Threat Specific Contingency Plan

Boll weevil

(*Anthonomus grandis*)

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Version 1.0 – 03/10/2021 – Dean Brookes

CRDC
COTTON RESEARCH AND DEVELOPMENT CORPORATION

Australian Government
Department of Agriculture, Water and the Environment

Contents

Acronyms and terminology

The following general terms are used in this document.

CRDC – Cotton Research and Development Corporation.

PHA – Plant Health Australia.

Squares – cotton flower buds.

Bolls – mature cotton fruit.

Volunteer cotton – cotton plants that have emerged unintentionally.

Ratoon cotton – cotton plants that have survived winter and regrown in the field.

Cropping period – during eradication, the time from squaring to defoliation.

Host-free period – during eradication, period where no reproductive hosts for the boll weevil should be available.

1. Purpose and background of this contingency plan

1.1. Purpose

This contingency plan provides background information on the pest biology and available control measures for the boll weevil (*Anthonomus grandis)* to assist with preparedness for an incursion into Australia. This contingency plan was developed for the Australian cotton industry.

This contingency plan provides guidelines and options for steps to be undertaken and considered when developing a Response Plan for incursion of 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.

The information for this plan has been sourced electronically, including information from industry literature associated with eradication and control efforts for the boll weevil in the United States of America (USA), and from the scientific literature. General and supporting material can be found from several sources in the USA, with eradication efforts from the southern parts of the US being most relevant to Australian conditions.

1.2. Background

The boll weevil (*Anthonomus grandis*) is an economically important pest of cotton (*Gossypium hirsutum* and *Gossypium barbadense*).

The risk of establishment following invasion and required response activities are separated into two annual periods, cropping periods, and host free periods. These terms are used throughout this document. The cropping period is defined here as the period from squaring to defoliation of the cotton crop. The host-free period is the remainder of the year. Be aware that the annual timing of the cropping period will differ depending on the cotton growing region.

Commercially grown cotton, *Thespesia populnea* and the ornamental *Hibiscus syracius* are the only known reproductive hosts of the boll weevil in Australia. Other native plant species may allow the weevil to reproduce. The potential of the weevil to reproductive on those plant species distributed throughout cotton growing regions should be investigated immediately following an incursion (Table 3).

Early suppression and containment of the weevil is crucial given the uncertainty of boll weevil reproductive potential on native Malvaceae. Some native species of *Gossypium* and *Hibiscus* are distributed across the primary cotton producing regions of Australia and reproduction on these host plants could significantly hinder eradication efforts. Immediate destruction or early harvest of any cotton crops within an area of incursion is prudent if the economic cost would be minimal to the industry overall.

2. Australian cotton industry

The Australian cotton industry is significant employer in the agricultural sector and provides an economic foundation to many regional and remote rural communities. In 2014, there were approximately 1,300 cotton growers, predominantly across Queensland and New South Wales but also a smaller number in Victoria. The industry employs up to 14,000 people both on-farm and activities that support the industry.

While the Australian industry produces only about 3% of annual global cotton production, Australian cotton is recognised as some of highest quality in the world and per hectare yields have been the highest in the world for more than 20 consecutive years. Around 4 million bales were produced in 2014 from 413,000 ha. Almost all cotton grown in Australia is exported, generating in excess of $2 billion in export revenue annually.

3. Eradication determination

The successful eradication of invasive, widely distributed, and long-established boll weevil populations in the US indicates that eradication is technically feasible over a large area. Boll weevil is an extremely damaging pest and eradication has brought significant economic returns in the United States (e.g., Hyde 2020). Eradication is the preferred approach and so an eradication strategy is detailed in this document that has been developed using eradication programs from the United States, but with Australian conditions and host plants in mind.

A minimum of two years with no detections of the pest may be necessary to confirm that no boll weevils remain before pest free status can be declared. This timeframe needs to be considered on a case-by-case basis, based both on the size of the infection, the distribution of the pest and any other technical information important to a specific incursion.

No specific eradication matrix has been determined for the boll weevil; however, the general decision process as outlined in Figure 1 should be followed in determining if an incursion of this pest will be eradicated, or, managed and contained. The final decision between eradication and management will be made through the National Management Group.

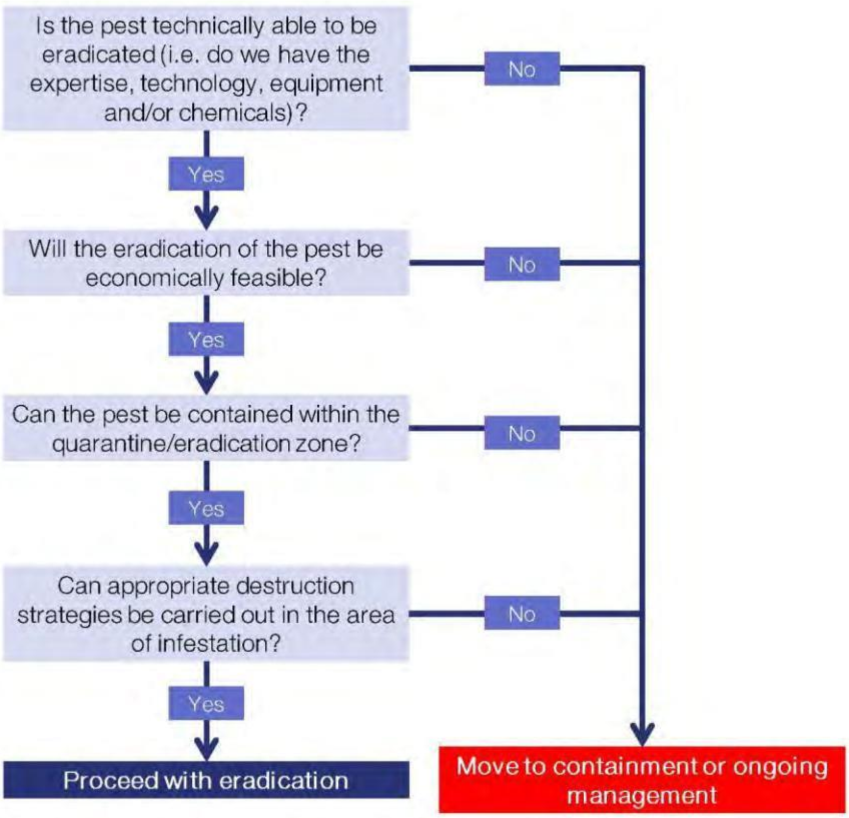

Figure 1. Decision outline for the response to an exotic pest incursion.

4. Impact

4.1. Impact summary

Cotton is the only crop affected economically by the boll weevil, but the impact is severe (Ramalho and Jesus, 1988). Invasion of the USA by the boll weevil early last century resulted in complete collapse of the cotton industry in many localities.

Eradication of the boll weevil from much of the United States brought significant economic returns to cotton growers. Recent eradication efforts in the Texas, USA, showed an economic return on eradication of $24 to $95 per acre (Hyde 2020).

The return of the cotton industry to prominence following eradication in many states in the United States is the strongest direct indicator of the economic impact of the weevil.

Invasion by the boll weevil would be highly disruptive to the integrated pest management practices of the Australian cotton industry. Chemical control options for the boll weevil are among the harsher control options in use in Australian cotton (Table 2) and ongoing chemical control of the boll weevil in Texas (U.S.) and South America is costly. Chemical control of boll weevil populations in Australia would result in more frequent sprays than the industry uses presently, with sprays being required as often as every 7-8 days (Showler, 2006a).

5. Biology

5.1. General description

Scientific name: *Anthonomus grandis grandis* Boheman, 1843.
Common name: Mexican cotton boll weevil (other common names are available from CABI).

A general description of the boll weevil is reproduced here from Drees and Jackman (1998): “The adults are brown to grayish-brown, fuzzy beetles with prominent snouts (or bills) bearing the mouthparts, and varying in size from 3.2mm to almost 12.7mm long. Larval stages, found inside cotton squares and bolls, are legless grubs with brown heads that grow to about ½ inch (12.7mm) long before forming a pupa that resembles the adult features but appears mummy-like.”

Important: No similar weevils are found in large numbers feeding in Australian cotton. Any weevils similar to the above description that are found feeding on, or in, cotton squares or bolls during an incursion should be collected and sent for identification.

Two subspecies of cotton boll weevil are known. The subspecies *Anthonomus grandis thurberi* is not considered as significant a pest of cotton as *Anthonomus grandis grandis*, but both are recorded as pests of cotton. The issue of subspecies is not resolved in the scientific literature (Alvarado et al. 2017, Raszick et al. 2021), but molecular analyses and biological information support the presence of multiple taxa within *Anthonomus grandis*, and so caution should be applied when using biological information during an incursion response.

5.2. Current distribution

The boll weevil is presently distributed only in North America, Central America, and South America (EPPO 2021). The weevil has been eradicated from some parts of the United States.

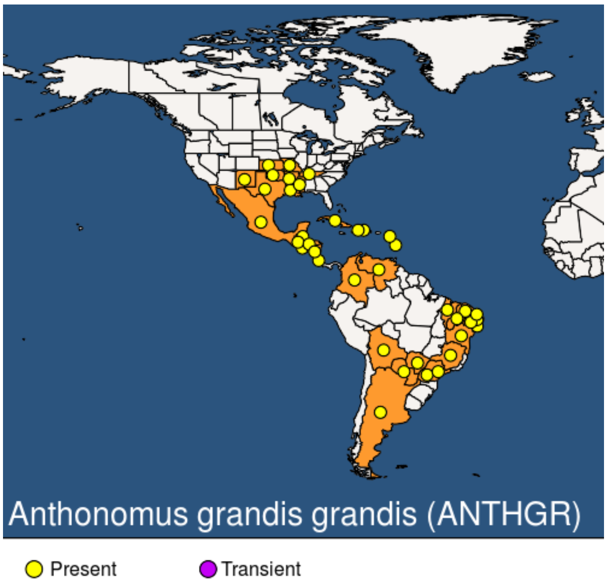

Figure 2. Worldwide boll weevil distribution as of 2021 (EPPO 2021).

Table 1. Countries where boll weevil *A. grandis grandis* is present, and details of its distribution if known, as of 2021 (EPPO 2021).

Continent	Country	Country code	Distribution
America	Argentina	AR	restricted distribution
America	Belize	BZ	no details
America	Bolivia	BO	no details
America	Brazil	BR	no details
America	Colombia	CO	no details
America	Costa Rica	CR	no details
America	Cuba	CU	widespread
America	Dominican Republic	DO	widespread
America	El Salvador	SV	no details
America	Guatemala	GT	no details
America	Haiti	HT	widespread
America	Honduras	HN	no details
America	Martinique	MQ	no details
America	Mexico	MX	widespread
America	Nicaragua	NI	no details
America	Paraguay	PY	restricted distribution
America	St Kitts-Nevis	KN	no details
America	United States of America	US	restricted distribution
America	Venezuela	VE	widespread
America	Argentina	AR	restricted distribution
America	Belize	BZ	no details

5.3. Diagnostics

All diagnostic information included in text here is sourced from other publications.

- **Diagnostic keys to larvae and pupae:** Ahmad and Burke (1972), Burke (1968), Anderson (1968)
- **Diagnostic key to adults:** Jones and Burke (1997).
- **A Field Guide to Boll Weevil Identification:** Jones and Williams (2001)

Discriminating between *A. grandis grandis* and A*. grandis thurberi* is difficult using morphological approaches but resources are available (Seok Kim et al. 2009, Jones and Williams, 2001).

Discrimination between the two subspecies should be possible using the cytochrome c oxidase subunit 1 (COI) mitochondrial gene barcoding region (Alvarado et al. 2017) but no specific molecular diagnostic protocols have been described.

Larvae (CABI 2020)**:** Mature white legless larvae are 5.6–8.1 mm in length, robust, thickest through middle abdominal segments, distinctly curved, tapered towards posterior end.

Pupae (CABI 2020)**:** White in colour, with a body length of 6.6-7.4 mm. Abdominal segment 9 bearing 2 posterior processes.

Adult (CABI 2020)**:** Body length 5.5-8.0 mm in length, reddish-brown in colour. Antennae slightly paler, sparsely covered with long, whitish, decumbent pubescence, denser along midline and laterally on pronotum, not intermixed with erect setae. Antennal funicle 7-segmented, basal segment much longer than second, apical segment distinct from club, club elliptical, not very loosely articulated. Scrobes long, straight, directed towards and terminating close to anterior margin of eyes, not approximate beneath. Eyes large, convex, subspherical, sloping dorsally in front. Pronotum very coarsely punctured. Elytra coarsely punctate-striate, interstices 4 and 5 tuberculate apically, interstice 3 without post-median tubercle or patch of long, reddish-orange setae. Profemora bearing 2 distinct spines, inner spine twice size of outer, mesofemora with outer spine greatly reduced, and absent in metafemora, metatibiae straight in both sexes, without spines, tarsal claws bifid. Abdomen with sutures between sternites straight, pygidium convex and not excavated.

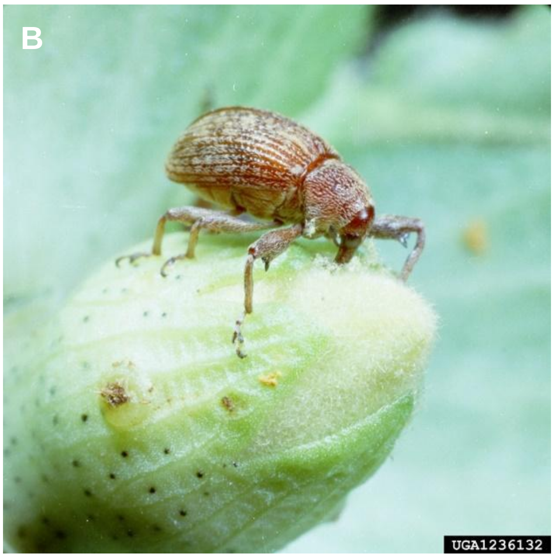

Figure 3. A. Typical egg-laying puncture (upper right edge on the left square) and feeding puncture (on square on right), **B.** Adult boll weevil on a cotton boll, **C.** Boll weevil larvae within a developing cotton boll, and **D.** Boll weevil larvae (left) and pupae (right) within a damaged cotton boll. **Source:** Clemson

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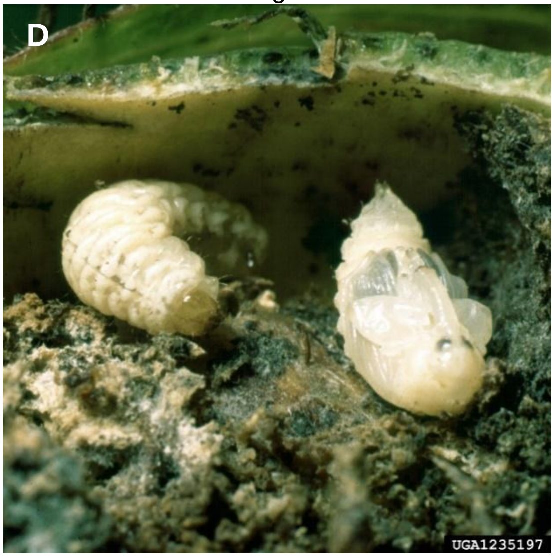
5.4. Life cycle and development

Boll weevils progress from egg to adult through four instars, a pre-pupal stage and pupal stage. Six to seven generations can be completed annually if suitable host plants are available (Drees and Jackman, 1998).

- Egg to adult takes 16-18 days (Drees and Jackman, 1998):
    - Eggs laid in cotton squares hatch in 2.5-5 days.
    - Larvae feed for 7-12 days and then pupate.
    - Pupae develop for 4-5 days before becoming adults and chewing their way out of the cotton square or boll that they developed in.

- Adults feed for 3-7 days before mating and the commencement of egg laying and adult lifespan varies by diet (Showler, 2007):
    - About 140 days on large cotton (*Gossypium hirsutum*) squares.
    - About 120 days on orange (*Citrus sinensis*) endocarp.
    - About 100 days on grapefruit (*Citrus paradisi*) endocarp.
    - About 80 days on prickly pear (*Opunita* spp.) endocarp.
    - Less than 20 days on the leaves and stalks of most plants.



The fruits of host plants are required for boll weevil reproduction and the larvae develop inside the fruits (Showler, 2009a). Some host plants only allow for partial development, and so finding larvae in fruits in the field is not conclusive evidence of reproductive potential.

5.5. Climate

The distribution of boll weevil through North, Central and South America indicates that it can survive in a variety of climatic conditions and suggests that host plant availability is more important for its establishment. Dry conditions are thought to limit the distribution and impact of the Mexican cotton boll weevil *A. grandis grandis.*

At temperatures between 30°C and 35°C development was slowed in both *A. grandis grandis* and *A. grandis thuberiae* (Fye et al., 1969).

The subspecies *A. grandis thurberi* is thought to be adapted to drier conditions than *A. grandis grandis*, but this subspecies is less frequently a pest of cultivated cotton and has a narrower distribution in the US (Burke et al., 1986).

5.6. Reproduction

Eggs are laid primarily in the fruits of some plants, all in the family Malvaceae (Showler, 2009a, Cuadrado, 2002, Gabriel, 2000). Most eggs are laid in medium sized cotton squares (3 – 6 mm in diameter) and on the upper half of cotton plants (Ramalho and Jesus, 1988).

Boll weevils begin laying eggs about 20 minutes after mating on average (Cross, 1973) and lay one egg per hour of daylight (Cross, 1973).

Adult boll weevils will emerge from squares and bolls at regular intervals which makes chemical control difficult.

Partial development of weevils occurs on some hosts in the United States. The presence of pupae in the fruits of a plant species is not conclusive evidence that reproduction is possible.

The time between feeding on medium and large cotton squares and oviposition is 5-7 days (Showler and Cantu, 2005).

Weevils are most fecund at 30°C (Greenberg et al., 2005).

5.7. Host plant interactions

The host plant associations of the boll weevil are summarized in **Appendix A:** Table 3.

Cotton (*Gossypium hirsutum* and *G. barbardense*) is the primary host of the boll weevil and the only important crop damaged by this pest.

All species in the genera *Hibiscus*, *Gossypium* and *Thespesia* are potential reproductive host plants, though most will not be suitable, as is the case in North America and South America (Cross et al. 1975).

Weevils reproduce on a much smaller subset of host plants than those they feed upon and these reproductive hosts are the most crucial for eradication.

Boll weevils locate their hosts visually and through olfaction (Pimenta et al., 2016, Magalhães et al., 2012) with fruiting plants being more attractive to weevils than others (Pimenta et al., 2016).
Boll weevils feed on a variety of host plants (see the previous section), either their fruits, nectar, or pollen. Fruits are necessary for reproduction (Showler, 2009a) and sustain weevils for longer times than other plant resources (Showler, 2007).

Boll weevils will feed year-round on volunteer cotton, and even reproduce during the right climates. Removal of all volunteer cotton is crucial for eradication.

5.7.1 Reproductive host plants

The boll weevil is primarily associated with cotton, in particular *Gossypium hirsutum*, and this is the only plant on which it causes economic damage (Ramalho and Jesus, 1988). The economic impact of the boll weevil has been severe in North America and South America and would likely be severe in Australia. Identification of reproductive hosts is crucial for eradication.

Known reproductive host plants present in Australia are cotton (*G. hirsutum* and *G. barbadense*). Control and removal of volunteer cotton from outside of cropping systems will be crucial for eradication of this pest. *Thespesia populnea* is a reproductive host (Cross et al., 1975) but in Australia this species is found in coastal areas away from most cotton growing regions. The ornamental *Hibiscus syracius* is a marginal reproductive host (Cross et al., 1975).

Ornamental and non-cultivated species from the genera *Gossypium,* Thespesia, Hibiscus and perhaps other Malvaceae may be reproductive host plants of the boll weevil. As in North America and South America, the majority of species will probably not support boll weevil reproduction (Cross et al., 1975).

Identifying whether any other native or introduced *Malvaceae* are reproductive hosts is the greatest source of uncertainty for eradication. Early during an incursion, eradication should proceed under the assumption that these alternative hosts cannot sustain boll weevil populations long term. Candidate reproductive Australian species which are distributed within or near primary cotton growing regions have been identified (potential reproductive hosts, Table 3) and the suitability of these hosts for reproduction should be evaluated experimentally as soon as is feasible in the event of an incursion.

5.7.2 Non-reproductive host plants

The boll weevil can sustain itself on the endocarp of some host plants that it cannot reproduce on. For example, studies have shown that the weevil can survive on prickly pear for about 80 days (*Opuntia* spp.), orange and grapefruit (*Citrus* spp.*)* for 120 and 100 days respectively, though up to 150 days for some individual weevils (Showler, 2007). It is possible that unknown native Australian plant species may allow for similar longevity or even reproduction.

Many other plant species can provide pollen and nectar resources to the boll weevil. These species are numerous but likely inconsequential to eradication. These families include Amaranthaceae, Asteraceae, Brassicaceae, Solanaceae, Euphorbiaceae, Fabaceae, Rutaceae, Cactaceae and Poaceae (Hardee et al., 1999, Pimenta et al., 2016, Showler, 2009a, Cuadrado, 2002, Cross et al., 1975).

Many native *Gossypium*, *Thespesia* and *Hibiscus* species are distributed within or near secondary cotton growing regions in northern Australia. All species in these genera should be considered as potential reproductive host plants in the event of an incursion. Species from these genera that are found in the primary cotton growing regions of Australia are named specifically in **Appendix A:** Table 3.

5.8. Cotton damage, oviposition and symptoms

When feeding, adult boll weevils drill holes into the side of squares (flower buds) or bolls (mature fruit). Female boll weevils also lay eggs in some of these feeding sites (Drees and Jackman, 1998).

After inserting the egg females cover the cavity with a sticky substance that turns into a hard wart-like blemish (Drees and Jackman, 1998).

Infected cotton squares and sometimes bolls abscise from the plant (Drees and Jackman, 1998). Abscised bolls will be shrivelled and small relative to their normal size (Showler, 2008).

Cotton lint inside fed-upon bolls is damaged.

5.9. Diapause

Boll weevils enter a state of dormancy and have increased longevity in response to poor conditions (e.g., unsuitable temperatures and low host plant availability) (Showler, 2009a).

Other studies have shown that bool weevils enter diapause at temperatures of 12.8°C to 29.4°C after not being provided with a food source (Spurgeon and Suh, 2018).

Boll weevil mortality is 95% with host-free periods of 17 weeks at 29.4°C, 30 weeks at 12.8°C, 31 weeks at 23.9°C and 40 weeks at 18.3°C; see (Spurgeon and Suh, 2018) Figure 5. One weevil survived for 54 weeks at 12.8°C but such events are rare (Spurgeon and Suh, 2018).

In colder climates, weevils move into nearby leaf litter, fence lines, irrigation ditches and wooded areas when host plants are not available. Under mild temperatures of about 20°C some boll weevils can survive for as long as 40 weeks dormant if they were reared initially on a suitable diet (Spurgeon and Suh, 2018).

Boll weevils are not thought to enter diapause or quiescence in subtropical regions (Showler, 2009a), and in such regions, can reproduce year-round if suitable hosts are available (Showler, 2007). Survival should be lower without available host plants under these conditions.

Quiescent adults can be found during mild winters and dry seasons in South America (Campanhola and Martin, 1987, Degrande, 1991, Gondim et al., 2001).

5.10. Dispersal

The sum of the boll weevil's dispersal capabilities resulted in an average rate of advance of about 80-100km annually during its invasion of the United States (Parencia Jr, 1978) and .

Dispersal through the United States by the boll weevil is thought to have occurred primarily via flight, and local movement of cotton products.

Boll weevil can occasionally travel large distances, as much as 50km from release sites (Johnson et al., 1975), and are presumed to do so on wind currents or machinery (Showler, 2009b). Marked weevils have been captured as much as 320km from release sites (Guerra, 1988). Accounting for rare long-distance dispersal during an incursion is only feasible by extending cultural control methods industry-wide.

Movement between cotton fields is low (Guerra, 1986) and so most movement will occur when the crop becomes unsuitable for the weevil following harvest (Showler, 2006b). Most weevils remain in the cotton crop, or move into nearby woodland post-harvest (Showler, 2003, Beerwinkle et al., 1996, Wolfenbarger et al., 1982).

6. Zoning

Surveillance and response activities differ across the zones (Figure 4). Details are provided in the subsequent sections. Zoning has been structured using U.S. eradication program guidelines, and information about boll weevil dispersal capabilities.

6.1. Pathways and movement controls

The only reasonable pathway for a boll weevil incursion into Australia is via freight. Weevils may be present as diapausing adults in refrigerated freight, or as weevils feeding on or developing within any suitable plant material (Appendix A: Table 3). Boll weevil has reportedly been intercepted in South Africa (EPPO 2021). Phosphine gas treatments may be suitable to treat boll weevil in shipping (EPPO 2021) and so freight treated in this way should be considered a lower risk.

Coastal areas where cotton is grown provide the most significant risk of an incursion. Further, ports near two coastal regions pose a higher risk of boll weevil establishment than other locations outside of cotton growing regions. *Thespesia populnea* is a reproductive host plant for the boll weevil and distributed across much of coastal Queensland. A higher density of native *Gossypium* spp. are found in coastal parts of the Northern Territory than in other parts of Australia, increasing the chance that any one of those species will allow for reproduction by the boll weevil.

Freight from regions where boll weevil is known to occur, directly into cotton grown regions in Australia, provides a risk of incursion if cotton fruits (whole or in part) are not entirely removed or treated prior to transport.

Texas Boll Weevil Eradication Foundation guidelines for treating machinery should be followed when moving machinery that has been in contact with cotton (TBWEF, 2021): "Cotton harvesting equipment and other equipment associated with the production and transport of cotton, as well as gin equipment, may be moved through a restricted area provided the equipment is free of hostable material, seed cotton and boll weevils in any stage of development by one of the following methods:

- removal by hand;
- high-pressure air cleaning;
- high-pressure washing; or
- fumigation"

Boll weevil movement between growing regions and cotton fields is most likely to occur via flight. Flight is more likely to occur when the cotton plant is an unsuitable host for the weevil, such as after defoliation and harvest.

Dispersal of weevils from cotton processing facilities during and after transport to a gin is unlikely (Sappington et al., 2006, Sappington et al., 2004a). Precautions should still be taken if the weather is cool (below 30°C) and if modules are being transported to the gin less than one week after harvest.

6.2. Destruction zone

The destruction zone is the infected field and all suspect premises, those cotton fields that can be connected to an infected premises by less than 500m.

At the beginning of an incursion (before pheromone traps are available) cotton plants in the destruction zone should be chemically treated weekly until harvest to suppress emerging adult weevil populations.

Destruction of cotton plants should only occur in the destruction zone if the growing region is isolated with respect to other cotton production and known reproductive hosts. Most boll weevil dispersal occurs post-harvest, and so crops should be destroyed only after being chemically treated, and after volunteer cotton has been removed entirely from the restricted area.

Surveillance and chemical control activities should be focused within the destruction zone during the early stages of an incursion to suppress boll weevil populations ahead of the first host-free period.

Movement of harvested cotton should occur outside of the destruction zone only at the beginning of the host free period, and only one week or more after harvest.

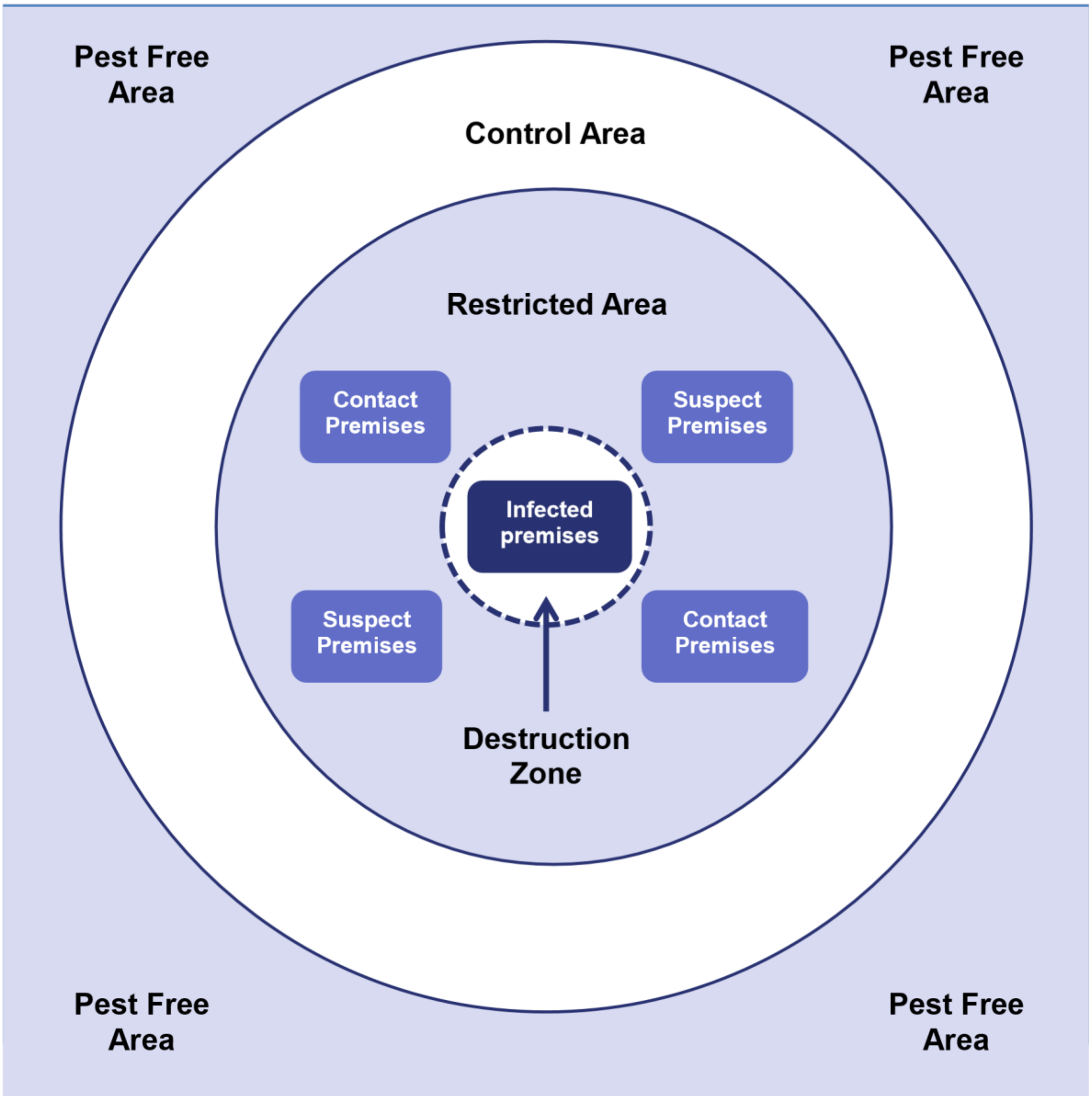


Figure 4. Schematic diagram of quarantine zones used during an EPP incursion (not drawn to scale).

6.3. Restricted area

The restricted area encompasses all cotton fields in a region that boll weevil is likely to be able to disperse to from infected premises by local flight. The restricted area must be decided upon by responders following initial surveys during any incursion, and the size of the cotton industry in the area, but may extend up to 100km to the entire control area.

Movement controls and surveillance of industry processing facilities apply within the restricted area, such as cotton gins.

Volunteer cotton must be removed entirely from the restricted area, and potential native reproductive host plants of the boll weevil must be surveyed.

Surveillance of all cotton fields in the restricted area must continue from the second growing period onward and until pest-free status has been declared.

6.4. Control area

The control area includes the restricted area, all infested premises, all suspected infested premises, and all areas that the boll weevil may disperse to from infected premises during a single cropping season (those within roughly 100km).

Occasional and undetectable dispersal of female boll weevils could establish the pest in a new locality. The likelihood of an incursion being isolated event is low as weevil populations have low abundance early after dispersal to a new region.

All cotton within the control area will be subject to a planting and harvest window.

6.5. Pest free area

It is best to assume that undetected boll weevils are present in pest free areas that are not being actively being monitored.

The chance of long-distance boll weevil dispersal is high, though only small numbers of insects are likely to disperse such distances. If feasible, planting and harvest windows should be in place industry-wide for two growing periods without a boll weevil detection even in regions outside the control area.

Contact should be made with industry pest scouts and agronomists to carry out surveillance industry-wide.

7. Surveillance

7.1. Technical information for planning surveys

Movement of weevils between cotton fields is infrequent (Guerra, 1986). Most movement will occur when the crop becomes unsuitable for the weevil during various end of season field operations (Showler, 2003).

Most weevil movement will occur via flight (Showler, 2006b) and long-distance dispersal on winds is possible (Guerra, 1988).

Movement may occur rarely on via machinery or cotton products, particularly squares and bolls that leave cotton farms (Sappington et al., 2004b).

Weevils emerging from diapause will be trapped more easily before cotton reaches the squaring stage. Cotton plants will compete with pheromone traps for weevil attraction from the squaring stage (Rummel and Curry 1986, Neves et al. 2013).

Fallen fruits should be examined during surveillance. Early life stages of the weevil will be hidden inside squares and bolls of cotton. Infested squares and some bolls abscise after 5-8 days.

Boll weevil may have been present in a region in low numbers in seasons prior to detection. Examine any volunteer cotton around the infected property for signs of damage. This activity could be undertaken for properties growing cotton in the Control Region and for any properties that have grown cotton in the past.

7.2. Surveillance tools

7.2.1. Pheromone Traps

Boll weevils are monitored using coloured pheromone traps that attract them visually and using pheromone lures with the aggregation pheromone grandlure (Benedict et al., 1985). Large numbers of traps are required for eradication, about one trap per 150m of cotton field edge or one trap per hectare of natural habitat.

- Traps use pheromone caps which must be replaced every two (2) weeks.
- Insecticide strips are optional but are replaced every four (4) weeks.

Pheromone traps are used to time insecticide applications.

Few boll weevil traps may be available during the early stages of an incursion. Boll weevil traps and pheromone traps should be ordered at the beginning of an incursion under the assumption that large numbers will be needed.

Insecticide strips are sometimes included in traps in the US but may not be necessary as they do not significantly increase the number of weevils captured (Suh et al., 2003). The strips will kill spiders and other predators that could remove weevils from the traps (Suh et al., 2003).

7.2.2. Visual inspection

Visual inspection of cotton plants is about eight times less effective than detection using pheromone traps (Hardee and Mitchell, 1997) but may nevertheless be necessary. See 'A field guide to identification of the boll weevil' for summary information use to determine the presence of the weevil (Jones and Williams, 2001).

Visual symptoms are reproduced in full from 'Pest Categorisation of *Anthonomus grandis*' (Jeger, M et al. 2017): The early stage of A. grandis attack is recognisable by a small puncture (either egg or feeding scars) at the side of the cotton flower bud which induces its abscission 5–8 days later: the bracteoles spread out, and buds turn brown and fall off. In later attacks, flowers turn yellow and fall to the ground, as do small bolls. Punctured large bolls usually remain on the plant and will be of poor quality (White and Rummel, 1978; EPPO, 1992; Showler, 2008; Neves et al., 2013).

7.3. Delimiting surveys

Surveillance should occur within a 5km zone around any detection sites and include existing cotton crops and any locations that might contain volunteer cotton plants. Surveillance should include the following activities:

- Visual inspect of all possible non-cotton host plants.
    - *Thespesia populnea* if the incursion is in a coastal region.
    - Ornamental species - only *Hibiscus syracius* is known so far and it is a relatively poor reproductive host.
    - Other potential Australian reproductive host plants in the region (Table 3).
- Pheromone traps placed at 100m intervals around the edge of all cotton fields and any sites with other possible host plants in the Control Region.
    - Traps are inspected weekly.
    - The growth stage of cotton near the trap is recorded.
- Early treatments and interventions aimed at establishing a host-free period should be undertaken during surveillance activities if possible.
    - Destruction or recording of any volunteer cotton plants (see latest Australian Cotton Production Manual for treatment options).
    - Destruction or heavy pruning of ornamental reproductive host plants.
- Samples should be sent for confirmation of identification (see section 7.7).

General surveillance and stakeholder engagement activities should be undertaken within a buffer zone around any detection sites.

Delimiting activities should continue until the end of the first growing period and resume when boll weevils are expected to emerge after diapause prior to planting in subsequent growing seasons.

7.4. General surveillance

Boll weevil surveillance requires engagement with producers and the general public. This may include setting and regular checking pheromone traps in urban and agricultural settings.

Pest monitoring is a common and frequent activity in the Australian cotton industry. Surveillance activities should involve private agronomists and pest checkers to help delimit the distribution of boll weevil early in an incursion and to ensure the weevil has not spread to new localities until pest-free status can be declared for the region.

7.5. Stakeholder engagement

Access to private property will be required for surveillance and treatment.

Engagement with current and past cotton growers, as well as secondary industries such as cotton gins, will be required to locate and destroy all volunteer cotton ahead of the host-free period.

Owner Reimbursement Costs (ORCs) cover certain costs associated with Response Plan actions including the destruction of crops, enforced fallow periods and additional chemical treatments which make up this contingency plan. Their purpose is to reduce the financial impact of the eradication response on growers. ORCs apply only to approved Response Plans aimed at eradication. ORCs are therefore not available to secondary industries that rely on cotton production, such as cotton gins. Engagement with these secondary industries will be necessary to minimise any impact to them and to ensure effective surveillance and successful eradication.

7.6. Surveillance of cotton processing facilities

Dispersal of weevils from cotton processing facilities during and after transport to a gin is unlikely (Sappington et al., 2006, Sappington et al., 2004a). Precautions should still be taken if the weather is cool (below 30°C) and if modules are being transported to the gin less than one week after harvest.

Gins and any similar cotton processing facilities considered a risk should be treated as cotton fields and be monitored with pheromone traps.

Harvested cotton modules should be moved from premises in the destruction area only at the beginning of the host free period.

7.7. Sample collection for identification

All boll weevil samples, whether collected in pheromone traps or by visual inspection, should be collected and transported for proper identification.

Follow the PLANTPLAN procedure for hard bodied pests but do not leave large holes in containers due to the small size of the boll weevil. Weevils can also be collected directly into 95% ethanol.

Photographs should be taken of any non-cotton host plants that the weevils are found on.

Boll weevil larvae collected from any non-cotton host plants should be placed live in tough and sealed plastic containers if possible. Fruits should be collected and placed with the larvae before both are sent to quarantine facilities for rearing.

Plant material and photographs of host plants can be used to aid identification of any non-cotton host plants. Leaves and flowers of non-cotton host plants should be collected separately to the weevils using the PLANTPLAN pathogen procedure. Plant samples should also be placed in hard plastic containers in case the small weevils have gone unnoticed.

8. Treatment and eradication

8.1. Summary

Eradication of the boll weevil in the United States utilised cultural control and chemical control methods. Boll weevil larvae are protected from chemical treatments while developing inside cotton fruits, and so a comprehensive approach is required for treatment and eradication. This approach is summarised below with text directly from the Texas Boll Weevil Eradication Foundation (TBWEF 2021):

"When a certain number of weevils, called the “trigger level,” have been caught in the traps around a field, the field receives an insecticide application. The insecticide used in the program is malathion."

"In addition to chemical control, the boll weevil eradication program relies on and promotes farmers using cultural controls such as planting during the most advantageous periods of time, using rapidly maturing varieties, harvesting early and thoroughly and destroying crop residues and failed plantings in a timely manner."
The eradication strategy for boll weevil aims to deny it suitable reproductive host plant fruits for a long period. Response activities are separated into a cropping period and a host-free period. These periods should be established for all cotton growing regions in Australia in the event of an incursion, given the considerable dispersal capabilities of the weevil and uncertain amount of time that would separate an initial incursion and first detection.

Cropping Period (squaring to defoliation): Known weevil populations are suppressed using pheromone trapping to trigger chemical treatments. The spatial extent of their populations is delimited during this period.

Host-free Period (7-8 months ideally): Eradication of the boll weevil will require a long period free from fruiting reproductive host plants. This is achieved using a strict planting and harvest window for cotton industry-wide and the removal of all volunteer cotton from all localities as a priority. The removal of all reproductive ornamental hosts from nearby urban areas, and surveys of potential native reproductive host plants in infected areas (Table 3) is also important.

8.2. Industry-wide activities for eradication

This section refers to treatment activities in the first year of an incursion. It is assumed that the boll weevil has dispersed outside of the regions in which it has been detected.

8.2.1. First growing period

Chemically treat, defoliate and harvest as soon as is reasonable across the entire Control Region. Consider that:

- Most weevil dispersal occurs following end of season activities such as harvest.
- The mortality of weevils in diapause is dramatically higher if temperatures are high (25°C and higher) when no host plants are available.
- Chemically treat harvested fields to kill weevil emerging from fallen bolls.

Cease planting of cotton in the Control Region following initial incursion.

Begin destruction of volunteer cotton throughout the Control Region to establish a host-free period following harvest.

8.2.2. Subsequent growing periods

Implement an early planting and early harvest strategy throughout the industry with an aim to:

- Prolong the host-free period.
- Prolong exposure of weevils to higher summer temperatures in the absence of reproductive host plants.
- Make all growing regions unsuitable for the weevil to account for long distance dispersal.

Alternative: If feasible, cotton should not be grown in the Control Region in the second growing period. Weevils will not survive longer than one year unless they can reproduce on native species. This is appropriate for small and isolated growing regions, or during periods when little cotton would be planted irrespective of an incursion.

8.2.3. Host-free periods

Ensure destruction of all volunteer and ratoon cotton before the host free period. Volunteer plants should be eliminated entirely.

Consideration should be given to cotton processing facilities, past cotton farms, and other locations where volunteer plants may go unnoticed.

During the host-free period, conduct:

- Pheromone trapping around cultivated secondary hosts in the Destruction Zone.
- Destruction of prickly pear (*Opuntia* spp.) in the Destruction Zone.
- Surveillance of potential native reproductive host plants (Table 3) to determine their reproductive potential.

8.3. Cultural control

8.3.1. Plant removal

Commercial, weed and ornamental host plants that allow for reproduction of the boll weevil in infected regions should be removed. If plants cannot be removed, they should instead be pruned heavily and repeatedly until boll weevil has been eradicated. *Hibiscus syracius* is the only known ornamental host plant but is normally grown in coastal areas of Australia.

All volunteer cotton must be removed from the Control Region (see latest Australian Cotton Production Manual for treatment options). Engagement needs to be undertaken with current and past cotton growers, processing facilities, and other associated industries to achieve this across the entire region. These plants are most likely to prolong the life of weevils and are much more likely to pose a problem than native hosts with an unknown reproductive potential.

8.3.2. Post-harvest control

High temperatures on the soil surface increase weevil mortality post-harvest (Greenberg et al., 2003).

Herbicide treatment of cotton fields post-harvest are used to suppress ratoon and volunteer cotton in eradication programs in Texas (Greenberg et al., 2007). Refer to the see latest version of the Australian Cotton Production Manual for ratoon and volunteer cotton treatment options.

Fallen bolls and squares may contain boll weevils must be destroyed post-harvest. Fallen bolls enhance weevil survival more than fallen squares (Greenberg et al., 2003).

Tillage increases the chance that weevils survive post-harvest on buried infested fruits (Greenberg et al., 2004). All post-harvest activities should take place after chemical treatment of the field.

Early planting and early harvest in the years following an incursion will extend the exposure of boll weevils to high temperatures in late summer.

Cotton fields with pathogens that could prevent effective surveillance or control interventions should not be planted until an area has been declared free of the weevil.

An industry-wide host free period post-harvest has the greatest probability of eliminating the weevil before its establishment.

8.4. Chemical control

Weevil larvae are protected from chemical treatments while developing inside cotton bolls. Chemical treatments need to be applied frequently enough that mortality is high in emerging weevils and few disperse from the field.

8.4.1. Spray triggers and frequency

Sprays are initiated in international eradication programs when detections of one or more weevils are made in pheromone traps (Option 1). Early during an incursion traps may not be available in high numbers and boll weevil numbers will likely also be low. Proactive sprays (Option 2) are appropriate to suppress weevil numbers in some situations, and these can be continued through until post-harvest treatment of fields.

Option 1: International eradication programs chemically treat cotton fields and all other fields within 400m whenever a single weevil has been found in a pheromone trap (see Texas Boll Weevil Eradication Training Materials).

Option 2: Proactive treatment every 7-8 days has been shown to be effective at suppressing boll weevil from the squaring stage (Showler, 2006a). This option is more appropriate during the early stages of an incursion when trapping capability will be limited, when the infested region is of limited size and when containment ahead of the first host free period is crucial. Chemical treatment with defoliation and post-harvest will reduce the number of weevils leaving cotton fields. Weevils disperse the greatest distances post-harvest.

Table 2. International chemical control options

Chemical	Concentration	Source	Notes
ULV Malathion	840g/ha	txbollweevil.org	Texas eradication program rate.
ULV Malathion	560-700g/ha	(Villavaso et al., 2000)	Lowest rates used.
ULV Malathion	1035g/ha	(Castro and Armstrong, 2009)	Standard rate.
Bifenthrin	112g/ha	(Castro and Armstrong, 2009)	Test of ULV Malathion alternative.

Fipronil	28-56g/ha	(Mulrooney et al., 1998)	All rates similarly effective against boll weevil.
Cyfluthrin	45g/ha	(Showler, 2006a) (Showler and Robinson, 2005)	Starting at large square formation (5.5-8mm) and continuing while large squares predominate.

Note: No pesticides have been approved for boll weevil control in Australia. APVMA permits will be required before pesticides can be used for the control of the pest. The limited options, and changing nature pesticide suitability, mean that chemical options have been compiled here (Table 3), but that none are specifically recommended.

8.5. International expertise and support

International expertise should be engaged from the beginning of any incursion of significant size, particularly regarding the complex and industry-specific surveillance program that would be required for a widespread eradication program. Texas in the US has ongoing boll weevil eradication programs and expertise in subtropical boll weevil ecology. Boll weevil eradication is ongoing in Texas (US) and Texas Boll Weevil Eradication Foundation (TBWEF) is a source of up to date protocols and expertise (https://www.txbollweevil.org/)

9. Incursion scenarios

The following incursion or response scenarios in particular are considered likely and may affect decisions to be taken, or recommendations made, in this document.

9.1. Early season incursion

The worse period for an incursion is early during the cotton cropping period. Economic losses from any crop destruction will be high and the length of the growing season gives boll weevils a greater chance to increase their population size, disperse and establish. If an incursion occurs during a cropping period harvest should occur industry wide as soon as is feasible, particularly in the Control Region. The first host-free period following an initial incursion should be extended as long as is feasible.

9.2. Small cotton growing regions

Cotton has a limited presence in some regions where it is grown. All crops in the Control Region should be chemically treated for boll weevil, defoliated and destroyed as soon as is feasible if the boll weevil is found in a region where little cotton is grown. Cotton should not be grown in this region for two subsequent cropping periods. This situation may also apply during years where low water availability sees little cotton planted in a region.

9.3. Declaring area freedom

Any locality where boll weevil has been detected must be monitored until there have been no detections of weevils for two cropping periods before it can be declared free of the weevil, but ideally longer given the low probability of reintroduction. This period is in line with eradication programs in the United States.

9.4. Detection near coastlines

Boll weevil detected near coastlines have an increased risk of establishment on non-cotton host plants that will be difficult to control. *Thespesia populnea* is a known reproductive host of boll weevil that is distributed widely on Queensland coastlines. The year-round production of flowers and fruits in *T. populnea* represents the greatest risk of boll weevil establishment in Australia.

9.5. Declaring establishment

If weevil numbers are increasing in the years following eradication efforts, it is likely that some aspect of their biology is not well understood. Eradication efforts should transition to a research program, similar to that in the United States, which would resolve how the weevil sustains itself through the host free period. Eradication could then be attempted again at a later date as has occurred with the Texas Boll Weevil Eradication Program.

10. References

AHMAD, M. & BURKE, H. R. 1972. Larvae of the weevil tribe Anthonomini (Coleoptera: Curculionidae), *Entomological Society of America*.

ALVARADO, A., JONES, R. W., PEDRAZA-LARA, C., ALVARADO VILLANUEVA, O. & PFEILER, E. 2017. Reassessment of the phylogeography and intraspecific relationships of western and eastern populations of the boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae), in North America. *Biological Journal of the Linnean Society*, 122, 29-45.

ANDERSON, D. 1968. Observations on the Pupae of *Anthonomus grandis grandis* Boheman and *A. grandis thurberiae* Pierce (Coleoptera: Curculionidae). *Annals of the Entomological Society of America*, 61, 125-129.

BEERWINKLE, K. R., LOPEZ JR, J. D. & MCKIBBEN, G. H. 1996. Seasonal responses of boll weevils to pheromone traps in cropped and adjacent uncropped areas of east-central Texas. *Southwestern Entomologist* 21**,** 407-419.

BENEDICT, J., URBAN, T., GEORGE, D., SEGERS, J., ANDERSON, D., MCWHORTER, G. & ZUMMO, G. 1985. Pheromone trap thresholds for management of overwintered boll weevils (Coleoptera: Curculionidae). *Journal of Economic Entomology,* 78**,** 169-171.

BURKE, H. R., CLARK, W. E., CATE, J. R. & FRYXELL, P. A. 1986. Origin and dispersal of the boll weevil. *Bulletin of the ESA,* 32**,** 228-238.

CAMPANHOLA, C. & MARTIN, D. F. 1987. *Observação de adultos de bicudo em hibernação,* Jaguariúna, EMBRAPA-CNPDA Comunicado Técnico 1.

CASTRO, B. A. & ARMSTRONG, J. S. 2009. Comparative efficacy of selected insecticide alternatives for boll weevil (Coleoptera: Curculionidae) control using laboratory bioassays. *Journal of Cotton Science*. 13, 189-195.

CROSS, W. H. 1973. Biology, control, and eradication of the boll weevil. *Annual Review of Entomology,* 18**,** 17-46.

CROSS, W. H., LUKEFAHR, M. J., FRYXELL, P. A. & BURKE, H. R. 1975. Host plants of the boll weevil. *Environmental Entomology,* 4**,** 19-26.

CUADRADO, G. A. 2002. *Anthonomus grandis* Boheman (Coleoptera: Curculionidae) in central and south west area of misiones, Argentina: pollen as feeding source and their relationship with the physiologic state in adult insects. *Neotropical Entomology,* 31**,** 121-132.

DEGRANDE, P. E. 1991. *Aspectos biológicos do bicudo,* Campo Grande, UFMS.

DREES, B. M. & JACKMAN, J. A. 1998.

A Field Guide to Common Texas Insects, University of Minnesota, Gulf Pub.

EPPO. 2021. *Anthonomus grandis grandis*(ANTHGR). European and Mediteranean Plant Protection Organisation (EPPO) Global Database. https://gd.eppo.int/taxon/ANTHGR

FYE, R. E., PATANA, R. & MCADA, W. C. 1969. Developmental periods for boll weevils reared at several constant and fluctuating temperatures. *Journal of Economic Entomology,* 62**,** 1402-1405.

GABRIEL, D. 2000. Biologia del picudo del algodonero *Anthonomus grandis* Boh., 1843, en hospederas alternantes a través de la oviposición artificial. III. Seminario Internacional Manejo Integrado del Picudo del Algodonero en Argentina, Brasil y Paraguay. *Actas del Seminario, Ribeirão Preto, Brazil,* 59**,** 62.

GONDIM, D. M. C., BELOT, J. L., SILVIE, P. & PETIT, N. 2001. *Manual de identificação das pragas, doenças, deficiências minerais e injúrias do algodoeiro no Brasil,* Cascavel, COODETEC.

GREENBERG, S. M., SETAMOU, M., SAPPINGTON, T. W., LIU, T. X., COLEMAN, R. J. & ARMSTRONG, J. S. 2005. Temperature-dependent development and reproduction of the boll weevil (Coleoptera: Curculionidae). *Insect Science,* 12**,** 449-459.

GREENBERG, S. M., SHOWLER, A., SAPPINGTON, T. W. & BRADFORD, J. 2004. Effects of burial and soil condition on postharvest mortality of boll weevils (Coleoptera: Curculionidae) in fallen cotton fruit. *Journal of Economic Entomology,* 97**,** 409-413.

GREENBERG, S. M., SMART, J., BRADFORD, J., SAPPINGTON, T. W., NORMAN, J. & COLEMAN, R. 2003. Effects of conventional vs. conservation tillage systems on population dynamics of boll weevil (Coleoptera: Curculionidae) in dryland cotton. *Subtropical Plant Science,* 55**,** 32.

GREENBERG, S. M., SPARKS JR, A. N., NORMAN JR, J. W., COLEMAN, R., BRADFORD, J. M., YANG, C., SAPPINGTON, T. W. & SHOWLER, A. 2007. Chemical cotton stalk destruction for maintenance of host-free periods for the control of overwintering boll weevil in tropical and subtropical climates. *Pest Management Science,* 63**,** 372-380.

GUERRA, A. A. 1986. Boll-weevil (coleoptera, curculionidae) movement - dispersal during and after the cotton season in the lower Rio-Grande valley of Texas. *Southwestern Entomologist,* 11**,** 10-16.

GUERRA, A. A. 1988. Seasonal boll-weevil (Coleoptera, Curculionidae) movement between northeastern Mexico and the Rio-Grande Valley of Texas, USA. *Southwestern Entomologist,* 13**,** 261-271.

HARDEE, D. & MITCHELL, E. 1997. Boll weevil, *Anthonomus grandis* Boheman (Coleoptera: Curculionidae): a summary of research on behavior as affected by chemical communication. *Southwestern Entomologist* 22**,** 466-491.

HARDEE, D. D., JONES, G. D. & ADAMS, L. C. 1999. Emergence, movement, and host plants of boll weevils (Coleoptera : Curculionidae) in the Delta of Mississippi. *Journal of Economic Entomology,* 92**,** 130-139.

JEGER, M., BRAGARD, C., CAFFIER, D., CANDRESSE, T., CHATZIVASSILIOU, E., DEHNEN-SCHMUTZ, K., GILIOLI, G., GREGOIRE, J. C., MIRET, J. A. J. & NAVARRO, M. N. 2017. Pest categorisation of *Anthonomus grandis*. EFSA Journal, 15.

JOHNSON, W. L., CROSS, W. H., LEGGETT, J. E., MCGOVERN, W. L., MITCHELL, H. C. & MITCHELL, E. B. 1975. Dispersal of marked boll weevil: 1970-1973 studies. *Annals of the Entomological Society of America,* 68**,** 1018-1022.

JONES, R. W. & BURKE, H. R. 1997. New species and host plants of the *Anthonomus grandis* species group (Coleoptera: Curculionidae). *Proceedings of the Entomological Society of Washington*, 99, 705-719.

JONES, R. G. & WILLIAMS, M. R. 2001. *A field guide to boll weevil identification,* Mississippi State University, Office of Agricultural Communications.

MAGALHÃES, D. M., BORGES, M., LAUMANN, R. A., SUJII, E. R., MAYON, P., CAULFIELD, J. C., MIDEGA, C. A. O., KHAN, Z. R., PICKETT, J. A. & BIRKETT, M. A. 2012. Semiochemicals from herbivory induced cotton plants enhance the foraging behavior of the cotton boll weevil, *Anthonomus grandis*. *Journal of Chemical Ecology,* 38**,** 1528-1538.

MULROONEY, J., WOLFENBARGER, D., HOWARD, K. & GOLI, D. 1998. Efficacy of ultra low volume and high volume applications of fipronil against the boll weevil. *Journal of Cotton Science*. 2, 110-116.

NEVES, R. C., SHOWLER, A. T., PINTO, É. S., BASTOS, C. S. & TORRES, J. B. 2013. Reducing boll weevil populations by clipping terminal buds and removing abscised fruiting bodies. *Entomologia Experimentalis et Applicata*, 146, 276-285.

PARENCIA JR, C. R. 1978. *One hundred twenty years of research on cotton insects in the United States,* USA, US Deptartment of Agriculture.

PIMENTA, M., MATA, R. A., VENZON, M., CUNHA, D. N. C., FONTES, E. M. G., PIRES, C. S. S. & SUJII, E. R. 2016. Survival and preference of cotton boll weevil adults for alternative food sources. *Brazilian Journal of Biology,* 76**,** 387-395.

RAMALHO, F. S. & JESUS, F. M. M. D. 1988. Distribution of boll weevil (A*nthonomus grandis* Boheman) eggs within cotton plants. *Tropical Agriculture, UK,* 65**,** 245-248.

RASZICK, T. J., DICKENS, C. M., PERKIN, L. C., TESSNOW, A. E., SUH, C. P. C., RUIZ-ARCE, R., BORATYNSKI, T. N., FALCO, M. R., JOHNSTON, J. S. & SWORD, G. A. 2021. Population genomics and phylogeography of the boll weevil, Anthonomus grandis Boheman (Coleoptera: Curculionidae), in the United States, northern Mexico, and Argentina. *Evolutionary Application*s, 14, 1778-1793.

SAPPINGTON, T. W., ARNOLD, M. D., BRASHEARS, A. D., PARAJULEE, M. N., CARROLL, S. C., KNUTSON, A. E. & NORMAN JR, J. W. 2006. Dispersal of boll weevils (Coleoptera: Curculionidae) from cotton modules before ginning. *Journal of Economic Entomology,* 99**,** 67-75.

SAPPINGTON, T. W., BRASHEARS, A. D., PARAJULEE, M. N., CARROLL, S. C., ARNOLD, M. D. & BAKER, R. V. 2004a. Potential for escape of live boll weevils (Coleoptera : Curculionidae) into cottonseed, motes, and cleaned lint at the cotton gin. *Journal of Economic Entomology,* 97**,** 1773-1781.

SAPPINGTON, T. W., BRASHEARS, A. D., PARAJULEE, M. N., CARROLL, S. C., ARNOLD, M. D., NORMAN JR, J. W. & KNUTSON, A. E. 2004b. Potential for transport of boll weevils (Coleoptera: Curculionidae) to the cotton gin within cotton modules. *Journal of Economic Entomology,* 97**,** 934-940.

SEOK KIM, K., SZENDREI, Z., RODRIGUEZ-SAONA, C., MULDER JR, P.G. & SAPPINGTON, T.W., 2009. Molecular diagnostic for boll weevil (Coleoptera: Curculionidae) based on amplification of three species-specific microsatellites. *Journal of Economic Entomology*, *102*(2), pp.759-766.

SHOWLER, A. T. 2003. Effects of routine late-season field operations on numbers of boll weevils (Coleoptera: Curculionidae) captured in large-capacity pheromone traps. *Journal of Economic Entomology,* 96**,** 680-689.

SHOWLER, A. T. 2006a. Boll weevil (Coleoptera : Curculionidae) damage to cotton bolls under standard and proactive spraying. *Journal of Economic Entomology,* 99**,** 1251-1257.

SHOWLER, A. T. 2006b. Short-range dispersal and overwintering habitats of boll weevils (Coleoptera : Curculionidae) during and after harvest in the subtropics. *Journal of Economic Entomology,* 99**,** 1152-1160.

SHOWLER, A. T. 2007. Subtropical boll weevil ecology. *American Entomologist,* 53**,** 240-249.

SHOWLER, A. T. 2008. Relationships of abscised cotton fruit to boll weevil (Coleoptera : Curculionidae) feeding, oviposition, and development. *Journal of Economic Entomology,* 101**,** 68-73.

SHOWLER, A. T. 2009a. Roles of host plants in boll weevil range expansion beyond tropical Mesoamerica. *American Entomologist,* 55**,** 234-243.

SHOWLER, A. T. 2009b. Three boll weevil diapause myths in perspective. *American Entomologist,* 55**,** 40-48.

SHOWLER, A. T. & CANTU, R. V. 2005. Intervals between boll weevil (Coleoptera : Curculionidae) oviposition and square abscission, and development to adulthood in Lower Rio Grande Valley, Texas, field conditions. *Southwestern Entomologist,* 30**,** 161-164.

SHOWLER, A. T. & ROBINSON, J. R. C. 2005. Proactive spraying against boll weevils (Coleoptera : Curculionidae) reduces insecticide applications and increases cotton yield and economic return. *Journal of Economic Entomology,* 98**,** 1977-1983.

SPURGEON, D. W. & SUH, C. P.-C. 2018. Morphology, diet, and temperature-dependent host-free survival of the boll weevil, *Anthonomus grandis* (Coleoptera: Curculionidae). *Journal of Insect Science,* 18**,** 8.

SUH, C. P.-C., SPURGEON, D. W. & HAGOOD, S. 2003. Evaluation of kill strips on boll weevil (Coleoptera: Curculionidae) mortality in pheromone traps and impact on weevil escape. *Journal of Economic Entomology,* 96**,** 348-351.

VILLAVASO, E., MCGOVERN, W. & MULROONEY, J. Malathion and boll weevil eradication: application rates, mistblower effectiveness, and bait stick quality evaluation. 2000 Proceedings Beltwide Cotton Conferences, San Antonio, USA, 4-8 January, 2000: Volume 2., 2000. National Cotton Council, 1067-1069.

WHITE, J. R. & RUMMEL, D. 1978. Emergence profile of overwintered boll weevils and entry into cotton. *Environmental Entomology*, 7, 7-14.

WOLFENBARGER, D. A., GRAHAM, H. M., NOSKY, J. B. & LINDIG, O. H. 1982. Boll weevil (Coleoptera: Curculionidae): marking with rubidium chloride sprays on cotton and dispersal from cotton. *Journal of Economic Entomology,* 75**,** 1038-1041.

Appendix A – Host plant information

Table 3. Known and potential host plants of the boll weevil in eastern Australia.

Common Name	Scientific Name	Family	Host type	Importance of host[1]	Presence in Australia	Reference
Cotton	*Gossypium hirsutum*, *G. barbadense*	Malvaceae	Reproductive (good)	Very High	Yes	
Ornamental Hibiscus	*Hibiscus syriacus*	Malvaceae	Reproductive (poor)	Medium	Yes (coastal)	
Grapefruit, orange	*Citrus* spp.	Rutaceae	Non-reproductive	Low-Medium	Yes	
Okra	*Abelmoschus* spp.	Malvaceae	Non-reproductive	Low	Yes	
Portia tree	*Thespesia populnea*	Malvaceae	Reproductive (good)	Medium	Yes (coastal)	
Prickly pear	*Opuntia* spp. including *O. lindheimeri*	Cactaceae	Non-reproductive	Medium	Yes	
Pollen and nectar	Various	Various	Non-reproductive	Low	Yes	
Hibiscus spp.[2] of unknown suitability	Notable species - *H. tridactylites, H. brachysiphonius, H. verdcourtii, H. meraukensis, H. sturtii*	Malvaceae	Unknown	Low-High	Yes (species in cotton regions noted)	
Gossypium spp.[2] of unknown suitability	Notable species - *G. sturtianum, G. australe*	Malvaceae	Unknown	Low-High	Yes (species in cotton regions noted)	
Thespesia spp.[2] of unknown suitability	Notable species - none.	Malvaceae	Unknown	Low-High	Yes (species in cotton regions noted)	

[1]Overall importance represents the combined importance of the host plants for eradication based on their reproductive potential and suitability as a food resource.

[2]Only notable species, those distributed through eastern cotton growing regions, are listed here. However, all species in the genera *Hibiscus, Gossypium* and *Thespesia* are potential reproductive host plants.

Appendix B – Existing materials

The following existing materials can be found from external sources.

A Field Guide to Boll Weevil Identification (Jones and Williams 2001):
https://www.mafes.msstate.edu/publications/technical-bulletins/tb0228.pdf