based on their potential likelihood to currently have or receive an incursion of this pest. Surveillance activities within these regions will either: allow for the area to be declared pest free and maintain market access requirements; or establish the impact and spread of the incursion to allow for effective control and containment measures to be carried out.

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

Phase 1:

Identify properties that fall within the buffer zone around the infested premise.

Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action).

Phase 2:

Preliminary survey of host crops in properties in buffer zone establishing points of pest detection.

Phase 3:

Surveillance of an intensive nature to support control and containment activities around points of pest detection.

Phase 4:

Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the disease. Pathways to be considered are:

Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment;

The producer and retailer of infected material if this is suspected to be the source of the outbreak;

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);

Movement of plant material and nursery stock from controlled and restricted areas; and

Storm and rain events and the direction of prevailing winds that result in wind-driven spread of the insect during these weather events.

Phase 5:

Surveillance of nurseries, backyards and native and weed plants that may act as hosts or as refuge for Sunn Pest.

Phase 6:

Agreed area freedom maintenance, post control and containment.

2.5.3 Post-eradication surveillance

Specific methods to confirm eradication of *E. integriceps* may include:

- Use of pheromone traps is not possible at present. Kontev et al. 1978 reported the identification of sex pheromones of the *E. integriceps* Sunn pest from similarly trapped volatiles. Staddon *et al* 1994 and Abdollahi 1995 reported that males of this scutellerid attract nearby females with vanillin and ethyl acrylate, and identified the major component in male sex pheromone as a homosesquiterpenoid. Gries *et al.,* (unpublished) are further investigating isolation and identification of sex pheromones of this Sunn pest. At this stage, further experimental work is required that proves that caged virgin male *E. intergriceps* do indeed attract females, before available for use in pheromone traps.
- Surveys comprising soil or plant sampling for *E. integriceps* should be undertaken for a minimum of 12 months after eradication has been achieved. In cereals a routine inspection using a metric 50/50 cm frame or an entomological sweeping net may be adequate. In wheat crops, 20-40 surfaces are analysed for insects on the plants and on the surface of the soil using metric frames. In this way, the average density per square metre is established. Insect collection with sweeping net is more superficial, and leads to more approximate results because insects on the soil surface are not recorded.

2.5.4 Reference documents

- PLANTPLAN, Appendix 18: Disinfection and decontamination – Plant Health Australia (2006).
- Technical guidelines for the development of pest specific response plans – Dr Peter Merriman and Dr Simon McKirdy (2005), Plant Health Australia.

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4. http://www.invasive.org/images/768x512/5190030.jpg [image of *Eurygaster integriceps*]

Appendices

Appendix 1. Standard diagnostic protocols

For a range of specifically designed procedures for the emergency response to a pest incursion refer to Plant Health Australia's PLANTPLAN, Appendices 2 and 3.

Appendix 2 Experts, resources and facilities

The following table lists the experts who can be contacted for professional diagnostics and advisory services in the case of an incursion.

Expert	State	Details
Dr Mali Malipatil	Vic	Principal Research Scientist Department of Primary Industries PB 15, Ferntree Gully Delivery Centre Victoria 3156 Ph: (03) 9210 9222 mallik.malipatil@dpi.vic.gov.au
Mr Tom Weir	ACT	Principal Curator CSIRO Entomology GPO Box 1700 Canberra, A.C.T., 2601 Ph: (02) 6246 4267 Tom.Weir@csiro.au

The following table lists the facilities available for diagnostic services in Australia.

Facility	State	Details
DPI Victoria Knoxfield Centre	Vic	621 Burwood Highway Knoxfield VIC 3684 Ph: (03) 9210 9222 Fax: (03) 9800 3521
DPI Victoria Horsham Centre	Vic	Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111 Fax: (03) 5362 2187
DPI New South Wales Elizabeth Macarthur Agricultural Institute	NSW	Woodbridge Road Menangle NSW 2568 PMB 8 Camden NSW 2570 Telephone: (02) 4640 6327 Fax: (02) 4640 6428
DPI New South Wales Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100 Fax: (02) 6763 1222
DPI New South Wales Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999 Fax: (02) 6938 1809
SARDI Entomology Group - Waite Main Building, Waite Research Precinct	SA	Hartley Grove Urrbrae 5064 South Australia Ph: (08) 8303 9400 Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668 Fax: (07) 3896 9446
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721 Fax: (08) 9474 2658

Appendix 3. Communications strategy

A general Communications Strategy is provided in PLANTPLAN, Appendix 6.

Appendix 4 Market access impacts

Within the AQIS PHYTO database, the only country that appears to have a specific statement regarding area freedom from Sunn Pest is Brazil. Should Sunn Pest be detected or become established in Australia, other countries may require specific declarations.