INDUSTRY BIOSECURITY PLAN
FOR THE GRAINS INDUSTRY

Threat Specific Contingency Plan

Spotted stem borer

Chilo partellus

Prepared by Kalang Consultancy Services Pty Ltd

and Plant Health Australia

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Plant Health AUSTRALIA

GRDC Grains Research & Development Corporation

CRC PLANT biosecurity

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1 Purpose of this Contingency Plan

This Contingency Plan provides background information on the pest biology and available control measures to assist with preparedness for an incursion into Australia of Spotted stem borer (*Chilo partellus*). 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

Chilo partellus (Swinhoe, 1885)

Other names; *Chilo zonellus* (Swinhoe, 1884); *Argyria lutulentalis* (Tams, 1932); *Crambus zonellus*

Common names: spotted stem borer; spotted stalk borer; durra stalk borer; pink borer; spotted sorghum stem borer

2.1.1 General information

Taxonomic position – Phylum: Arthropoda; Class: Insecta; Order: Lepidoptera; Family: Crambidae;

The spotted stem borer (*Chilo partellus*) is one of the most important and destructive pests of sorghum and maize in India (Jotwani and Young 1972) and in East and Southern Africa (Atwal 1976) causing widespread damage, particularly in the warmer lowland areas in Africa (Van Hamburg 1979). *C. partellus* invaded Africa from Asia sometime before 1930 when it first arrived in Malawi (Tams 1932). Since arriving it has spread to most countries in East and Southern Africa. Its damage levels can reach 75% crop loss and if left uncontrolled total crop failure may occur (Latif et al 1960). There is also evidence that in some locations the exotic stem borer is displacing indigenous stem borer species (Overholt et al 1994).

The plants can be affected at the flowering stage, post-harvest, seedling stage, as well as the vegetative growing stage (CAB 2007). Plant parts affected include the fruit/pods, growing points, leaves, stems or the whole plant (CAB 2007). In young plants the shoot can be killed, causing a “dead heart”. In older plants the upper part of the stem usually dies as a result of the boring of the caterpillars.

In external appearance, *C. partellus* can resemble other species of *Chilo* (Bleszynski 1970), but can be distinguished from them by diagnostic characters of the male and female genitalia. *C. partellus* is most closely related to *C. tamis*, a species from southern India.

C. partellus infestations are detected by walking through crops looking for characteristic holing of funnel leaves, the presence of dead hearts and holes in tunnelled stems. Samples of affected stems can then be removed and dissected to retrieve larvae and pupae, from which adults can be reared for identification (CAB 2007).

Two parasitic wasps that attack stem borers were introduced from Asia to East Africa for biological control of *C. partellus*. *Cotesia flavipes* attacks caterpillars of the spotted stem borer and *Xanthopimpla stemmator*, a wasp, attacks the pupa of stem borers. *Cotesia flavipes* has caused a 32-55% decrease in stem borer densities (Kfir et al 2002).

C. partellus has a shorter development period than the indigenous stem borer *C. orichalcociliellus* (Ofomata et al 2000). A study in Kenya showed that *C. partellus* had a higher fecundity than *C. orichalcociliellus* at 25^{o}C and 28^{o}C, but not at 31^{o}C. In addition more *C. partellus* eggs survived to the first instar stage with the larvae developing faster than *C. orichalcociliellus* in maize and sorghum. This shorter development stage explains the species competitive advantage over the slower developing *C. orichalcociliellus* (Ofomata 2000).

Many cereal stem borers have a resting period (diapause) towards the end of the cropping season, spent as fully grown caterpillars in dry crop residues. *C. partellus* can develop continuously all year round in regions where there is sufficient water and an abundance of host plants. In other regions, with long dry periods in winter or in summer, the borer enters into a resting period. In Kenya, *C. partellus* diapauses for several months in the dry season, however, populations without a resting period have also been reported from the coastal regions of Kenya and Uganda. Nonetheless in the coastal areas of Kenya in periods between cropping, some stem borers may diapause in maize stubble whilst others remain active migrating to alternate hosts and wild host grasses close by, where they survive during the non cropping dry season (Songa et al 2002).

2.1.2 Life cycle

The eggs are laid on the underside of a leaf near the midrib in 3-5 rows, in groups of 50-100. The eggs are flat, oval, creamy white in colour and about 0.8 mm in length. The eggs hatch 4 - 8 days later. The young larvae (caterpillars) produce characteristic leaf windowing. After a few days they bore down inside the funnel, and then move outside the stem and then back in again once above the internode. In older plants the larvae can also live in the developed heads. The larvae are up to 25 mm long when fully grown, with a prominent reddish-brown head. The body is creamy white to yellowish-brown in colour, with purple-brown longitudinal stripes and usually with very conspicuous dark-brown dorsal spots. The prothoracic shield is reddish-brown to dark-brown, shining and with a pale medial furrow. Prominent dark-brown plates give the larvae its characteristic spotted appearance. The larval period takes 28-35 days (CAB 2007).

Pupation occurs in a small chamber within the stem. Female pupae are up to 15 mm long, slender, shiny and light yellow-brown to dark red-brown, with bands of small spines on the dorsal anterior margins of the fifth to seventh abdominal segments and with six dorsal spines and two large, thorn-like flattened ventral spines on the last abdominal segment. The pupal period takes 7-10 days.

Adults emerge from pupae in the later afternoon or early evening and are active at night. Adult moths rest on plants and plant debris during the day and are seldom seen, unless disturbed. Females release a pheromone to attract males then mate soon after emergence from the pupae. Two or three days after emergence each female lays 200 to 600 eggs in separate batches.

Adults are relatively small moths with wing lengths ranging from 7 to 17 mm. Females are generally larger than males and both sexes rest with the wings folded over the abdomen. The forewings are generally light yellow-brown with some darker scale patterns forming longitudinal striations which are usually darker at the wing margins. The hindwings are white.

The whole life cycle takes between 3 and 4 weeks, sometimes longer in colder months and shorter in warmer months. There can be at least 6 generations per year in areas with suitable climates, such as Southern India, but in less favourable areas larvae pass the winter or dry season in diapause in stems

and stubble. They may remain inactive in the diapause phase for up to six months, before pupating and completing their development early in the following growing season.

C. partellus has been shown to be an efficient coloniser. The stem borer survives the dry winters (with subzero temperatures) by diapausing low in the dry stalks, often beneath the soil. Hibernating populations of *C. partellus* terminate diapause emerging as moths about 1 month earlier than the indigenous *Busseola fusca* stem borer. Emerging earlier enables *C. partellus* to infest the grain sorghum crop before the indigenous species thus becoming the predominant borer. The life cycle of *C. partellus* is also 3 weeks shorter than the indigenous species, giving a further competitive advantage because of its higher potential rate of increase Kfir (1997).

A recent study in North-East Pakistan showed that overwintering population of *C. partellus* varied between 19 and 29% (Ashfaq and Farooq-Ahmad 2002).

2.2 Affected hosts

2.2.1 Host range

Chilo partellus is an important pest of cultivated cereals, especially maize (*Zea mays)*, sorghum (*Sorghum bicolour)* and pearl millet *(Pennisetum glaucum)*. It has also been recorded from rice (*Oryza sativa*), foxtail millet (*Setaria italic*), finger millet (*Eleusine coracana*) and sugar cane (*Saccharum officinarum*), as well as from many grasses of the Poaceae family including *Sorghum halepense*, *Sorghum verticilliflorum*, *Panicum maximum*, *Pennisetum purpureum*, *Hyparrhenia rufa, Vossia cuspidata* and *Rottboellia compressa*.

2.2.2 Geographic distribution

C. partellus is native to Asia, but became established in East Africa in the 1950s. Since then it has spread to Southern and Central Africa.

2.2.3 Symptoms

Leaves show irregular scars, holes and windows caused by the feeding of *C. partellus* larvae. Seriously affected plants, especially young plants, dry up entirely or partly showing the ‘dead heart’ symptom due to the death of central leaves. They later feed at the growing point, which may then be killed. Older larvae tunnel extensively in stems and in maize cobs, weakening the stems, which may break and dislodge. Damage to inflorescences may interfere with grain formation, causing chaffy heads in sorghum. Similar symptoms can also be produced by other species of cereal stem borer. Early attacked plants are stunted in growth and the ears are poorly developed. Stem tunnelling by older caterpillars interferes with transference of nutrients to the grain. Stem borer damage results in plant stunting, lodging, stem breakage and direct damage to ears. Infestations increase the incidence and severity of stalk rots and may increase the contamination of grains with toxin producing fungi.

Symptoms on affected plant parts are varied.

- Fruit/pods can be affected by both internal and external feeding
- Growing points are damaged by internal feeding, boring and the development of ‘dead heart’
- Leaf damage caused by internal feeding followed by the development of honeydew or sooty mould

- Stem damage is caused by internal feeding and development of 'dead heart'
- Whole plant damage results in development of 'dead heart'

2.3 Entry, establishment and spread

2.3.1 Entry potential

Rating: Low

With due consideration of the biology of *C. partellus* the most likely modes of entry of this pest into Australia would be through the movement of host plant material, and to a smaller extent, through natural movement of the pest into Australia from South-East Asia. A lesser, but still significant, pathway for entry is trade in used machinery.

The host plant material mode of entry can be considered to include both legal and illegal importations of host plant material. Neither the major or minor hosts of *C. partellus* are commonly traded as ornamentals or cut flowers and foliage, leaving trade in germplasm, artefacts and material for manufacturing/processing as the most likely legal importation pathways.

Trade in germplasm of the hosts of *C. partellus* is typically restricted to seed for sowing, except for the case of sugarcane germplasm where setts are commonly traded. *C. partellus* is not known to be associated with seed for sowing, excluding this pathway from further consideration. Existing AQIS import requirements for *Saccharum* spp. setts are strong and effectively manage the risk of *C. partellus* and other stem borers entering Australia via this pathway.

Similarly, existing Australian Quarantine and Inspection Service (AQIS) import requirements for artefacts and plant material for manufacturing/ processing provide effective risk mitigation to greatly minimise the potential for *C. partellus* to enter Australia via these pathways.

AQIS conditions for imported machinery are designed to manage the risk of contaminating organisms, plant material, soil and other quarantinable debris entering Australia via this pathway. Key to this management regime is the requirement for a high degree of cleanliness of imported machinery which is managed through an intensive audit regime.

The potential for entry of *C. partellus* into Australia through illegal imports is managed through the regulation and screening of traded commodities into Australia's seaports and airports. An alternative route is via the illegal movement of host plant material into Northern Australia from South East Asia. Northern Australia Quarantine Strategy (NAQS) and the Northern Australian states have strategies in place to detect the entry of this, and a range of other target organisms, into Australia via this route. These strategies are also aimed at early detection of these organisms should they enter Northern Australia through natural dispersal mechanisms.

Taking into consideration the potential pathways of entry of *C. partellus*, along with existing Australian regulatory controls of these pathways and natural dispersal mechanisms of this organism, the potential for entry into Australia is considered to be **low**.

2.3.2 Establishment potential

Rating: Medium

The geographical range of hosts (both major and minor) within Australia is relatively large, providing a suitable range for establishment of this pest should it enter Australia and reach these areas. Sallam

and Allsopp (2002) developed extensive match indices for *C. partellus* establishment in sugar cane production areas in Australia. These match indices were derived from climatic conditions in various countries in Asia and Africa throughout the natural and introduced range of *C. partellus*, and show marked variations in establishment estimates for sugar cane production areas in Australia. In their estimate they explain this variation in establishment potential in Australia as being dependent upon which biotype is introduced.

While there are marked variations in match indices for potential establishment in Australia the studies of Sallam and Allsopp (2002) show clear overlaps in establishment potentials. In consideration of the tropical and sub-tropical range of *C. partellus* in its native and introduced range, its previously considered establishment potentials in Australian sugar cane production areas, and the range of suitable hosts (both commercial and wild), the establishment potential for *C. partellus* in Australia is considered to be **medium**.

2.3.3 Spread potential

Rating: High

The literature (e.g. Kfir et al 2002) provides an account of the spread of *C. partellus* through Africa in the 20th century. Following its initial identification in Malawi in the 1930s, and subsequent identification in Tanzania in the 1950s, this organism has now spread through Botswana, Ethiopia, Kenya, Lesotho, Mozambique, Somalia, South Africa, Swaziland, Zambia and Zimbabwe.

The spread potential of *C. partellus* in Australia is largely dependent on the location of its introduction and at what stage the incursion is detected. If the incursion occurs in a commercial production area and remains undetected the spread potential may be enhanced by the ready availability of host crops, movement of the pest as a contaminant of host material and machinery, and its ability to naturally disperse. Where the introduction occurs in non-commercial areas and or remote areas the spread potential may be restricted due to limitations in host plant availability, limited movement as a contaminating organism and its natural dispersal ability.

The spread potential of *C. partellus* in both of these scenarios will also be dependent on the biotype of the organism and its ability to adjust or adapt to the ensuing conditions in the region of introduction. While it is not clear how many introductions occurred in the African continent resulting in the widespread distribution of the organism there, it is inferred in the literature that the organism as a species is readily able to spread into less optimal areas and adjust to those conditions. An example of this is its ability to respond to its environment by entering diapause in Southern Africa where winters are cooler and dryer, whereas in the warm low-lying areas in South Africa no diapause takes place (Kfir et al 2002).

From a review of the available literature the spread potential (in relation to commercial production areas) for *C. partellus* in Australia is estimated to be high where no specific quarantines are in place. Spread potential within and between remote and isolated host reservoirs is estimated to be low. The overall spread potential would conservatively be estimated to be **high**.

2.3.4 Economic impact

Rating: High

C. partellus is a major pest of maize, sorghum and pearl millet in Asia and in parts of Africa where it has become established. It has been shown to be generally less important but locally troublesome on rice, sugarcane and other crops. Its importance as a pest is growing in Southern Africa. Kfir (1997)

showed that *C. partellus* populations have overtaken other stemborers as an important pest, even at higher altitudes than the coastal regions where it had first become established. In East Africa it is acquiring greater importance and becoming more successful than indigenous congeners (Ofomata et al 2000). Studies in Kenya investigating yield infestation relationships on maize (Reddy and Sum 1992) and the development of predictive estimations of maize loss in South Africa (Bate et al 1992) show the economic implications of *C. partellus.*

Kfir et al (2002) provides an interesting overview of losses experienced throughout Africa due to this pest. South African yield losses in both maize and sorghum due to this pest are estimated to exceed 50%. Similar or higher yield losses are experienced in other African countries; in Mozambique third-generation *C. partellus* larvae have been reported to infest 87% of late planted maize cobs and 70% of grain crops. In particular Provinces in Mozambique 100% plant infestation resulting in considerable yield losses has been recorded.

High levels of damage are common throughout resource-poor production areas in Africa where costs preclude the use of insecticides. Kfir et al (2002) summarises a 50-60% yield loss for sorghum and 30-70% infestation rate in maize in resource-poor areas in Zimbabwe. Corresponding yield losses in commercial production areas where insecticides are used are less than 30%.

The high yield losses experienced in Africa due to the introduction and spread of *C. partellus* demonstrate the destructive potential of this stem borer should it establish and spread in Australia. While a range of management tools are currently available to reduce yield losses due to *C. partellus* these tools may be costly or not always applicable in an Australian production context. The estimated economic impact for *C. partellus* should it be introduced and spread in Australia is **high**.

2.3.5 Environmental impact

Rating: Very Low

During a review of the literature no studies into the impact of *C. partellus* on the environment, following its introduction and spread in Africa, could be identified. A reasonable level of research into *C. partellus* associations with native vegetation in Africa has been conducted, however, this research has been directed at gaining an understanding of potential host reservoirs and the evaluation of alternate hosts for use as trap crops. Other studies have concluded that *C. partellus* has the ability to displace (through competition) other native stem borer species.

Researchers in Africa (for example, Berg 2006, Khan et al 2006) have demonstrated that when given the option (e.g. through two-choice tests) *C. partellus* will preferentially oviposit on wild host crops such as *Pennisetum purpureum* than on commercially produced maize crops. This preferential oviposition behaviour works in the favour of maize producers as these wild host crops act as trap crops for the pest by lowering the pest pressure on commercial crops. An additional advantage is the low survival rate of immature stages of *C. partellus* on these trap crops.

A number of these native wild host species (e.g. *P. purpureum*, *P. ciliare* and *P. clandestinum*) have been naturalised in Australia, predominantly for the purpose of providing forage for cattle. An introduction of *C. partellus* into Australia would be expected to have an impact on these naturalised species should it spread within their range. *P. alopecuroides* is a *Pennisetum* species native to Australasia, and similarly it would be reasonable to expect that *C. partellus* would have an impact on this species. No information is available as to the effects *C. partellus* has had on ecosystems where it has attacked wild hosts in Africa, however, it is assumed the impact would be minimal.

If introduced into Australia there is potential that *C. partellus* could attack native Poacea species, particularly those with characteristically thicker stems (see Songa et al 2002). However, it would be

reasonable to expect that overall damage (apart from some aesthetic value) to these species would be minimal.

Based on an assessment of the limited information available the potential environmental impact of *C. partellus* on ecosystems in Australia is assessed to be **very low**.

2.3.6 Overall risk

Rating: Medium

Using the Biosecurity Australia (2001) Risk Estimation Matrix as a guide, the overall risk estimate for *C*. *partellus* is **medium**. This risk estimate does not factor in the estimated environmental risk of very low.

2.4 Diagnostic information

2.4.1 Diagnostic protocol

No diagnostic protocol exists for *C. partellus*.

Traditional taxonomic methods based on keys and descriptions are adequate for identification of *C. partellus*. In coloration and general appearance *C. partellus* resembles many other species of *Chilo* and can only be identified accurately by examination of the male and female genitalia. Illustrated descriptions can be found in Polaszek (1998). Bleszynski (1970) has also published technical descriptions of adults including illustrated descriptions of the male and female genitalia.

The male genitalia have a median, strong tapering projection on the edge of the valve. The juxta plate has a large triangular central lobe, two basal notches and lateral arms not extending dorsally to the edge of the valve. The aedeagus has a bulbous basal projection and a ventral arm.

The female genitalia have a heavily sclerotized and swollen ostial pouch which is longitudinally wrinkled and deeply notched caudally between two semi-circular lobes. There is no bridge linking the ostial pouch with the eighth tergite, and the posterior apophyses are not dilated. Further details can be found in Betbeder-Matibet (1990).

2.5 Response checklist

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

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

- Zoning
- Reporting and communication strategy

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

2.6 Delimiting survey and epidemiology study

Delimiting surveys should comprise local surveys around the area of initial detection concentrating on areas of poor growth. Delimiting surveys are useful to determine the extent of spread of the pest and provide information for review and further development of the Response Plan.

2.6.1 Sampling method

C. partellus infestations are detected by walking through crops looking for characteristic holing of funnel leaves, the presence of dead hearts and holes in tunnelled stems. Leaves and leaf sheaths should be carefully examined for eggs and young larvae. Samples of affected stems can be removed and dissected to retrieve larvae and pupae, from which adults can be reared for identification. This method can also be used for the detection of *C. partellus* in older crops or crop residues.

As other stem borers cause similar symptoms retrieval of caterpillars and pupae, and confirmation of their identity by rearing adults for identification, is essential to ensure correct diagnoses.

Songa et al (2001) provide a protocol used for the mass-rearing of stem borers in Kenya which is useful background information for the purpose of rearing immature *C. partellus* specimens for identification purposes.

2.6.1.1 NUMBER OF SPECIMENS TO BE COLLECTED

As large a number of specimens as possible should be collected to allow examination of genitalia to confirm species identification.

2.6.1.2 PREFERRED STAGE TO BE COLLECTED

Of the four life stages (egg, larva, pupa and adult) only adults are readily identifiable to species using morphological features. Sallam and Allsopp (2002) provide an overview of the morphological characteristics of *C. partellus* larvae, however, identification of adults is much more reliable.

2.6.1.3 HOW TO COLLECT

Adult moths can be hand collected into glass vials by sweeping from foliage with a hand net. Eggs and young larvae can be collected on leaf material while older larvae and pupae can be collected through dissecting infested stem material.

2.6.1.4 HOW TO COLLECT PLANT SAMPLES IF REQUIRED

Leaves and stems with suspect infestations should be picked and placed between sheets of newspaper to permit slow drying. For laboratory rearing of adult moths, leaves and stems containing

pupae or mature larvae can be collected in a large jar and kept in a constant temperature room for regular checking.

2.6.1.5 HOW TO PRESERVE PLANT SAMPLES

Leaves and stems with larvae can be stored between sheets of dry newspaper. This will assist to keep specimens intact while helping to remove excess moisture from the plant material which may encourage the growth of pathogens and mould.

2.6.1.6 HOW TO PRESERVE MOTHS

Sallam and Allsopp (2002) recommend that *Chilo* spp. samples be preserved in 95+% ethanol. Ethanol is not, however, an ideal preservation medium where DNA analysis of specimens is to be undertaken. Recent work by Mandrioli et al (2006) demonstrated that acetone is the more preferred wet preservation medium for lepidopteran specimens where DNA preservation is required. In addition to the DNA preservation qualities of acetone this medium is suitable for use at room temperature and is effective at preserving morphological features of specimens.

Where taxonomic expertise is readily available and identification can be carried out quickly it may be more practical to keep the moths alive or kill and relax the insect immediately prior to transport.

2.6.1.7 HOW TO TRANSPORT MOTHS

Vials containing the samples in a preservative should be sealed to avoid leakage and packed in a manner to minimise shock to the vials. It is important to ensure that vials are filled with preservative so as to remove excess air which, through movement of the vial, will allow agitation of the preservative and quickly degrade the specimen.

Live insects should be packaged in a strong, sealed container.

A word of caution on both methods:

- Where a quarantine situation occurs special authority will be needed to remove live exotic insects from the quarantine area
- Transport/airline regulations may preclude the transportation of ethanol or acetone. Contact the relevant transport authority or company for advice

2.6.1.8 HOW TO TRANSPORT PLANT SAMPLES

Leaves and stems with suspect pupae or larvae should be mailed as a flat package between sheets of dry newspaper. Special authority will be needed to remove live exotic insects from the quarantine area.

2.6.2 Epidemiological study

Any epidemiological study of *C. partellus* will need to consider the biology of the pest (including survival potential, rate of reproduction and methods/rates of dispersal) along with biotic and abiotic factors of its environment (including host plant availability, climate, geographical features, predators, parasites and pathogens).

2.6.3 Models of spread potential

No pre-designed model is available to predict the spread of spotted stem borers.

2.6.4 Pest Free Area (PFA) guidelines

The establishment and maintenance of pest free areas can be a resource-intensive process. Prior to development of a pest free area due consideration should be given to alternative methods (eg. treatments, enclosed quarantine) that achieve an equivalent biosecurity outcome to a pest free area. A benefit-cost analysis is useful for this purpose.

Where an evaluation justifies the establishment and maintenance of a pest free area the requirements of ISPM No. 4 (IPPC 1995) should be met. In defining and establishing the pest free area due consideration of the biological characteristics of *C. partellus*, along with the climatic and geographic features of the area, will need to be given.

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

There are a number of methods available for the control of stem borers including sanitation, the use of insecticides, management of habitat, intercropping and the use of biological control agents. Selection of control methods, and combinations of methods, may be dependent on whether the infestation occurs in a commercial production area or non-commercial area. Selection of control methods may also depend on whether the infestation is localised or widespread.

2.7.1 General procedures for control

- Keep traffic out of affected areas and minimize movement in adjacent areas
- Adopt best-practice farm hygiene procedures to retard the spread of the pest between fields and adjacent farms
- Stop irrigating affected (irrigated crops) areas and use bunding to divert overland flood flows around them (both irrigated and dryland crops)
- After surveys are completed, destruction of the infested crop is an effective control
- Quarantine areas quickly put in place to restrict and control the movement of regulated articles (eg. host plant material, soil and machinery) within and out of the affected area
- On-going surveillance of infested paddocks to ensure *C. partellus* is eradicated

2.7.2 Control if small areas are affected

Where the incursion is restricted to a small area the likelihood of eradication is generally greater than for a large area. Initial control efforts should presume eradication is the aim.

2.7.3 Control if large areas are affected

Where the incursion has spread extensively control efforts may be targeted towards containment rather than eradication. The decision to eradicate or contain will need to be made on a case-by-case basis.

2.7.4 Cultural control

Practice good crop hygiene, this includes the destruction of crop residues (stems and stubbles). Remove volunteer crop plants and/or alternative hosts. This reduces carryover of stem borers from one growing season to the next, and will help limit the most damaging attacks on young crops early in the growing season.

Burning of crop debris breaks the life cycle by destroying larvae that hibernate inside stalks and plant material. It has been suggested that the partial burning of stalks will result in the killing of 95% of larvae, a practice not yet adopted by West African farmers (Adesiyum and Ajays 1980). Where previous cultivation practise has depended upon crop debris adding organic matter to the soil to maintain soil structure, other organic material input methods need to be developed.

Damage avoidance by manipulation of sowing dates may also be used to avoid periods of peak adult activity. However, this is not practical in situations where lack of water is a major constraint as farmers often plant after first rains.

Studies on several stem borers in Africa showed that soil nutrient levels, such as nitrogen, greatly influenced nutritional status of the plant and the plant's tolerance to stem borer attack. Although an increase in nitrogen is related to higher pest level loads and tunnel damage, there is also an increase in plant vigour with a net benefit to the plant as reflected in lower yield loses (Sétamou et al 1995; Mgoo et al 2006).

Intercropping maize with cowpea is an effective way of reducing damage by the spotted stem borer caterpillars migrating from neighbouring plants. Intercropping maize with molasses grass (*Melinis minutiflora*), a non-host for stem borers, will also reduce stem borer infestation on maize. This grass produces volatile agents which repel stem borers but attract the parasitic wasp *Cotesia sesamiae* (**www.infonet-biovision.org/default/ct/92/pests**).

Planting an outer encircling row of some highly preferred hosts to act as a trap plant is also useful for the management of stem borers. Examples of trap plants are Napier grass *(Pennisetum purpeum)* and Sudan grass (*Sorghum vulgare sudanense*), which are common fodder plants in Africa. Napier grass for example, is highly attractive to egg laying moths, but only a few caterpillars complete their lifecycles on it. When they enter the stem the plant produces a gummy substance that kills the caterpillars. Thus Napier grass provides natural control of stem borers by acting as a trap crop attracting moths.

In Africa a 'Push-Pull' strategy has been developed combining use of intercropping and trap crop systems where farmers used Napier grass and the legume *Desmodium* as intercrops.

2.7.5 Host plant resistance

Host plant resistance is a likely tool for managing *C. partellus*. As part of a PhD thesis (Javed 2005) 400 different exotic and indigenous maize germplasm accessions were screened for resistance to *C. partellus*, with 95 accessions surviving. Breeding for resistance to stem borer was discussed 18 years earlier at a workshop in India (Agrawal and Taneja 1989) and in later years by Kishore (1992) and Elbadawi et al (1997).

2.7.6 Chemical control

Granular formulations of benfuracarb, carbofuran and furathiocarb were evaluated as soil applications at planting in maize field trials in South Africa and were found to be effective in the control of *C. partellus*, *Busseola fusca* and *Cicadulina mbila*. These chemicals provided effective residual protection over most of the pre-tasseling period (Van Rensburg et al 1991). Because of the cost, use of chemical control is rarely justified in low input agricultural systems (Ingram 1958; Mathez 1972). In addition, the boring characteristic of the larvae protects them against the sprays and hence regular sprays may be required which subsistence farmers in developing countries cannot afford (Sithole 1989). Good control responses in India were obtained using Quinalphos 5G and endosulfuran 4G (Katti and Verma 1988).

2.7.7 Mechanical control

Destruction of alternative host plants and deep ploughing of crop residues can assist with control as adults experience difficulty in emerging from puparia buried deeply in soil. In South Africa, slashing maize and sorghum stubble was found to result in the destruction of 70% of the *C. partellus* population in these crops. Subsequent ploughing and discing was found to destroy a further 24% of the population (Kfir et al 2002).

The effects of tillage on reducing stem borer populations are a combination of the damage it inflicts on larva/pupae (through either direct damage, burial in the soil or exposure to adverse weather) along with exposing larvae to natural enemies such as birds, rodents and spiders (Kfir et al 2002).

2.7.8 Biological control

There are a number of known natural enemies of cereal stem borers in East Africa including parasitoids of eggs, larvae and pupae. Predators like ants, spiders, earwigs, nematodes and microbial pathogens have also been reported to attack different life stages under various natural conditions. In general, evidence has shown that indigenous natural enemies are unable to keep stem borer populations below economic injury levels (Bonhof et al 1997). Natural enemies successful in controlling *C. partellus* include the pathogen *Bacillus thuringiensis kurstaki* and the parasitoid *Cotesia flavipes*. *B. thuringiensis kurstaki* attacks stem borer larvae and *Cotesia flavipes* has been successful in attacking stem borer larvae in Kenya, Pakistan, South Africa, Uganda and Tanzania (CAB 2007). Parasitoids mentioned in the literature are usually members of the Hymenoptera and Diptera families. Information on the biology of the main genera and species has been recorded in the papers of Smith et al (1993) and Polaszek (1998). Recent research work on stem borers has been focusing on the introduction of exotic parasitoids in countries where *C. partellus* is widespread. *Cotesia flavipes* is a small wasp that acts by locating the stem borers while the stem borers are feeding inside the plant

stems. The wasp lays about 40 eggs into the stem borer. Once they hatch the larvae of the parasitic wasp feed internally in the stem borer before exiting and spinning cocoons.

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, infested plant material or soil should be disposed of by autoclaving, high temperature incineration or deep burial
- Any equipment removed from the site for disposal should be double-bagged
- 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 or farm degreaser

3.1.2 Decontamination protocols

Machinery, equipment and vehicles in contact with infested plant material or soil or present within the Quarantine Area should be washed (or alternatively steam cleaned) 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. General guidelines for wash down areas are as follows:

- Located away from crops or sensitive vegetation
- Readily accessible with clear signage
- Access to fresh water and power
- Mud free, including entry and exit points (e.g. gravel, concrete or rubber matting)
- Gently sloped to drain effluent away
- Effluent must not enter water courses or water bodies
- Allow adequate space to move larger vehicles
- Away from hazards such as power lines

- Waste water, soil or plant residues should be contained (see Appendix 18 of Plant Health Australia (2008))
- Disposable overalls and rubber boots should be worn when handling infested soil or plant material in the field. Boots, clothes and shoes in contact with infested soil or plant material should be disinfested at the site or double-bagged to remove for cleaning. Non-disposable clothing should be washed in hot water at 60°C or higher (Sallam and Allsopp 2002)
- Skin and hair in contact with infested plant material or soil should be washed

3.1.3 Priorities

- Confirm the presence of the pest
- Prevent movement of vehicles and equipment through affected areas
- Priority of eradication/decontamination of infected host material

3.1.4 Plants, by-products and waste processing

- Infested plant material should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial
- All straw from susceptible hosts should be destroyed by burning as pupae can survive for long periods in dry straw

3.1.5 Disposal issues

- Particular care must be taken to minimize the transfer of infested soil or plant material from the area as eggs, larvae and pupae may have been inadvertently deposited in/on the soil in plant debris.

3.2 Quarantine and movement controls

3.2.1 Quarantine priorities

- Plant material and soil at the site of infestation to be subject to movement restrictions
- Machinery, equipment, vehicles and disposable equipment in contact with infested plant material or soil to be subject to movement restrictions

3.2.2 Movement control for people, plant material and machinery

Movement controls need to be put in place to minimise the potential for translocation of the pest as a contaminant of plant material, soil or other articles.

Movement of people, vehicle and machinery, from and to affected farms, must be controlled to ensure that infested soil or plant debris is not moved off-farm on clothing, footwear, vehicles or machinery. The following measures can be used to effect controls on movement:

- Signage to indicate quarantine area and/or restricted movement in these zones
- Fenced, barricaded or locked entry to quarantine areas
- Movement of equipment, machinery, plant material or soil by permit only
- Clothing and footwear worn at the infested site should either be double-bagged prior to removal for decontamination or should not leave the farm until thoroughly disinfested, washed and cleaned
- Hay, stubble or trash must not be removed from 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 a hard surface, preferably a designated wash-down area, to avoid mud being re-collected from the affected site onto the machine

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 or pasture should be destroyed after the level of infestation has been established. The delimiting survey will determine whether or not neighbouring host crops are infested and need to be destroyed. The Destruction Zone may be defined as contiguous areas associated with the same management practices as the infested area (i.e. the entire trial, paddock or farm if spread could have occurred prior to the infestation being identified).

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

Decontamination 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 a detergent, a farm degreaser or a 1% bleach solution in a designated wash down area as described in 3.1.2

3.4.2 Decontamination if pest is identified in a small or large areas

Where crop residues are left *in situ* for any reason regular applications of an effective insecticide should be made until the residues are destroyed.

3.4.3 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:

- Surveying all host growing properties in the pest quarantine area
- Surveying all properties identified in trace-forward or trace-back analysis as being at risk
- Surveying all host growing properties that are reliant on trade with interstate or international markets which may be sensitive to *Chilo* spp. presence
- Surveying commercial nurseries selling at risk host plants
- Surveying other host growing properties, backyards and abandoned fields

3.5.2 Survey regions

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

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

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

Phase 1	• Identify properties that fall within the buffer zone around the infested premise • Complete preliminary surveillance to determine ownership, property details, production dynamics and tracings information (this may be an ongoing action)
Phase 2	• Preliminary survey of host crops in properties in buffer zone establishing points of pest detection
Phase 3	• Surveillance of an intensive nature, to support control and containment activities around points of pest detection

Phase 4	• Surveillance of contact premises. A contact premise is a property containing susceptible host plants, which are known to have been in direct or indirect contact with an infested premises or infected plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the disease. Pathways to be considered are: ○ 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 ○ Storm and rain events and the direction of prevailing winds that result in air-born dispersal of the pathogen during these weather events
Phase 5	• Surveillance of nurseries, gardens and public land where plants known to be hosts of pathogen are being grown
Phase 6	• Agreed area freedom maintenance, pest control and containment

3.5.3 Post-eradication surveillance

The period of pest freedom sufficient to demonstrate that eradication of the pest has been achieved will be determined by a number of factors, including the life cycle duration of the stem borer species concerned (in relation to temperature), whether the pest is known to be able to enter diapause in the prevailing climatic conditions of the area, cropping conditions, the previous level of infestation and the control measures applied. As a guide, the period of pest freedom required to confirm eradication should be no less than two generations of the pest.

- Establishment of sentinel plants at the site of infestation
- Maintain good sanitation and hygiene practices throughout the year
- The monitoring traps or sentinel plants should remain in place and be inspected on a fortnightly basis for a further 6 weeks and then on a monthly basis
- Surveys comprising plant sampling for *C. partellus* to be undertaken for a minimum of 12 months after eradication has been achieved

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4.1 Websites

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Insect Pests of Cereals in Ethiopia (**ethiopia.ipm-info.org/insect_pests_ethiopia/Chilo_partellus.htm**)

IPM World textbook (**ipmworld.umn.edu/chapters/overholt.htm**)

Infonet BioVision (**www.infonet-biovision.org/default/ct/92/pests**)

5 Appendices

Appendix 1. Standard diagnostic protocols

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

Appendix 2. Experts, resources and facilities

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

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

Expert	State	Details
Dr Andrew Mitchell (for DNA analysis)	NSW	Research Leader Biotechnology NSW DPI – Wagga Wagga Agricultural Institute (02) 6938 1931 **andrew.mitchell@dpi.nsw.gov.au**
Dr Marianne Horak (for morphological ID)	ACT	CSIRO Entomology Australian National Insect Collection (02) 6246 4259 **Marianne.Horak@csiro.au**

Table 3. *Diagnostic service facilities 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 SA 5064 Ph: (08) 8303 9400; Fax: (08) 8303 9403
Grow Help Australia	QLD	Entomology Building 80 Meiers Road Indooroopilly QLD 4068 Ph: (07) 3896 9668; Fax: (07) 3896 9446
Department of Agriculture and Food, Western Australia (AGWEST) Plant Laboratories	WA	3 Baron-Hay Court South Perth WA 6151 Ph: (08) 9368 3721; Fax: (08) 9474 2658

Appendix 3. Communications strategy

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

Appendix 4. Market access impacts

Within the AQIS PHYTO database, no countries appear to have a specific statement regarding area freedom from *C. partellus* (March 2009). Should *C. partellus* 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 *Chilo partellus.*