Industry Biosecurity Plan for the Grains Industry
Threat Specific Contingency Plan

Sorghum shoot fly
Atherigona soccata

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1 Purpose of this Contingency Plan

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

2 Pest information/status

2.1 Pest details

2.1.1 General information

Taxonomic position – Class: Insecta; Order: Diptera; Family: Muscidae; Genus, *Atherigona*; Species, *soccata*

Atherigona soccata (Rondani, 1871)

Common names: Sorghum shoot fly, sorghum stem fly, millet stem fly

Atherigona soccata is recognised as the major species of shoot fly infesting sorghum. Larvae of this genus live as primary pests in the stems/shoot of grasses.

Atherigona soccata is almost certainly present in all the sorghum-growing areas in Africa, Asia and Mediterranean Europe. This species has not yet been reported in Australia, however damage by *A. soccata* has been observed in sorghum in Queensland, Australia (HC Sharma, unpublished data). Damage by *A. soccata* at the seedling stage (5 to 30 days after seedling emergence) leads to typical dead heart symptoms, whereby the maggot attacks cuts the growing point, and as a result the central leaf dries up forming a dead heart. If shoot infestation occurs under conditions of high humidity infested plants may not produce the typical dead heart symptoms and the damaged leaf becomes thin and papery and wraps around the other leaves. As a result, the plants may fail to grow normally.

Losses due to sorghum shoot fly vary between seasons and locations. The late sown crops generally suffer greater shoot fly damage because of build up of shoot fly populations on the early sown crops. The losses are aggravated with uneven rainfall resulting in staggered plantings.

2.1.2 Life cycle

Sorghum shoot fly populations are usually abundant during the rainy season under moderate temperatures and high humidity with an increase in populations generally recorded 20 to 30 days after the onset of monsoon rains. Population density is generally low during the hot dry summer in southern India and during the winter season in northern India. Sorghum shoot fly occurs in tropical and subtropical areas in Africa, the Mediterranean, Middle East, and South-East Asia as far east as the Philippines (Pont, 1973; CIE, 1973; Pont and Magpayo, 1995). Shoot-fly infestations are normally high in the post-rainy season crop planted in September-October. Temperatures above 35°C and below 18°C and continuous rainfall reduce shoot fly abundance (Taneja *et al.*, 1986). During the off-season, the insect survives on alternative hosts (*Sorghum* spp., *Echinochloa colonum, E. procera, Cymbopogon* sp., *Paspalum scrobiculatum* and *Pennisetum glaucum*), tillers of ratooned crops and volunteer/fodder sorghum.

Shoot fly females are attracted to the host plant for oviposition by the odours emitted from the host plant. Females of *A. soccata* are attracted both to the volatiles emitted by susceptible seedlings and to phototactic (optical) stimuli that facilitate orientation to the host for oviposition (Nwanze *et al*., 1998).

Females of *A. soccata* lay cigar-shaped eggs singly on the lower surface of the leaves, at the 1- to 7-leaf stage. Eggs are laid generally singly parallel to the midrib on the under surface of the 3rd to 5th leaf. Under high shoot-fly pressure, there may be several eggs on the same leaf. Sometimes, as many as 25 eggs may be laid on the same seedling. Most often, these eggs are laid by different females. Eggs are deposited parallel to the midrib and hatch in the early morning hours 2 to 5 days later (Sharma 1996). Three larval instars develop over a period of about one week at an average temperature of 27°C (Swaine and Wyatt 1954).

The larva migrates to the upper side of the leaf, moves along the leaf whorl reaching the growing point through the leaf sheath. The larva cuts the growing point, resulting in wilting and drying of the central leaf, known as dead heart. The larva feeds on the decaying plant tissue. The dead heart can be pulled out easily, and it produces an offensive smell. Normally, the damage occurs 1 to 4 weeks after seedling emergence. The damaged plants produce side tillers, which may also be attacked. Larval development is completed in 8-10 days, and pupation takes place mostly at the base of the stem, and sometimes in the soil. The pupal period lasts for 8 days in south India, and up to 14 days in north India (Sharma 1996). The pupae stage lasts for 7 to 10 days.

Under favourable temperature (20-30°C) and relative humidity (>60%), the life cycle is completed in 15 to 18 days (Srivastava 1985).

The adults are dark brown and similar to domestic housefly, but nearly half the size with the males smaller than the females. The adults usually live for 10 to 20 days. Adult longevity is quite variable and depends on environmental conditions and the availability of host plants (Sharma 1996).

Sorghum shoot fly populations may be recorded throughout the year, and there may be 15 to 16 generations in a year. In more temperate areas (e.g. Italy) there may be 5 to 6 generations (Bene 1986). Priyavratha Rao and Narasimha Rao (1956) indicated that there is no diapause during the off-season, and the adults hide in the stubble of the ratooned sorghum. In Italy, overwintering takes place as a mature larva or pupa (Bene 1986).

2.1.3 Dispersal

- Even though adult sorghum shoot flies have functional wings capable of flight that can allow dispersal into new areas and new fields, adults have been recorded to disperse only short distances. However, if strong winds are present adult flies can be displaced hundreds of kilometres in a day.
- In areas of intensive cultivation or areas with a continuous presence (gaps of no more than 10 km) of suitable hosts, adult insects may successfully disperse to adjacent grain fields.
- Sorghum shoot fly eggs, larvae and pupae can be readily transported with agricultural products in infested seedlings, soil, shipping containers or vehicles carrying agricultural produce.
- The pupal stage of this pest can survive for long periods without a host in dry soil and can therefore be spread in seed, machinery or equipment with soil contamination.

2.2 Affected hosts

2.2.1 Host range

Cultivated sorghum, *Sorghum bicolor* is the preferred host of Sorghum Shoot Fly (Davis and Seshu Reddy 1981). It can develop on many grasses particularly Johnson grass, *Sorghum halepense*. Other host grasses include *Brachiaria, Cynodon, Echinochloa, Eragrostis, Panicum, Pennisetum, Setaria* and other *Sorghum* spp. and can even develop on wheat and corn although cereals other than sorghum are unimportant as hosts for multiplying *A. soccata* (Davis and Seshu Reddy 1981; Gahukar 1991).

Sorghum halepense is by far the most important alternative host plant other than the cultivated sorghum (Davis and Seshu Reddy 1981). The wide range of wild grass hosts emphasizes the adaptability and potential danger of this insect (CABI 2007).

2.2.2 Geographic distribution

Atherigona soccata is probably present wherever sorghum is grown in countries where this crop originated (Sharma 1996). It occurs in the Mediterranean area (Srivastava 1985), Africa (Seshu Reddy 1991), India (Srivastava 1985), China (Shie *et al*. 1981; Gahukar 1991), Thailand (Meksongsee and Chawanapong 1985), Vietnam (Waterhouse 1993), and Philippines but is absent from Taiwan and Indonesia (Pont and Magpayo 1995). It does not appear to be present in North or South America.

2.2.3 Symptoms

Damage by *A. soccata* at the seedling stage (5 to 30 days after seedling emergence) will lead to the typical dead heart symptoms. The larva migrates to the upper side of the leaf, and moves along the leaf whorl until it reaches the growing point where the larvae cut the growing point. As a result the central leaf dries up forming a dead heart, which can be pulled out easily and produces a rotting smell. Normally the damage occurs 1 to 4 weeks after seedling emergence. Seedlings of 5 to 30 days old are generally susceptible to shoot fly damage. Older plants (>30 days after seedling emergence) are not usually damaged by *A. soccata* however, under conditions of high humidity during the rainy season, infestation may occur. Under these conditions the infested plants do not produce the typical dead heart symptoms. In this instance, the damaged leaf becomes thin and papery, wrapping around the other leaves. The plants may fail to grow normally. Late infestations may also damage the panicle in the formative stage, resulting in rotting or drying up of a portion of the panicle affected by shoot fly damage.

As a result of damage to the growing point, the damaged plant produces side tillers, which often serve as a means of recovery for the plant unless the tillers are exposed to another infestation of *A. soccata* in the susceptible stage (0 days after initiation of tiller production) (CABI 2007).

Some seedlings may not have typical symptoms, but still produce side tillers in response to temperature or moisture stress. Some genotypes have an inherent capacity to produce more tillers.

2.3 Entry, establishment and spread

There is little scope for the movement of this insect from one region to another, except through live sorghum seedlings. There may be some short-distance movement through adult migration/dispersal. It is probably for this reason that this insect has not spread to areas where sorghum is grown in Australia (CABI 2007). The invasive pest may enter Australia via imported plant material containing leaves, seedlings or material for propagation, where the eggs and larvae are borne internally.

Entry potential: Medium

Eggs, larvae, pupae and adults should not escape normal quarantine inspection although pupae can be present in soil and pant material in improperly cleaned equipment. The Philippines is the closest country to Australia with established populations. There is a low probability of the fly moving through Indonesia or New Guinea of its own accord.

Establishment potential: High

If the female fly arrives on the northern coastline of Australia, in order to establish they would have to be mated and find a suitable host. Sorghum shoot fly has a high reproductive rate (15 to 18 day life cycle in optimum conditions) with the potential to produce many generations in a season and for this reason the likelihood of establishment is high.

Spread potential: High

Suitable hosts of wild sorghum and many grasses are spread throughout the sorghum growing area. Adult flies can be displaced hundreds of kilometres in a day on strong winds.

Economic impact: Medium

A. soccata is considered a key pest of sorghum (Young and Teetes 1977). Where *A. soccata* occurs it is listed among the most important pests: Africa (Seshu Reddy 1991), Eastern Africa (Seshu Reddy and Omolo 1985). It is considered to be the worst sorghum pest in southern China (Shie *et al*. 1981). In Australia, throughout the sorghum production area, it would probably reach damaging levels and require chemical control in most years.

Environmental impact: Negligible

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

Overall risk: Medium

2.4 Diagnostic information

2.4.1 Diagnostic protocol

Shoot flies are identified by microscopic examination of adult flies. Pont (1973) and Pont and Magpayo (1995) give a comprehensive description of *A. soccata* males and females. The most important diagnostic characters are the male hypopygial prominence and trifoliate process.

The adult fly is about 4 mm long, looks like a small house fly, head and thorax of female are pale grey, the abdomen is yellowish with paired brown patches, and the male is more blackish. The larvae are 8-10 mm long, have white or yellowish colour. The eggs are white, elongate in shape and measure 0.8 X 0.2 mm.

A. soccata can be distinguished by the presence of yellow palpi in the males, and dark brown interfrontalia. The male has the fore femur entirely yellow, fore tarsus without erect hairs, and the wings with a dark smudge around the tip of sub-costa (Pont, 1973). The stripes on the scutum are poorly

developed, fore tibia is usually only darkened at the tip, fore tarsus mainly yellow, and tergites 1 + 2 and 5 have no dark spots. The hypopygial prominence has a pair of lateral branches, which are usually truncated. Species of *Atherigona* are most easily and reliably identified by the male genetalia. Because of the close similarity between species in external features, and the tendency for certain characters, colour and pattern to vary, the male genitalia need to be dissected for identification. The trifoliate process is dark brown, and with distinctly sloping shoulders. There is some variation in the width of the median piece and in the outline of its tip.

In females, the fore-legs are mainly dark brown, femur yellow, and tibia yellow on basal third. The shape of the tergite 8 is of importance, and can be used for a reliable separation from *A. oryzae*, as is the shape of the sternite 7; tergite 8 is brown, darker on the anterior margin, and divided into the usual three lobes, and with a pair of small, separated, anterioir sclerites, the lateral lobes narrow, median broad and shorter, and apically concave and almost straight (Pont (1973); Pont and Magpayo (1995)).

No diagnostic protocol is available.

2.5 Response checklist

2.5.1 Checklist

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

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

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

2.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of poor growth, particularly where the seedlings have died. The extent of the survey beyond the initial infected crop should be guided by the test results from the surrounding crops. As sorghum shootfly can survive on wild grass hosts it may be necessary to include the adjoining grasslands and pastures in the survey.

2.6.1 Sampling method

Adults of sorghum shoot fly *A. soccata* can be observed resting on the under surface of leaves, and can be caught in a fishmeal baited square pan or plastic jar trap (Taneja *et al*., 1986). The presence of white cigar-shaped eggs on the under surface of the leaves, and dead hearts at the seedling stage (1 to 4 weeks after seedling emergence), can be used to detect shoot fly infestation. The presence of maggots in the damaged shoots can be used to confirm the shoot fly damage, but note that other species of Diptera (e.g. Chloropidae) also infest stems and may cause primary damage or secondary damage alongside *A. soccata*.

Sampling method can be taken from the Grains Industry Biosecurity Plan 'Diagnostic protocol for the detection of leafminers' prepared by Malipatil & Wainer (2006). Any personnel collecting insect or leaf 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 available within PLANTPLAN, Appendix 3 (Plant Health Australia 2008a).

Number of specimens to be collected

A large sample of specimens would be preferable. The aim is to obtain an adult male. Adult females are identifiable with certainty only to genus level; therefore males are needed to examine genitalia details to confirm species identification.

Preferred stage to be collected

Of the four life stages (egg, larva, pupa and adult) only adults are identifiable to species using morphological features.

How to collect

Adult sorghum shoot flies are found resting on the under surface of leaves and can be caught in a fishmeal baited square pan or plastic jar trap. Adult flies can be hand collected into glass vials or vacuum collected either with vacuum sampler, or swept from foliage with a hand net.

The leaves and seedlings containing pupae or mature larvae could also be collected in a large jar for rearing in the laboratory for obtaining adult shoot flies. They need to be kept in a constant temperature room and checked regularly for emergence of adult flies.

How to preserve sorghum shoot flies

Adults and larvae can be placed in 70% ethanol and stored indefinitely, although their colour fades gradually with time. Specimens required for molecular diagnostic work should be killed and preserved in absolute ethanol or frozen (-80°C).

How to transport sorghum shoot flies

Vials of ethanol should be sealed to avoid leakage and packed with cushioning material in a strong box.

2.6.2 Epidemiological study

The degree of spread would depend on the amount of time the pest was present prior to detection. Due to its short life cycles (possibly 16-18 generations per year) the rate of increase could be high. It is unknown how far adults will travel to find a food source. Points to consider within the epidemiological study of sorghum shoot fly are provided in Section 2.6.4.

2.6.3 Models of spread potential

No modelling data are available for spread of sorghum shoot fly in broadacre cropping.

2.6.4 Pest Free Area (PFA) guidelines

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

- Design of a statistical delimiting field survey for symptoms on host plants and for the presence or absence of Sorghum shoot fly adults or larvae.
- Plant and soil sampling using appropriate diagnostic tests.
- Survey around irrigation systems or waterways that may have transported the pest.

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

2.7 Availability of control methods

The cryptic nature of the pest hidden on the underside of the leaf and below the 'deadheart' near growing point in leaf whorl makes treatment difficult and therefore a combination of control measures are needed for successful eradication. Good hygiene methods are encouraged, including isolation of newly imported material to prevent any pest associated with a consignment spreading to other crops.

2.7.1 General procedures for control

- Keep traffic out of affected areas and minimize it in adjacent areas. For irrigated crops, stop irrigating affected areas. Use bunding to divert overland flood flows in both irrigated and dryland crops.
- Adopt best-practice farm hygiene procedures to retard the spread of the insect between paddocks and adjacent farms. Do not move soil from infested paddocks to non-infested paddocks.
- To minimise the build up of shoot fly populations, paddocks should be ploughed after crop harvest and shortly before sowing, and crop residues should be collected and destroyed before the onset of rains to reduce carry over from one season to the next.
- Early and uniform sowing reduces the damage by sorghum shoot fly.

- Cultural pest control operations such as high seeding rates, balanced fertilizer application, field sanitation, weeding and intercropping with legumes reduce the damage by shoot fly but will not necessarily eradicate the pest.
- Sowing with shoot fly-resistant cultivars such as M 35-1, Swati, CSV-15R and Phule Yashoda during the post-rainy season will aid pest management.
- Overseas researchers have shown insecticide and seed treatment methods are also effective at reducing sorghum shoot fly populations.

2.7.2 Control if small areas are affected

- Minimizing traffic movement
- Adopting best practice hygiene
- Spraying/removing hosts (indication of area that would need to be managed around initial infection).
- Soil may contain pupae so should not be moved around, and hay / stubble should be destroyed by burning
- Shoot flies are abundant during rainy season under moderate temperatures and high humidity.

2.7.3 Control if large areas are affected

If large areas were affected control methods would be similar to the control of small areas. There may also be some scope for area wide management through cultural practices (see below).

2.7.4 Cultural control

Crop husbandry practices to suppress shoot fly populations are best suited for sorghum growing countries of Africa and Asia. Some of the cultural practices that can be used to minimise shoot fly infestation are found in CABI (2007) and are:

Sowing date

- Infestation can be reduced by early sowing, 7-10 days before the onset of monsoon rains, to avoid the active period of shoot fly emergence. If early sowing is not possible then use high seed rate to compensate for later thinning out of the dead hearts from infested fields.

Nutrient management

- Shoot fly damage can be influenced by factors that affect plant growth. The application of nitrogen fertiliser and the biofertiliser *Azospirillum* together with the physical characteristics of the soil and moisture content can affect plant growth and influence shoot fly incidence.

Plant density

- Plant stand has a significant effect on shoot fly infestation. High seeding rate helps reduce shoot fly damage. Seedlings under high planting density have narrow leaves, which are less attractive for egg laying.

Intercultivation / weeding

- Intercultivation can reduce pest populations by exposing the pupae to parasite predators and other adverse environmental factors.
- Pull out infested seedlings and alternate hosts such as fodder sorghums and grasses and their residues, and then destroy by burning.

Crop rotation

- Crop rotation can minimise pest damage by confusing the insects with chemical aromas emitting from non host plants, and using crop combinations that encourage the activity and abundance of natural enemies.
- It has been shown that shoot fly damage is reduced when sorghum is intercropped with leguminous crops.
- Fallowing and a closed season will reduce the carryover and build-up of the shoot fly from one season to the next.

Field sanitation

- Fallowing removes insects from their natural hosts reduces the carry over and build up of pests from one season to another.

2.7.5 Host plant resistance

Host plant resistance is an important component for the management of this pest in all areas where the sorghum shoot fly is a pest. Trials in southern Africa and Asia have shown significant differences in resistance to this pest damage among varieties tested. Some varieties in southern and eastern Africa have been identified as being medium to high level resistant to attack by sorghum shoot fly.

2.7.6 Chemical control

Prior to the application of any chemicals to control the pest, an investigation will be required to confirm that chemicals identified below are registered and approved for use on the pest and/or host. New registrations for the use of chemicals can be obtained from http://www.apvma.gov.au. General enquiries on chemical use can be made to APVMA (Australian Pesticides and Veterinary Medicines Authority) Ph: (02) 6210 4700.

Care must be taken with the organophosphates as some are phytotoxic to sorghum. Carbaryl, carbofuran, fenvalerate and endosulfan can be used to control sorghum shoot fly. Dusts, granules or sprays may be applied, depending on the time and mode of application (Kundu *et al.* 1978).

In India a number of chemicals have been used for the control of this pest – treating the seeds before sowing with imidacloprid or chlorpyriphos or monocrotophos; application of carbofuran or phorate at time of planting in the rows, or spraying with endosulfan after the emergence of seedlings (Sharma *et al.* 1996).

There are no chemicals currently registered in Australia for the control of this pest.

2.7.7 Mechanical control

Mechanical cultivation can reduce pest populations by exposing the pupae to parasites and predators, and other adverse environmental factors.

2.7.8 Biological control

There is very little information available on the role of natural enemies in population dynamics of *A. soccota* and the extent of parasitism/predation. A range of natural enemies attack the sorghum shoot fly in other countries – parasitic wasps attack eggs and larvae, and predators cause high mortality of eggs. Some spiders are important predators on eggs. Some important parasitoids are *Trichogramma simmondsi* and *T. chilonis* (on eggs), *Neotrichoporoides nyemitawus, Aprostocerus* sp., *Opius* sp. and *Spalangia endius* (on larvae). Mass rearing techniques are available only for *T. chilonis* (Singh and Sharma 2002).

3 Course of action – Eradication methods

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

3.1 Destruction strategy

3.1.1 Destruction protocols

- Disposable equipment, infected plant material or soil should be disposed of by autoclaving, high temperature incineration or destroyed by deep burial. Any equipment removed from the site for disposal should be double-bagged.
- Herbicides could be used to destroy the infected crops or pastures.
- Infected crops or pastures could be ploughed in.
- Insecticides could be used to destroy the pest.
- Farm machinery used in destruction processes need to be thoroughly washed, preferably using a detergent such as Decon 90.

3.1.2 Decontamination protocols

If containment, eradication and/or best practice hygiene measures are implemented, machinery, equipment, vehicles in contact with infected plant material or soil or present within the Quarantine Area, should be washed to remove soil and plant material using high pressure water or scrubbing with products such as a farm degreaser disinfectant or a 1% bleach (available chlorine) 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
- Site, including entry and exit points should be mud free (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines
- Waste water, soil or plant residues should be contained (see PLANTPLAN 2008 Appendix 18).
- Disposable overalls and rubber boots should be worn when handling infected soil or plant material in the field. Boots, clothes and shoes in contact with infected soil or plant material should be disinfected at the site or double-bagged to remove for cleaning.
- If hands, skin or hair have been in contact with infested plant material or soil they should be washed.
- Decon 90 (Enviroequip) is a suitable detergent for using to decontaminate equipment or personnel.
- All chemicals used according to label.

3.1.3 Priorities

Specific priorities for eradication

- Confirm the presence of the pest.
- Prevent movement of vehicles and equipment through affected areas.
- Priority of eradication/decontamination of infected host material.
- Control sorghum shoot fly populations to prevent further spread.
- Inform all groups within the industry.
- Determine the extent of infection through survey.

3.1.4 Plants, by-products and waste processing

- All infested seedlings and alternate / susceptible host material such as grasses should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial.
- Infected paddocks should be ploughed in to remove food and decrease larval survival (see 2.7.7).
- Also hay, stray or stubble residues should be collected and destroyed after harvesting by burning to reduce carry-over of pest from one season to another.

3.1.5 Disposal issues

- Once introduced and established, pupae can survive in soils for long periods, even in the absence of plant hosts and thus be difficult to eradicate.
- Particular care must be taken to minimize the transfer of infected soil and trash from the area.
- Raking and burning infected crops is not an option as this procedure is likely to spread the eggs, larvae and pupae greater distances during the raking phase.

3.2 Quarantine and movement controls

3.2.1 Quarantine priorities

- Plant material and soil at the site of infection to be subject to movement restrictions.
- Machinery, equipment, vehicles and disposable equipment in contact with infected plant material or soil to be subject to movement restrictions.
- Adult sorghum shoot flies have wings and can move short distances making establishment of quarantine practical.

3.2.2 Movement control for people, plant material and machinery

Once established sorghum shoot fly will be difficult to eradicate. Therefore, any zoning, quarantine or movement controls will usually pertain to containment and management unless detection occurs soon after establishment.

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

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

Examples of movement controls include:

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

3.3 Zoning

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

3.3.1 Destruction zone

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.

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

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

Particular care needs to be taken to ensure that soils and plant material are not moved into surrounding areas not showing symptoms of disease, as eggs or larvae can remain on seedlings and pupae can sometimes remain in the soil.

3.3.2 Quarantine zone

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

3.3.3 Buffer zone

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

3.3.4 Restricted Area

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

3.3.5 Control Area

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

3.4 Decontamination and farm clean up

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

3.4.1 Decontamination procedures

General guidelines for decontamination and clean up

- Refer to PLANTPLAN (Plant Health Australia 2008) for further information.
- Keep traffic out of affected area and minimize it in adjacent areas.
- Adopt best-practice farm hygiene procedures to retard the spread of the 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 Decon 90 detergent, a farm degreaser or a 1% bleach solution in a designated wash down area as described in 3.1.2.
- Only recommended materials should be used when conducting decontamination procedures, and should be applied according to the product label.

3.4.2 General safety precautions

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

3.5 Surveillance and tracing

3.5.1 Surveillance

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

Initial surveillance priorities include the following:

- Survey of all properties in the quarantine area with known hosts;
- Survey of all properties identified in trace-forward analysis as being at risk;
- Survey of all host growing properties that are reliant on trade with interstate or international markets which may be sensitive to Sorghum shoot fly presence;
- Survey of all commercial nurseries selling at risk host plants; and
- Survey of other host growing properties and backyards.

3.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (section 3.3) for Sorghum shoot fly, 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 and pastures 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 pest. 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 soil from controlled and restricted areas; and
- 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 Sorghum shoot fly are being grown.

Phase 6:

Agreed area freedom maintenance, pest control and containment.

3.5.3 Post-eradication surveillance

Specific methods to confirm eradication of Sorghum shoot fly may include:

- Monitoring of sentinel plants using soil from the paddock is undertaken. Sentinel plants are to be grown in pots using soils removed from the affected site that may contain sorghum shoot fly pupae. Plants are to be grown under quarantine containment glasshouse conditions and monitored for symptoms of infection.

- Surveys comprising soil and plant sampling for Sorghum shoot fly to be undertaken for a minimum of 12 months after eradication have been achieved. This pest has short life cycle, hence surveys may need to be repeated every 3 - 4 weeks.
- Balanced fertilizer application, reduce use of organic manure (eg cattle manure) as is known to attract adult shoot flies.

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5 Appendices

Appendix 1. Standard diagnostic protocols

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

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 Ph: (02) 4640 6327; Fax: (02) 4640 6428
DPI New South Wales Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
DPI New South Wales Wagga Wagga Agricultural Institute	NSW	PMB Wagga Wagga NSW 2650 Ph: (02) 6938 1999; Fax: (02) 6938 1809
SARDI Plant Research Centre - 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
CSIRO Entomology (identification capability)	ACT	PO Box 1700 Canberra ACT 2601

Appendix 3. Communications strategy

A general Communications Strategy is provided in PLANTPLAN

Appendix 4. Market access impacts

Within the AQIS PHYTO database, no countries appear to have a specific statement regarding area freedom from Sorghum shoot fly. Should Sorghum shoot fly be detected or become established in Australia, some countries may require specific declarations. Latest information can be found within PHYTO, using an Advanced search "Search all text" for Sorghum shoot fly (October 2008).