INDUSTRY BIOSECURITY PLAN
FOR THE GRAINS INDUSTRY

Threat Specific Contingency Plan

Corn earworm

Helicoverpa zea

Prepared by Kalang Consultancy Services Pty Ltd

and Plant Health Australia

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Plant Health AUSTRALIA

GRDC Grains Research & Development Corporation

CRC PLANTbiosecurity

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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 corn earworm (*Helicoverpa zea*). 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 (Plant Health Australia, 2008) and be endorsed by the National Management Group prior to implementation.

2 Pest information/status

2.1 Pest details

Helicoverpa zea (Boddie, 1850)

Other Names: *Heliothis zea* Boddie, *Heliothis armigera auct.nec Huebner* Hübner, *Bombyx obsoleta* Fabricius, *Chloridea obsoleta* Fabricius, *Heliothis ochracea* Cockerell, *Heliothis umbrosa* Grote, *Phalaena zea* (Boddie)

Common Names: Corn earworm, American cotton bollworm, bollworm, New World bollworm, sorghum headworm, tomato fruitworm, vetchworm

2.1.1 General information

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

Helicoverpa zea is a major agricultural pest that feeds on a number of different crop species, including corn, cotton, sorghum, tomatoes and beans. The common name used is dependent on the crop it has infested. For example, it is known as the cotton bollworm when found on cotton and the corn earworm when feeding on corn. *H. zea* is prevalent throughout, and limited to, North and South America, with widespread infestations in the USA, Mexico, Ecuador, Paraguay, Chile, Uruguay and Trinidad and Tobago (CAB, 2007). In the USA, *H. zea* is responsible for major losses in crop yield, including cotton (Chilcutt et al., 2003) and tomato (McLeod et al*.,* 1996). Major losses are particularly evident when infestation occurs late in the growing season (Chilcutt et al*.,* 2003).

Infested plants are characterised by the presence of bore holes in young leaves, flowers and fruiting structures. Larvae show a preference for young plant material, particularly flowers and fruit. For example, in corn *H. zea* will attack the tip of the ear and the silks (Ajmat de Toledo et al*.,* 1994) and will only destroy the entire cob under high infestation rates. Identification of infestations is difficult due to the destructive larvae burrowing into the plant tissue to feed, small eggs and pupation occurring under the soil surface. Capturing the moths by emergence, blacklight or sex pheromone traps is the most common way of identifying *H. zea* infestation.

Infestations of corn earworm can be controlled with standard pesticides, such as pyrethroids, however, the location of larvae within plant tissues can make delivery of chemicals to the insects difficult. The recent introduction of transgenic plants carrying *Bacillus thuringiensis* (*Bt*) genes have been effective in controlling infestations of the pest in cotton (Layton et al*.,* 1999) and corn (Buntin et al*.,* 2004). Hybrid lines of crop plants have been successful in reducing infestation rates and yield

losses. No current biological control for *H. zea* is in use, but a number of natural pathogens, parasitoids and predators are known.

Adult moths have a brown body (20-25 mm long) with a central dark spot, particularly clear from underneath. Forewings (32-45 mm) vary in colour between light brown in females to greenish in males. Moths are mainly nocturnal, and can live for up to 17 days, laying up to 1500 eggs. Eggs are laid singularly, preferentially on corn silks, with hatched larvae moving to feeding sites such as flowers, fruit and leaves. Larvae colour changes are evident throughout development with successive molts, starting from light grey and changing though dark brown and finally to a bright pinkish colour. Mature larvae become cannibalistic resulting in only a single larvae being found at most feeding sites. Pupation occurs following the larvae dropping from the plant to soil and producing a pupation chamber 5-15 cm below the surface of the soil. The entire life cycle can be completed within 30 days under optimal conditions.

Adult moth movement occurs in response to poor local conditions for reproduction. While short range movement is largely independent of weather conditions, medium and long range dispersal occurs downwind. Migratory flights at 1-2 km altitude can result movements of up to 400 km.

2.1.2 Life cycle

The corn earworm is active throughout the year in tropical and subtropical climates, but is restricted to the summer months in colder climates. In ideal conditions the life cycle can be completed in about 30 days, with up to ten generations per year. Eggs are usually laid on the silk of corn or on fruiting structures, and are deposited singly. The eggs are flattened spheres with radial ribs, and measure about 0.6 mm in diameter and 0.5 mm in height. These are green when laid, and turn red and finally grey before hatching 2-3 days after laying.

Larvae (caterpillars) are grey with black heads after hatching and during this early stage move about the plant finding suitable feeding sites. Mature larvae darken to a brown colour, with the exception of the final instar (stage between molts) where the colouration changes to a bright pattern, often pinkish. The final body size is approximately 40 mm. As larvae mature they become cannibalistic, resulting in only one larvae being found at each feeding site. The presence of black thorn-like microspines on the body and a light coloured head distinguish the corn earworm from the fall armyworm (*Spodoptera frugiperda*) and the European corn borer (*Ostrinia nubilalis*). Larvae leave the plant and develop into pupa 5-15 cm below the surface of the soil. These are dark brown in colour, approximately 20 mm long and 5.5 mm in width, and develop in 10-25 days.

Adult moths have a brown body 20-25 mm long and often bear a small dark spot centrally. Forewing colours vary from pale brown (females) to greenish (males) with darker transverse markings. Wingspan is between 32-45 mm. Adults live between 5-17 days, with their activity principally being nocturnal. Females can lay up to 35 eggs per day, to a total 500-1500 eggs.

2.2 Affected hosts

2.2.1 Host range

H. zea shows a preference for corn (*Zea mays*), cotton (*Gossypium*) and sorghum (*Sorghum bicolour*), particularly their fruit and flowers. Other major hosts of *H. zea* include *Abelmoschus esculentus* (okra), *Cajanus cajan* (pigeon pea), *Capsicum annuum* (bell pepper), *Glycine max* (soyabean), *Helianthus annuus* (sunflower), *Lycopersicon esculentum* (tomato), *Phaseolus* (beans) and *Solanum melongena* (aubergine).

2.2.2 Geographic distribution

H. zea is widespread throughout North and South America, but infestations have not been reported elsewhere.

2.2.3 Symptoms

H. zea larvae attack fruiting structures resulting in damage from feeding and through facilitation of disease and other insect pests. Larvae excavate the interior of affected cotton bolls and will also leave bore holes. Bore holes are also seen in tomato fruit, cabbage and lettuce hearts, legume pods and flower heads following attack. In corn, *H. zea* leaves serial bore holes in the apical leaf and eat the top few centimetres of the cobs when they develop. High incidences of disease (introduced into damaged tissue) can result in increases in cob damage. On larger plants, eggs can be found stuck to the silks.

Symptoms on affected plant parts are varied:

- Fruit/pods/seeds can be affected by both internal and external feeding
- Growing points are damaged by internal feeding, boring and external feeding
- Inflorescence damage caused by both internal and external feeding
- Leaf damage caused by external feeding

2.3 Entry, establishment and spread

2.3.1 Entry potential

Rating: Low

H. zea is relatively polyphagous in its feeding habit, with in excess of 100 plant species being recorded as hosts. While eggs and larvae are generally found in close association with the flowers and fruits of host plants they can also be found on growing tips and leaves. Adults prefer to oviposition close to flowers and fruit, but as they are nectar and other exudate feeders they frequent trees and shrubs for their food source (Capinera, 2007). The only stage in the lifecycle not associated with plants is the pupal stage which occurs in earthen chambers at depths of up to 15 cm in the soil.

Trade in fresh produce, ornamental plants, cut flowers/foliage and soil, therefore, are particularly relevant pathways to consider when assessing the potential for human assisted entry of *H. zea* into Australia. Soil (and potting media) can largely be discounted as a likely pathway for entry given that targeted controls are in place to manage the risks associated with imports of this material. Soil is not permitted entry into Australia in association with nursery stock (i.e. nursery stock must be imported either bare rooted or in approved media). Soil can generally only be imported untreated for use in a quarantine approved premises (such as an analytical laboratory), and specific controls need to be put in place to manage the disposal of soil used in a quarantine approved premises. Where soil is imported with the intention of release it is subject to either heat treatment or gamma irradiation. Further evaluation of this pathway is not considered necessary.

Given the relatively polyphagous nature of *H. zea* the potential for movement on cut flowers/foliage and ornamental plants must be considered. There is a mandatory methyl bromide fumigation requirement for all cut flowers/foliage (commercial and private) imported into Australia from the US

and Mexico. This is due to the risks posed by the glassy winged sharp-shooter (*Homalodisca vitripennis*). However, methyl bromide fumigation is a requirement for cut flowers/foliage from all sources due to the risk of contaminant organisms, so the fumigation requirement would be expected to remain in place should the status of glassy winged sharp-shooter change in the Americas or Australia.

Ornamental plants (i.e. bare-rooted stock and not budwood or tissue culture) present another potential pathway for *H. zea* entry into Australia. As far as can be ascertained from the AQIS ICON database, any nursery stock (apart from tissue cultures) imported from the Americas must undergo mandatory methyl bromide fumigation. Many, if not all, of these imports also require post-entry quarantine.

Given the close association of *H. zea* eggs and larvae with fruiting structures the fresh produce pathway presents a risk for the entry of this pest into Australia. While larval activity will generally be visible on fruit, leading to their culling during harvest and packing procedures, the presence of eggs will not be as evident.

Fruit of five of the better known hosts of *H. zea* can be imported into Australia from the Americas as fresh produce. These are corn, capsicum, cabbage, strawberries and cucurbits. Corn can only be imported in the immature state and must be free of live insects, disease symptoms, contaminant seeds, soil and other debris. Consignments are subject to a 600-unit sample inspection on arrival. While not an AQIS requirement, trade in immature corn usually involves removal of the husk prior to export. This essentially mitigates the risk of eggs being associated with the produce, and makes detection of larvae and their activity much easier to observe during packing procedures.

Capsicums can be imported only from recognised fruit fly Pest Free Areas in the US. Imported capsicum fruit must be free of live insects, disease symptoms, contaminant seeds, soil and other debris. No other pre-export requirements (apart from those relating to phytosanitary certification, integrity and security of the consignment) can be identified in ICON.

Cabbages can be imported from the US from areas considered to be free of *Pieris* spp. (cabbage butterflies). Cabbages must be free of live insects, disease symptoms, contaminant seeds, soil and other debris, and are subject to the same phytosanitary certification, integrity and security requirements as those commodities outlined above.

Strawberry fruit can be imported from the US subject to a mandatory pre-export methyl bromide fumigation treatment. Upon arrival in Australia consignments are subject to a 600-unit sample inspection, and following visual inspection, 10% of these fruit are dissected. Strawberry fruit must be free of live insects, disease symptoms, contaminant seeds, soil and other debris.

Marrow, squash, pumpkin and zucchini can be imported only from recognised fruit fly pest free areas in the US. Imported cucurbits must be free of live insects, disease symptoms, contaminant seeds, soil and other debris. No other pre-export requirements (apart from those relating to phytosanitary certification, integrity and security of the consignment) can be identified in ICON.

EPPO/CABI (1996) provides a summary of the dispersal ability of the moth. Adult *Helicoverpa* moths are quite mobile with three modes of movement being observed: short-range, long-range and migration. Typically, short-range dispersal occurs within a crop where the moth flies low over the foliage. Long-range dispersal generally involves downwind flight between crops at a height up to 10 m, and may cover distances of up to 10 km. Migratory flights, which may last for several hours, occur at heights up to 2 km and may cover distances of hundreds of kilometres. EPPO/CABI (1996) concludes that transatlantic dispersal (i.e. migration from North America to Europe via wind currents) is a possibility for this moth, but highlight that this potential has not been demonstrated. Any attempt to conclude a similar scenario where migration of the moth to Australia from the Americas via air

currents would need a very careful and in-depth analysis of the aeroecological boundary layer conditions and survivability of the moth.

Imported machinery, while being a potential pathway, is not given in-depth consideration here due to the stringent hygiene requirements for these imports.

From the available information the potential for entry of *H. zea* into Australia via the human assisted (i.e. imports of plants and their products) pathway is considered to be low. This is because the standard phytosanitary requirements for each of these pathways, along with the commercial processes that typically happen prior to exports of these products, and the additional measures imposed for some products, reduces the unrestricted risk considerably.

The potential for entry through natural migratory processes is considered to be negligible. The overall potential for entry of *H. zea* into Australia is considered to be **low**.

2.3.2 Establishment potential

Rating: High

The geographic range of hosts (including those not preferred but that can still sustain this organism) and suitable climatic zones for establishment of *H. zea* in Australia is large. Therefore, it is reasonable to expect that should suitable numbers of *H. zea* enter Australia in a viable condition there is a realistic potential for the organism to establish. The number of generations per year would be dependent on where the establishment occurred, with development being slowed and/or stopped by cool weather and drought.

The geographic range and dispersal ability of *H. zea* in the Americas, along with patterns of related species (*H. punctigera* and *H. armigera*) already in Australia, provides further evidence to support the potential of this organism to establish in Australia. The geographic range of *H. zea* does not currently overlap with the two species mentioned above, so no information is available to demonstrate that the establishment potential of *H. zea* would be reduced through competition with these endemic species.

Establishment in Australia would likely be inconspicuous because of the similarity of this species to *H. armigera*, resulting in the chance that *H. zea* infestations may be ignored and not reported.

However, through an analysis of the host ranges of *H. zea* and *H. armigera* Pogue (2004) estimates that the potential economic losses caused by *H. armigera* should it establish in the US would be higher than the existing losses from *H. zea*. It is difficult to determine whether *H. armigera* may potentially dominate or out-compete *H. zea* should it arrive in Australia and limit *H. zea* establishment and/or spread potential.

Based on its native range, its polyphagous nature and the success of closely related species in Australia, the establishment potential for *H. zea* is considered to be **high**.

2.3.3 Spread potential

Rating: High

H. zea is a facultative seasonal nocturnal migrant, with adults migrating in response to poor local conditions for reproduction (EPPO/CABI 1996). Short-range dispersal occurs just above crops. For an in-depth coverage of local dispersal of *H. zea* refer to Culin (1995). Long range flights of up to 10 km are not uncommon where the moths move from crop to crop. These flights are typically aided by prevailing winds (i.e. movement is down wind). Further flights (known as migrations) have been

analysed and mapped using radar technology and through the identification of pollen stuck to the adult moths.

A number of authors (e.g. Hagerman, 1998) provide an interesting overview of the migratory ability of *H. zea*, a summary of which follows (for a more in-depth review, publications such as Westbrook (2008) should be consulted).

The conditions in Ontario, Canada, are too severe for *H. zea* to overwinter (and therefore establish), with the entire population being killed by low temperatures. This pest, however, is a significant problem in late season sweet corn there, resulting in a large percentage of low-grade corn at harvest. It has been demonstrated that populations of *H. zea* re-establish themselves in Ontario each Spring through migration from the Southern US and Mexico. These migrations are weather-dependent, and the timing of the moths arrival in Ontario varies from year to year. Young adults begin their migration north in early spring, and subsequent generations continue to move with the prevailing winds into Canada. It is thought that three generations are needed to effect the annual migration from Mexico to Ontario.

Migratory movements of related species (e.g. *H. armigera*) have been demonstrated in Australia and other countries. Given the facultative migratory nature of *H. zea* its spread potential within Australia is estimated to be **high**.

2.3.4 Economic impact

Rating: Medium

Based on prior analyses CAB (2006) summarises that *H. zea* is an important economic pest species in North America, being second only to codling moth (*Cydia pomonella*). The success and importance of this pest is due to its high fecundity, polyphagous larval feeding habits, high mobility of larvae locally and adults over significant distances, and facultative diapause of the pupal stage.

The serious and costly damage caused by this pest is due to the larval feeding preference of reproductive structures and growing points rich in nitrogen on high value crops (e.g. maize cobs, sorghum heads and cotton bolls). Damage to maize grown for silage or grain is not of economic significance, with losses being typically at 5%. However, these crops serve as a focus, or reservoir, of infestation.

Cook and Weinzierl (2004) report a 2.5% annual loss in field corn, with losses in the southern US reaching 16.7%. Losses in sweet corn are estimated to reach 50%.

In Virginia the infestation level of *H. zea* on soyabean is variable, with approximately 33% of the total acreage treated for this pest, costing growers about $1.5-2 million annually.

As mentioned under establishment potential above Pogue (2004) estimates that the economic losses resulting from an introduction of *H. armigera* in the US would exceed those already experienced as a result of the endemic *H. zea*. It is difficult to estimate the potential economic impact of this pest in Australia in relation to how it would compete or interact with endemic *Helicoverpa* and other pest species. For example, it may be able to displace endemic species in some circumstances, but changes in the overall economic impact may or may not be discernable. In other situations it may establish and become a secondary pest but economic impact levels might be barely detectable. The potential economic impact is therefore conservatively estimated as **medium**.

2.3.5 Environmental impact

Rating: Unknown

Given the extensive range of wild hosts this organism has been recorded in association with, it is inevitable that some level of environmental impact would result through its introduction into Australia. High economic losses are experienced in the native range of this organism in the US because of the larval preference for feeding on reproductive structures and growing points. However, these economic losses would not necessarily translate to the same level of environmental losses of wild hosts given that damage to fruiting structures may not limit the ability of the wild host to reproduce or displace other pests.

While there are numerous records of *H.* zea associated with wild hosts in the Americas, it appears little work has been directed at quantifying the level of damage sustained by these wild hosts. Environmental impact is therefore difficult to estimate and therefore a rating of **unknown** is assigned, but it is acknowledged that some impact would occur.

2.3.6 Overall risk

Rating: Low

2.4 Diagnostic information

2.4.1 Diagnostic protocol

H. zea adults are very similar to, and difficult to distinguish from, *H. armigera* adults on the basis of external morphological characteristics. Microdissection and slide-mounting of the genitalia is required for specific identification. However, even in this microscopic analysis some aspects require a series of closely related species for comparison. Immature specimens cannot be reliably identified. Pogue (2004) provides good coverage of the diagnostic separation of the two species through dissection of the male genitalia.

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 & 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

Sampling for eggs and larvae in maize is difficult and often not carried out because eggs are difficult to detect and larvae burrow down into the silks soon after hatching (Capinera, 2007). Tell-tale signs of *H. zea* activity on maize plants include serial holes in the leaves of young plants after whorl feeding on the apical leaf. In larger plants silks are grazed and careful examination may reveal eggs stuck to the silks (CAB, 2006). As maize ears develop the larvae attack the soft milky grains in the tip of the cob. Verification of the presence of *H. zea* larvae will generally necessitate the dissection of the tip of the cob.

In other crops with highly visible fruiting structures evidence of *H. zea* presence and activity may be more easily detected. For example, eggs may be more easily detected on tomato and aubergine fruit and larval bore holes may be easily seen. Herbert et al. (2003) provide a comprehensive field scouting plan for *H. zea* larvae in soybean crops. The methodologies discussed involve the use of standard beat cloths, rigid beat cloths and sweep nets.

In monitoring *H. zea* populations in soybean production in the US, traps are used in combination with field scouting. Both pheromone and black light traps are used, with pheromone traps being very selective but only useful for collecting males. Black light traps are much less selective, catching both sexes of a range of species. In monitoring programs, trap captures are used to provide an indication of when more intensive field scouting activities should begin (Herbert et al., 2003).

General protocols for collecting, dispatching and transporting of samples are available from PLANTPLAN, Appendix 3-5 (PHA 2008).

2.6.1.1 NUMBER OF SPECIMENS TO BE COLLECTED

As many specimens as possible (minimum of 10) should be collected to allow for comparative microscopic examination of the genitalia for specific identification. Adult moths can be used for identification while immature specimens will need to be grown out to adults for identification purposes.

2.6.1.2 PREFERRED STAGE TO BE COLLECTED

Of the four life stages (egg, larva, pupa and adult) only adult moths can be reliably identified to species level using comparative microdissection techniques.

2.6.1.3 HOW TO COLLECT

Adult moths can be captured in traps (emergence, blacklight or pheromone) or hand collected into glass vials by sweeping from foliage with a hand net. However the most practical and reliable method is the collection of plant organs (usually flowers and fruit) containing larvae in a large jar for rearing adults in the laboratory.

2.6.1.4 HOW TO COLLECT PLANT SAMPLES

Leaves, flowers and fruiting bodies 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 help to keep the specimens intact and assist in removing excess moisture from the plant material which may otherwise encourage the growth of pathogens and mould.

2.6.1.6 HOW TO PRESERVE MOTHS

Authors recommend varying concentrations of ethanol for preserving Lepidopteran specimens, ranging from 70-95%, but sometimes concentrations as high as 100% are recommended. While ethanol is useful as a preservative where morphological characteristics of an adult moth will be used for specific determination, it is not ideal as a preservative where DNA analysis of specimens is to be undertaken. At present this is not an issue as DNA analysis tests are not currently available for this species.

Should DNA analytical techniques be developed for this species in the future, Mandrioli et al. (2006) recommends acetone as the preferred preservative for Lepidopterans. Acetone has the additional advantage of being effective at preserving morphological features of Lepidopteran specimens at room temperature.

Where taxonomic expertise is readily available and identification can be carried out quickly it may be practical to keep adult 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

For detailed information on transport and packaging requirements for suspect emergency plant pests refer to PLANTPLAN (Plant Health Australia, 2008)

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 *H. zea* will need to consider the biology of the organism (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

Significant research has been undertaken in the US on local and long-distance dispersal of *H. zea* which may be used as a foundation for developing models to estimate its spread potential in Australia. For example, Culin (1995) provides an account of the local dispersal of male *H. zea* moths within a 4 km diameter area in corn crops in South Carolina. Westbrook (2008) provides an account of the long distances migration of this species.

Predictive migration models have been investigated for those *Helicoverpa* species present in Australia. A simulation model of the long-distance migration of *H. armigera* and *H. punctigera* in Australia has been described (Rochester et al., 1996), which may be applicable to *H. zea*.

2.6.4 Pest Free Area guidelines

The establishment and maintenance of Pest Free Areas (PFAs) can be a resource-intensive process. Prior to development of a PFA due consideration should be given to alternative methods (e.g. treatments, enclosed quarantine) that achieve an equivalent biosecurity outcome to a PFA. A benefit-cost analysis is useful for this purpose.

Where an evaluation justifies the establishment and maintenance of a PFA 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 *H. zea*, 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 *H. zea* 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 (e.g. host plant material, soil and machinery) within and out of the affected area
- On-going surveillance of infested paddocks to ensure *H. zea* 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

A range of cultural control techniques can be used in the management of *H. zea*. Many of these may already be used for endemic *Helicoverpa* species in Australia. For soybeans, early planting and the use of specific resistant varieties to increase the chance of soybeans being beyond the susceptible flowering stage when the moths are mobile (Herbert et al., 2003). This also permits natural enemies the chance to increase in population before the movement of *H. zea*.

Avoid the application of unnecessary insecticide sprays as *H. zea* caterpillars feeding on soybean leaves rarely cause economic damage (Herbert et al., 2003). Avoiding unnecessary insecticide applications also allows build-up of natural enemy populations.

Preferred crops, such as corn (in the green silk stage) and lima beans may be useful for luring *H. zea* moths away from less preferred crops (Capinera, 2007). However, it is difficult to maintain trap crops

in an attractive state for protracted periods. Where populations of *H. zea* first develop on host weed crops the management of these weeds is very important. Weed hosts can be treated by mowing, herbicides and the application of insecticides.

Hagerman (1998) describes a traditional method of control of *H. zea* in corn which is still occasionally used by organic growers and home gardeners. Mineral oil is applied to the silk of each ear of corn, which effectively deters *H. zea*. This is a time-consuming process and the oil left at the ear tip may be distasteful to consumers.

2.7.5 Host plant resistance

Host plant resistance is not yet completely adequate for protecting corn from *H. zea* injury, but is a valuable component in any multifaceted pest management program (Capinera, 2007). Resistance in corn may be derived from physical characteristics, such as husk tightness and ear length that can impede larval entry into the ear kernels, or chemical factors which inhibit larval growth.

Some transgenic crop varieties are now available which incorporate 1-2 genes from the bacterium *Bacillus thuringiensis*, which has a high-level of toxicity to many Lepidopteran insects. While these crops can provide a reasonable level of protection against *H. zea* (and other pests) their use should be considered in the context of a multifaceted pest management program rather than as a stand alone control treatment. An example of these crops is Bollgard II® cotton which is commonly used in both the US and Australia as part of pest management programs to control damaging Lepidopteran pests.

2.7.6 Chemical control

As with other control methods the use of chemicals should form part of an integrated approach to pest management, thereby ensuring resistance does not build up in the target pest. The application of chemicals requires well-considered timing, however, as larvae often tend to enter fruiting/reproductive structures which may shield them from any insecticides applied.

Pyrethroids have traditionally been one of the cheapest and most widespread insecticides used against this pest. In some areas, however, *H. zea*, is becoming increasingly resistant to Pyrethroid insecticides, necessitating the use of other products.

Brickle et al. (2001) conducted a series of evaluations in 1998 and 1999 on six insecticides of different chemistries against *H. zea* in transgenic and conventional cotton. The outcomes of this research should be considered in relation to chemical control of transgenic versus conventional crops, as well as in control programs in wet versus dry land cropping systems.

It is likely that those chemicals currently registered for control of *H. armigera* and *H. punctigera* in Australia would have an equivalent level of control against *H. zea*. Farrell (2008) provides significant coverage of chemicals registered for use on cotton in Australia.

2.7.7 Mechanical control

Tillage, particularly in autumn, is important in significantly reducing the overwintering success of *H. zea* pupae (Capinera, 2007). It is likely that pupae-busting techniques currently used in Australia against *Helicoverpa* spp. would be appropriate for control of *H. zea*. A full description of the pupae-busting techniques used in Australian cotton production for the control of *H. armigera* can be found in Farrell (2008).

Plowing and tillage of stubble material is also useful in reducing late populations of *H. zea* by destroying eggs and larvae that may still be present on the crop residue.

2.7.8 Biological control

While numerous natural enemies of *H. zea* have been identified, they are usually not effective at causing high levels of mortality or preventing crop injury (Caperina, 2007). Further, while application of the bacterium *Bacillus thuringiensis* and entomopathogenic nematodes are useful in suppressing this pest some crop damage will still occur as larvae need to complete their development before they are killed.

Biological control agents are, however, very useful in helping to suppress *H. zea* populations and are important in any integrated approach to pest management. CAB (2006) provides an extensive list of parasites/parasitoids, predators and pathogens of *H. zea*.

The area of sexually-transmitted insect viruses has received interest in recent years as another potential biological control weapon against *H. zea*. The work by Burand & Tan (2006) demonstrated the ability of Hz-2V (gonad-specific virus) to alter the physiology and behaviour of infected insects in ways that facilitate the mass transmission of viruses.

While no protocol has yet been finalised for the use of sterile insect techniques in controlling *H. zea*, a reasonable level of research has been undertaken into the possible application of this technique in managing *Helicoverpa* spp. For further information on this topic refer to FAO/IAEA (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, 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

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

(available chlorine) 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
- Skin and hair in contact with infested plant material or soil should be washed

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

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/stubble from susceptible hosts should be destroyed by burning as late season eggs and larvae may be present on crop remnants

3.1.5 Disposal issues

Particular care must be taken to minimize the transfer of infested soil or plant material from the area as diapausing pupae may be present in the soil and larvae or eggs may be present on plant material

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 infested property to other infested properties.

3.3.1 Destruction Zone

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).

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 infested 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 infested premises and all suspected infested 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 infested 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 detergent, a farm degreaser or a 1% bleach (available chlorine) 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 analyses as being at risk
- Surveying all host growing properties that are reliant on trade with interstate or international markets which may be sensitive to *H.* zea presence
- Surveying commercial nurseries selling at risk host plants
- Surveying other host growing properties, backyards and abandoned fields and orchards

3.5.2 Survey regions

Establish survey regions around the surveillance priorities identified above (Section 3.5.1). 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 infested plants. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the pest. Pathways to be considered are: o Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment o The producer and retailer of infested material if this is suspected to be the source of the outbreak o Labour and other personnel that have moved from infested, contact and suspect premises to unaffected properties (other growers, tradesmen, visitors, salesmen, crop scouts, harvesters and possibly beekeepers) o Movement of plant material and soil from controlled and restricted areas o Storm and rain events and the direction of prevailing winds that result in air-borne dispersal of the pest during these weather events
Phase 5	• Surveillance of nurseries, gardens and public land where plants known to be hosts of *H. zea* 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 indicate that eradication of the pest has been achieved will be determined by a number of factors, including the life cycle duration of the pest (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 where diapause conditions are taken into account.

- 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 *H. zea* to be undertaken for a minimum of 12 months after eradication has been achieved

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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 (**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
Glenn Graham (for DNA analysis)	Qld	Centre for Identification and Diagnostics University of Queensland (07) 3365 1863 **g.graham@cpitt.uq.edu.au**
Kim Pullen (Morphological ID)	ACT	CSIRO Entomology Australian National Insect Collection (02) 6246 4007 **kimp@ento.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

Facility	State	Details
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 (Plant Health Australia, 2008).

Appendix 4. Market access impacts

Within the AQIS PHYTO database, no countries appear to have a specific statement regarding area freedom from *H. zea* (April 2009). However, it should be noted that the export conditions listed in PHYTO may be unique to Australia and would not necessarily include specific requirements for *H. zea* if the importing country recognises that this pest does not occur in Australia. Should *H. zea* be detected or become established in Australia some countries may require specific measures for exporting host commodities. Latest information can be found within PHYTO, using an Advanced search “Search all text” for *Helicoverpa zea.*