INDUSTRY BIOSECURITY PLAN

FOR THE NURSERY & GARDEN INDUSTRY

Threat Specific Contingency Plan

Tarnished plant bug

(*Lygus lineolaris*)

Plant Health Australia

September 2011

Plant Health AUSTRALIA

Nursery & Garden Industry Australia

Disclaimer

The scientific and technical content of this document is current to the date published and all efforts were made to obtain relevant and published information on the pest. New information will be included as it becomes available, or when the document is reviewed. The material contained in this publication is produced for general information only. It is not intended as professional advice on any particular matter. No person should act or fail to act on the basis of any material contained in this publication without first obtaining specific, independent professional advice. Plant Health Australia and all persons acting for Plant Health Australia in preparing this publication, expressly disclaim all and any liability to any persons in respect of anything done by any such person in reliance, whether in whole or in part, on this publication. The views expressed in this publication are not necessarily those of Plant Health Australia.

Further information

For further information regarding this contingency plan, contact Plant Health Australia through the details below.

Address:	Suite 1, 1 Phipps Close DEAKIN ACT 2600
Phone:	+61 2 6215 7700
Fax:	+61 2 6260 4321
Email:	**biosecurity@phau.com.au**
Website:	**www.planthealthaustralia.com.au**

1 Purpose and background 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 Tarnished plant bug (*Lygus lineolaris).*

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.

This contingency plan was developed for the Nursery and Garden Industry Australia (NGIA), and therefore is focussed on production nurseries covered by this association. In the event of an incursion, operations that are not covered by the NGIA or another Emergency Plant Pest Response Deed (EPPRD) signatory (e.g. retail nurseries), will not be represented or have a decision making say in any arrangements for emergency response.

The information for this plan has been sourced electronically including information sourced from CABI Crop Compendium (**www.cabicompendium.org**) and import risk analysis reports from Biosecurity Australia (Biosecurity Australia 2008 & 2009). Modifications and additions to the plan have been completed to make the information relevant to an incursion of Tarnished plant bug for the NGIA.

2 Australian nursery industry

The Australian nursery industry is a significant horticultural sector with a combined supply chain (production to retail/grower) valued at more than $6 billion dollars annually. The industry employs approximately 45,000 people spread over more than 20,000 small to medium sized businesses including production nurseries and retail outlets. The industry is located predominantly along the Australian east coastline and in major inland regions servicing urban and production horticulture.

Nursery production is a highly diverse primary industry servicing the broader $14 billion horticultural sector within Australia (Table 1). A pest incursion is likely to impact market access (see Appendix 3 for more information).

Table 1. *Nursery production supply sectors within Australian horticulture*

Production Nursery	Horticultural markets	Economic value
Container stock1	Ornamental/urban horticulture	$2 billion retail value
Foliage plants1	Interior-scapes	$87 million industry
Seedling stock2	Vegetable growers	$3.3 billion industry
Forestry stock3	Plantation timber	$1.7 billion industry
Fruit and nut tree stock2	Orchardists (citrus, mango, etc)	$5.2 billion industry
Landscape stock1	Domestic & commercial projects	$2 billion industry
Plug and tube stock4	Cut flower	$319 million industry
Revegetation stock1	Farmers, government, landcare	$109 million industry
Mine revegetation	Mine site rehabilitation	Value unknown
	Total horticultural market value	$14.5 billion

2.1 Notification process for the reporting of suspect pests

Early detection and reporting may prevent or minimise the long-term impact of an incursion into Australia of the Tarnished plant bug (*Lygus lineolaris).*

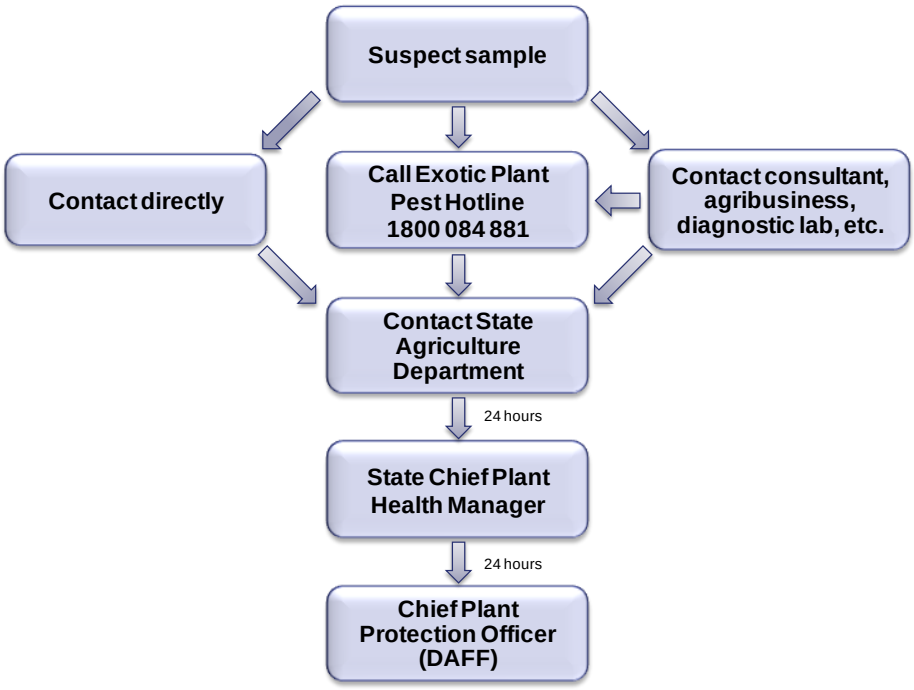

Figure 1. *Notification process for the reporting of suspect pests*

[1] Data sourced from Market Monitor
[2] Data sourced from Horticultural Handbook 2004
[3] Data sourced from ABARE 2005
[4] Data sourced from industry

3 Eradication or containment determination

The decision to eradicate should be based on the potential economic impact of host damage resulting from Tarnished plant bug infestation, the cost of eradication and on technical feasibility. Eradication costs must factor in long term surveys to prove the success of the eradication program. A minimum of two years with no detections of the pest may be necessary to confirm that no Tarnished plant bug 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 degree and distribution of the pest and other technical information from the Consultative Committee for Emergency Plant Pests. The final decision on response to a new pest incursion is to be made by the National Management Group.

No specific eradication matrix has been determined for Tarnished plant bug; however the general decision process as outlined in Figure 2 and Table 2 should be followed in determining if an incursion of this pest will be eradicated or managed/contained. The final decision between eradication and management will be made through the National Management Group.

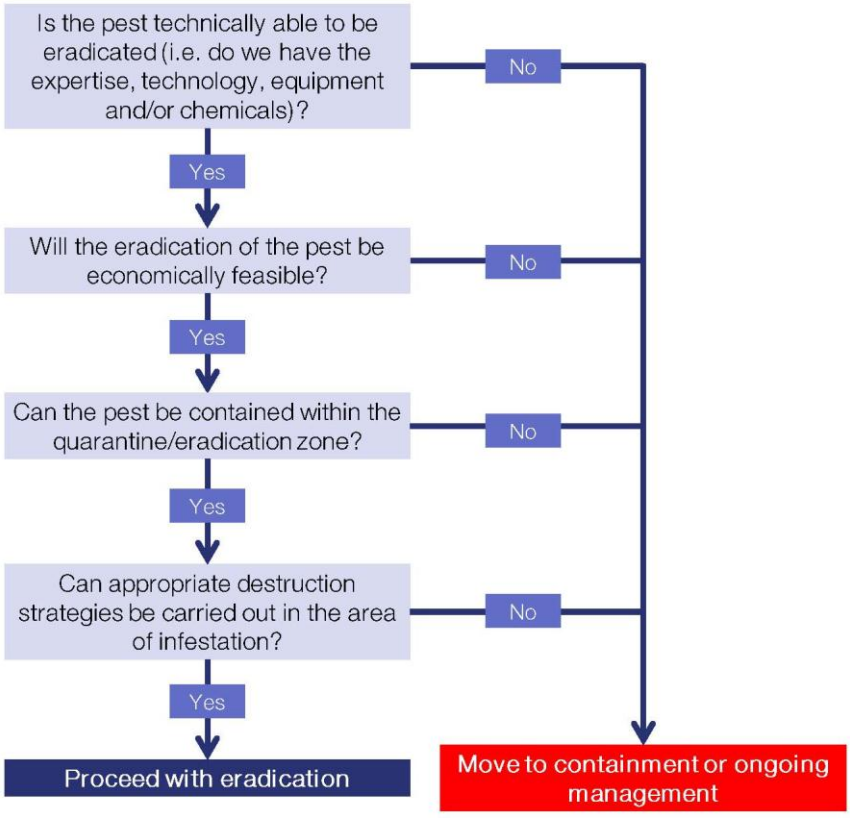

Figure 2. *Decision outline for the response to an exotic pest incursion*

Table 2. *Factors considered in determining whether eradication or alternative action will be taken for an EPP Incident (taken from Appendix 12 of PLANTPLAN)*

Factors favouring eradication	Factors favouring alternative action
• Cost/benefit analysis shows significant economic or amenity loss to industry or the community if the organism establishes. • Physical barriers and/or discontinuity of hosts between production districts. • Cost effective control for long term management difficult to achieve (e.g. limited availability of protectant or curative treatments). • The generation time, population dynamics and dispersal of the organism favour more restricted spread and distribution. • Pest biocontrol agents not known or recorded in Australia. • Vectors discontinuous and can be effectively controlled. • Outbreak(s) few and confined. • Trace back information indicates few opportunities for secondary spread. • Weather records show unfavourable conditions for pest development. • Ease of access to outbreak site and location of alternate hosts.	• Cost/benefit analysis shows relatively low economic or environmental impact if the organism establishes. • Major areas of continuous production of host plants. • Cost effective control strategies available. • Short generation times, potential for rapid population growth and long distance dispersal lead to rapid establishment and spread. • Widespread populations of known pest biocontrol agents present in Australia. • Vectors unknown, continuous or difficult to control. • Outbreaks numerous and widely dispersed. • Trace back information indicates extensive opportunities for secondary spread. • Weather records show optimum conditions for pest development. • Terrain difficult and/or problems accessing and locating host plants.

4 Pest information/status

4.1 Pest details

Common names:	Tarnished plant bug
Scientific name:	*Lygus lineolaris* Palisot de Beauvois, 1818
Synonyms:	*Capsus flavonotatus* Provancher, 1872 *Capsus lineolaris* Palisot de Beauvois, 1818 *Capsus oblineatus* Say, 1832 *Capsus strigulatus* Walker, 1873 *Lygus pratensis* var. rubidus Knight, 1941
Taxonomic position:	Kingdom, Animalia; Phylum, Arthropoda; Class, Insecta; Order, Hemiptera; Family, Miridae

4.1.1 Background

The family Miridae includes a large range of species, most of which feed on plants. This family are referred to as plant bugs and are characterised as generalised plant feeding insects that use needle-like mouth parts to extract plant juices from their hosts during all stages of their life (from nymphs to adults).

The genus *Lygus* is a group of insects containing over 40 plant bug species. Three economically significant species in this genus are *Lygus hespereus*, *Lygus elisus* and *Lygus lineolaris* are not present in Australia (CABI 2011) and are considered quarantine pests of national concern. These species are all very similar in morphology (biology and taxonomy) and are highly polyphagous.

The Tarnished plant bug (*Lygus lineolaris*) is a true bug (order Hemiptera) with the crossed wings and piercing-sucking mouthparts characteristic of this order of insects. The piercing-sucking mouthparts are inserted into the plant tissues, concurrently introducing toxic saliva into the plant and feeding. This pest causes various types of injury, including deformed leaves (as in beets and chard) and scarred, discolored stems or leaf petioles. In a number of fruits, the buds of the developing fruit are dwarfed and pitted. The tops of dill plants are often killed and blackened above the feeding wound.

It is a highly polyphagous species which attacks more than 130 economically important plant species from nursery stock and broadacre and horticultural crops. *L. lineoalaris* can be found throughout the USA, Canada and Mexico on a range of crops and ornamentals (Young 1986). This pest has caused significant yield losses in cotton, canola, mustard, seed lucerne, vegetable crops, fruit crops and also nursery stock and is the main pest of these crops in the eastern and southern USA (Schwartz and Foottit 1992). It has also been found to be a problem on many glasshouse species used as cut flowers including *Aster,* chrysanthemums, *Dahlia, Impatiens* and *Tagetes*.

More than 50% of cultivated plant pests grown in the United States are listed as host plants for Tarnished plant bugs (Capinera 2001). In its natural habitat in the United States, populations are greatest in flowering meadows and weedy patches. Tarnished plant bug populations will increase when flowers are abundant then decline when plants senesce. Some of the common flowers attacked by Tarnish plant bug are curly dock, cutleaf evening primrose, wild carrot, vetch and clover (Penn State University).

In the United States and Canada the Tarnished plant bug has also become a pest in conifer nurseries affecting plantings of pine (*Pinus* spp.), larch (*Larix* spp.) and Douglas fir (*Pseudotsuga* spp.) (Dixon 1989) where the main damage is caused by feeding on the newly emerged seedlings. Distortion of the terminal shoots and a loss of apical dominance may lead to seedlings forming multiple stems (Bryan 1989). This bug can also be a pest of poplar (*Populus* spp.) nursery stock (Sapio *et al*. 1982; Wilson and Moore 1985). Although it primarily feeds on plants, it has also been shown to feed on the eggs and larvae of Heliothis insects (Cleveland 1987).

The pest feeds on all aerial plant parts preferring leaf and flower buds, flowers, fruit and seeds. Damage is caused by the nymphs and adults piercing plant tissues then sucking out nutrient rich juices. *Lygus lineolaris* does not commonly transmit plant diseases but has been reported to transmit *Erwinia amylovora* to pear fruits (Stahl and Luepschen 1977).

Plant bugs are quick moving and easily disturbed. The adults are very active readily dispersing to new areas by flight in search of suitable hosts, when they attack the buds of fruit trees, seriously injuring the terminal shoots and fruits. They do not appear to lay their eggs on these plants to any great extent, but rather migrate to various herbaceous weeds, vegetables and flowers, where the eggs are either inserted full length into the stems, petioles or midribs of leaves or into buds, or are tucked in among the florets of the flower heads. Adults are oval shaped, light green to brown in colour (approx.

6 mm long) with black-tipped yellow triangles on the forewings with the wings sloping downward at the end. Nymphs are yellow green with five black dots and the eggs are long and curved.

4.1.2 Life cycle

The Tarnished plant bug is a small, flattened bug, which is generally brown in colour and mottled with splotches of white, yellow, reddish-brown and black. Tarnished plant bugs develop through five nymphal stages. The nymphs are very small and greenish-yellow, marked dorsally with four black dots on the thorax and one on the abdomen. Like the adults, the nymphs have piercing-sucking mouth parts and feed on plant tissues. The wings of the adults have a hard wing cover similar to that of a beetle with a smoky-brown membranous tip. The adults will fly readily when disturbed.

The adult bugs over-winter amongst weeds, leaves and bark (Cleveland 1982). As with all bugs there is no pupal stage, the life cycle only involves the egg, nymph and adult stages with the adults and nymphs tending to feed on the same material.

Adults become active as temperatures increase emerging early in the spring and feeding on newly developing buds and shoots before migrating to other plants to lay eggs on the leaves or flowers. Females may deposit eggs in stems, leaf parts as well as the flowers of host plants laying 1 to 3 eggs per day and between 30 to 120 eggs over her lifespan.

Figure 3. *Adult Tarnished plant bug. Image courtesy of University of Illinois.*

The adults are approximately 6 mm in length, and although they are true bugs (suborder Heteroptera), they have a flat, 'beetle-like' appearance with a small head projecting in front. Colour patterns vary considerably, ranging from greenish-yellow to brown (Kelton 1980). Males are generally darker than females. The body is marked with white, yellowish-brown, reddish-brown and black splotches. A distinguishing characteristic often seen is small but distinct yellow cream coloured 'Y'-shaped mark in the centre of the back (scutellum) behind the head. The cuneus (triangular section on the forewings) is pale with a black tip. The lateral margins of the mesoscutum are yellow or red (Schwartz and Foottit, 1992). The antennae and legs are long with the over-wintered adults being much darker in colour than the summer adults (Capinera 2001).

Figure 4. *Life cycle of the Tarnished plant bug (5 instars). Image courtesy of University of Georgia, Bugwood.org.*

Oviposition is usually restricted to the composite family (non-conifers). Typically, eggs are inserted into flowerlets or blossoms. The eggs are small (1 mm approx.) white in colour and slightly curved. They are oviposited into plant tissues. The hatchling nymph emerges from the opening where the top of the egg joins the surface of the plant tissue (Capinera 2001).

Figure 5. *Tarnished plant bug egg. Image courtesy of Scott Stewart, University of Tennessee, Bugwood.org*

Eggs hatch into nymphs about 7 days after being laid. Newly hatched nymphs are yellow to green in colour and 1 mm in length (approx.). There are five instars or nymphal stages, nymphs gradually becoming more like adults in appearance with each moult. The nymphs resemble adults without wings because of their incomplete metamorphosis. As the nymphs mature in later instars they develop yellow, green or black markings and wing pads in their final instar (Schwartz and Foottit, 1992) growing in size to 4.5 mm long.

***Figure 6**. Lygus lineolaris nymph feeding on broccoli during a feeding test. Image courtesy of Allen Cohen, USDA Agricultural Research Service*

The length of the life cycle can vary depending on temperature and environmental conditions. At 34^{o}C the Tarnished plant bug may take 12.5 days to progress through the five nymphal instars but at 12^{o}C the time can increase to 40 days.

On average, the life cycle is completed in approximately three to four weeks with three to five generations per year depending on location and latitude (Sutherland 1989; Broadbent *et al.* 2006). Pickel *et al.* 2006 reported that for some plant bug species there have been up to ten overlapping generations in a year. Numbers of tarnished plant bugs increase significantly by midsummer but they are well camouflaged and often go unnoticed (Rakickas and Watson 1974; Ridgeway and Gyrisco 1960). In cooler climates the adults overwinter in litter or other trash in protected areas, such as woods or ditch banks along fields.

Most greenhouse nursery damage in the northern hemisphere occurs during late spring to early summer (from mid-April to late June) (Cleveland 1982; Haseman 1918; Anonymous 1988). Good sanitation or chemical control methods are needed to control Tarnished plant bug populations. Once established in greenhouses Tarnished plant bug populations are hard to control. Reinfestation usually occurs through unscreened vents or doors during ventilation.

Plant bugs can also lay eggs and feed on weedy hosts. Control of weeds is encouraged as the presence of weeds can influence the number of plant bugs found in a commercial crop (Anthon 1993; Caprile *et al.* 2006). In British Columbia (and parts of the US), the importance of *L. lineolaris* on coniferous nursery stock has increased with the reporting of the plant bug feeding on and damaging conifer seedlings (Dixon 1989).

4.1.3 Dispersal

The adult *L. lineolaris* is a very active and mobile insect that flies readily when disturbed. Research has shown that this pest moves both within cotton fields and to disperse between fields and adjacent areas in California, with adults readily moving up to 15 metres/day (Bancroft 2005). It has also been shown that the both the Tarnished plant bug and Western tarnished plant bug are well adapted colonisers that are capable of flying with a full complement of eggs enabling them to exploit new habitats (Blackmer *et al.* 2004).

As adults are very active, they are unlikely to be included in commodity shipments. The movement of fruit is unlikely to be a significant factor in the spread of plant bugs between regions. Nymphs on the other hand are reclusive and could potentially hide in commodities such as cut flowers. Eggs are very small and as they are positioned in plant tissues they would also be difficult to detect during inspection of agricultural commodities (CABI 2011).

It is likely that if Tarnished plant bug was to become established on a suitable host in Australia that it would spread to other susceptible hosts. The species is widespread throughout the United States and found on many hosts. As Australia shares similar environmental conditions to the USA it would be expected that *L. lineolaris* would readily spread across Australia. Natural barriers may limit the natural movement of the pest in certain regions. There have been numerous reports of *L. lineolaris* covering significant distances in a single flight including the capture of bugs up to 5 km out to sea.

However, it is more likely that dispersal between regions and over long distances would be assisted by the movement of infested commodities including nursery stock.

4.2 Affected hosts

4.2.1 Host range

Tarnished plant bugs have an extremely wide host range, being able to complete their life cycle on over 328 plant species in North America, of which 130 species are economically important (Young 1986). A partial host list includes: lucerne, apples, apricots, beans, beets, blackberries, carrots, celery, cherries, clover, commercially grown flowers, cotton, cucumbers, currants, lettuce, peaches, peas, pears, peppers, plums, potatoes, quince, raspberries, strawberries, tobacco, tomatoes and turnips. *L. lineolaris* is most attracted to flowering plants in the families' Asteraceae and Brassicaceae (CABI 2011). It has also been suggested that *L. lineolaris* has the broadest documented feeding niche of any arthropod.

A comprehensive list of hosts is provided in Appendix 1 (Table 12).

4.2.2 Current geographic distribution

L. lineolaris is the most widely distributed *Lygus* species in North America. It occurs in all Canadian provinces, all states of the United States and throughout most of Mexico and is found in all agricultural areas from low to relatively high elevations, from east central Alaska southeast to Newfoundland and south to southern Mexico (Kelton 1975; Young 1986; Schwartz and Foottit 1992). The Tarnished plant bug *L. lineolaris* is displaced by *L. hesperus*, the Western tarnished plant bug on lucerne and cotton in western North America (Day 1987; Layton 2000).

Table 3. *Current worldwide distribution of the Tarnished plant bug*

Continent	Countries
Asia	Republic of Georgia
North America	United States of America, Canada, Bermuda, Mexico
Central America	El Salvador, Guatemala, Honduras

4.2.2.1 POTENTIAL DISTRIBUTION IN AUSTRALIA

Plant bugs (*Lygus* spp.) are widely distributed throughout northern America. Three species *Lygus elisus* van Duzee, 1914 (pale legume bug or lucerne plant bug), *Lygus hesperus* Knight, 1941 (Western tarnished plant bug) and *Lygus lineolaris* Palisot de Beauvois, 1818 (Tarnished plant bug) have been grouped together because of their related biology and taxonomy and are predicted to post a similar risk. None of these species are present in Australia (CABI 2011) and all are considered quarantine pests of national concern.

The potential distribution in Australia is based on information sourced from 'Import risk analysis report for fresh stone fruit from California, Idaho, Oregon and Washington' (Biosecurity Australia 2010) and 'Import risk analysis report for fresh apple fruit from the United States of America Pacific Northwest states' (Biosecurity Australia 2009). In each document it is considered highly unlikely that nymphal or adult plant bugs would remain associated with imported fruit but the principle risk is that eggs laid into the fruit would have the potential to enter Australia resulting in the establishment of exotic plants bugs in Australia. Plant bug eggs would also have the potential to survive on imported flowers.

It has been shown that eggs can survive 10^{o}C temperatures for 15 days without an increase in mortality, however with prolonged exposure over 30 and 45 days egg mortality increases with fewer adults produced (Snodgrass and McWilliams 1992). Egg development could then continue after fruit has been removed from cool storage (Zalom *et al.* 2008).

Successful transfer to a suitable host would require the plant bug to locate a host. The Tarnished plant bug is polyphagous and known to feed on a wide selection of hosts, crops, commercially grown flowers, fruit trees, forest tree nurseries and weeds so is expected to disperse quickly (CABI 2011).

4.2.3 Symptoms

Lygus lineolaris can feed on all aerial parts of a plant but prefers to feed on reproductive plant structures namely, leaf and flower buds, flowers, fruits and seeds. Nymphs and adults feed by sucking juices from the plant. Yellowing and distortion of the plants' growing points result from the feeding on buds and new growth. With continued feeding, dwarfing, blackening or die-back of the shoots may also occur. Other symptoms include blemished or distortion of fruit. Examples of these symptoms are the dieback of shoots on asparagus (Grafius and Morrow 1982) and the resultant flower death, fruit deformity or apical seediness of strawberries (Handley 1991) and dimpling (or 'catfacing') around the feeding site in peaches and apples.

Tarnished plant bug affects many parts of its host. Table 4 is a summary outlining symptoms.

Table 4. *Tarnished plant bug symptoms and plant part affected*

Plant part affected	Symptoms
Fruit	premature drop, lesions: on pods, discoloration, abnormal patterns, abnormal shape
Growing point	Dieback, distortion, lesions
Inflorescence	Fall or shedding, blight, necrosis, discoloration (non-graminaceous plants), distortion (non-graminaceous plants)
Leaves	Abnormal colours
Seeds	Empty or shrivelled grains, lesions on seeds, distortion
Stems	Discoloration of bark
Whole plant	Dwarfing, distortion, resetting

Figure 7*. Damage to a daisy. Image courtesy of Whitney Cranshaw, Colorado State University, Bugwood.org.*

Figure 8. *"Dirty bloom" or damage to anthers of bloom. Image courtesy of Ronald Smith, Auburn University, Bugwood.org*

4.3 Diagnostic information

There is no molecular test to distinguish different *Lygus* spp., however a field key is regularly used to distinguish *Lygus hesperus* from other common plant bugs in the United States. This key developed by Mueller *et al*. (2003) is called 'A field key to the most common *Lygus* species found in agronomic crops of the central San Joaquin Valley of California'. The key is used to distinguish between three species reportedly found in the Central San Joaquin Valley of California namely *L. hesperus* (Western tarnished plant bug), *L. elisus* (Pale green bug) from *L. lineolaris* (Tarnished plant bug).

The key features of *L. lineolaris* distinguishing it from the other species include the following and are found in Table 5 (Mueller *et al*. 2003; Kelton 1975).

For a list of diagnostic facilities and advisory services that can be utilised in the event of an incursion see Section 9.2 Appendix 2.

Table 5. *Key features distinguishing L. lineolaris from other species*

Lygus lineolaris	
Male	length 4.9-5.74 mm, width 2.38-2.8 mm
Head	length 0.91 mm, width 1.12 mm. Yellowish brown, middle of clypeus, lorum, and jugum marked with reddish or black; line above head
Antennae	antennal socket red or black; frons smooth, median line and submedian diagonal line red or black. I – 0.56 mm, reddish brown, black beneath; II – 1.40-1.82 mm, brown, base and apical third black; III – 0.88 mm, black; IV – 0.74 mm, black. 2.24-2.52 mm long
Pronotum	1.96-2.31 mm wide at base; yellowish brown to reddish brown; outer callus, two dots or rays behind, black; basal angle and often subbasal margin at base, black; anterior angles rounded; shallowly and widely punctate.
Mesoscutum	black, lateral margins reddish.
Scutellum	yellowish, two median and lateral lines, black or reddish.
Hemelytron	reddish brown; darker at apex of corium; cuneus pale green, basal and inner margins reddish, tip black; wing membrane fuscous, veins reddish; pubescence moderately long and dense, yellowish.
Ventral surface	reddish brown, sternum and middle of abdomen black; legs yellowish, usual markings on femora reddish brown.
Female	length 5.25-5.95 mm, width 2.52-3.01 mm. Rostrum: 2.17-2.52 mm long. Much like male in colour, markings, and appearance, but more robust.

The description above is for overwintered adults with summer adults similar in size but with colour varying from pale yellow with few black markings to reddish brown, and to almost completely black with few pale yellow markings. Nonetheless, the characteristic pattern on the head, and the reddish or pale lateral markings of the mesoscutum, and the rather long and dense pubescence readily distinguishes this species from its close relatives. Summer adults may appear as early as the end of April in the northern hemisphere and later at higher altitudes and as the season progresses northward (Mueller *et al*. 2003).

4.4 Pest risk ratings and potential impacts

A pest risk analysis has been carried out on this pest, taking into account the entry, establishment and spread potentials, together with the economic and environmental impact of establishment. A summary of these ratings are shown in Table 6. Based on this information, the Tarnished plant bug is considered a Medium overall risk to Australia.

Table 6. *Pest risk ratings for the Tarnished plant bug as determined in the Nursery and Garden IBP (Plant Health Australia, 2008)*

Potential or impact	Rating
Entry potential	Medium
Establishment potential	High
Spread potential	High
Economic impact	Medium
Overall risk	Medium

4.4.1 Entry potential

Rating: Medium

As adults of *L. lineolaris* are very active insects and fly readily when disturbed, it is therefore unlikely that they would remain on imported produce or plants (eg fruit or cutflowers) or be included in commodity shipments. On the other hand nymphs are reclusive and hard to see and could potentially hide in certain commodities, such as flower crops. Eggs are very small and once inserted into plant tissues, detection would be unlikely during inspections of agricultural commodities.

Unless fruit damage or other symptoms are obvious, fruit containing eggs are not expected to be removed by grading and culling operations.

Even though *L. lineolaris* is a very common pest on a wide variety of commodities in northern America (United States, Canada and parts of Mexico) it has limited global distribution elsewhere and it would appear not to pose a large phytosanitary risk from imported materials other than plant material from northern America.

4.4.2 Establishment potential

Rating: High

To establish a reproductive population a mated female or 'immatures' of both sexes would be necessary. Eggs would need to enter, hatch and develop to adulthood, locate each other and successfully mate. Female *Lygus* bugs attract males with pheromones (Wardle and Borden 2003) increasing the probability of mating. Climatic conditions in Australia are varied ranging from southern temperate regions to tropical and subtropical as well as Mediterranean climatic regions, each of which are similar to regions in the US, Canada and Mexico suggesting that climate would not be a restricting factor for establishment. The high reproductive rates and dispersal abilities of the *Lygus* spp. indicate that there would be few barriers to spread.

Tarnished plant bug is a polyphagous feeder and known to feed on a wide selection of hosts crops and fruit and commercially grown flowers, fruit trees, forest trees and weeds (CABI 2011) and evidence suggests that it may have the widest host range of any arthropod (Young 1986). Therefore there is sufficient availability of suitable hosts for the establishment of these pests in Australia.

4.4.3 Spread potential

Rating: High

With similar environmental conditions to northern America, Australia would therefore be suitable for the spread of this pest. It has been shown that parasitoid wasps are effective against the Tarnished plant bug (Sohati *et al*. 1992) and other *Lygus* spp. (Broadbent *et al.* 2006) but it is not known what role if any, endemic parasitoids would play in Australia in biological control. Natural barriers like desert and mountain ranges may limit the natural movement between regions but *Lygus* spp. are well adapted colonisers that are capable of flying.

There is potential for movement of *Lygus* spp. between regions and over long distanced by movement of infested commodities such as nursery stock. The movement of fruit is unlikely to be a significant factor in the spread of *Lygus* spp. between regions.

4.4.4 Economic impact

Rating: Medium

Tarnished plant bug is highly polyphagous resulting in direct losses to many economically important crops and nursery stock including in cotton, canola, lucerne, asparagus, apple, peaches, strawberry, raspberries, poplars, celery, broad bean and seedling conifer trees in nurseries.

4.4.5 Environmental, amenity and human health impact

Lygus spp infest a large variety of plants with the potential to affect many amenity species in urban, suburban and rural a reas. Hosts would include conifers and weed species. Other potential environmental effects would be the increased use of pesticides. Introduction of a pest to a new region can also lead to competition for resources with native plant bugs including mirids (Biosecurity Australia 2008).

5 Pest management

5.1 Response checklist

The following checklist (Table 7) provides a summary of generic requirements to be identified and implemented within a Response Plan.

Table 7. *Checklist of requirements to be identified in a Response Plan*

Checklist item	Further information
Destruction methods for plant material, soil and disposable items	Sections 6.1.1 and 6.1.2
Disposal procedures	Section 6.1.5
Quarantine restrictions and movement controls	Section 6.3
Decontamination and property cleanup procedures	Section 6.5
Diagnostic protocols and laboratories	Sections 4.3 and 9.2
Trace back and trace forward procedures	Section 6.6
Protocols for delimiting, intensive and ongoing surveillance	Section 5.2
Zoning	Section 6.4
Reporting and communication strategy	See PLANTPLAN

For a range of specifically designed procedures for the emergency response to a pest incursion and a general communication strategy refer to PLANTPLAN (Plant Health Australia, 2010). Additional information is provided by Merriman and McKirdy (2005)[5] in the Technical Guidelines for Development of Pest Specific Response Plans.

5.2 Surveys and epidemiology studies

Information provided in Section 5.2.1 to 5.2.3 provides a framework for the development of early detection and delimiting surveys for Tarnished plant bug in Australia.

Where Tarnished plant bugs are found in a production nursery that is in close proximity to potential host plants (including weeds), periodically inspect nearby hosts for signs of Tarnished plant bug infestation by examining leaves closely and looking for resultant damage. Infested sources within a production nursery may provide an opportunity for Tarnished plant bugs to spread outside the production nursery.

As the adult plant bugs are very active they will readily disperse to new areas in search of suitable hosts (herbaceous weeds, vegetables and flowers). Plant bugs can also lay eggs and feed on weedy hosts. Control of weeds is encouraged to limit plant bug multiplication. The adult bugs may also over winter amongst weeds, leaves and bark.

[5] Available on the PHA website (**www.planthealthaustralia.com.au/go/phau/biosecurity/general-biosecurity-information**)

As feeding by this pest (both nymphs and adults) causes damage to all aerial plant parts, it is important to check all parts of the plant for visible damage.

Agricultural inspectors and other production nursery visitors should avoid moving infested plant material between production nurseries. Shoes, tools and vehicle tyres should be thoroughly washed of soil and then sanitised with a registered disinfectant. Extra precaution should be taken when working in areas known to be infested, including disposable overboots that may be used and disposed of on-site.

5.2.1 Technical information for planning surveys

When developing surveys for Tarnished plant bug presence and/or distribution, the following characteristics of the pest provide the basic biological knowledge that impact on the survey strategy:

- Tarnished plant bugs have a wide host range and share a number of similarities with other native plant bugs (Fletcher 2007)
- Host species in Australia are likely to be numerous and widely dispersed.
- Movement of the pest can occur by flight or by human assistance through the transfer of nursery stock
- The risk of pest movement on machinery, equipment and personal effects is high
- Production nursery greenhouses and significant proportions of Australia have favourable climatic conditions for the spread and establishment of Tarnished plant bug
- As Tarnished plant bugs spread readily in a greenhouse or production nursery environment the tracing of plant material from one nursery to another needs to be taken into consideration

5.2.2 Surveys for early detection of an incursion in a production nursery

The success of an eradication response to a Tarnished plant bug incursion in a production nursery is more likely following early detection of the pest before the insect has had the opportunity to disperse to a wide area. It is therefore necessary to consider pathways and plan surveys accordingly. Important points to consider when developing early detection surveys in commercial production nurseries are:

- The adult Tarnished plant bug is a small flattened bug, about 6 mm in length. They are generally brown in colour with yellow and black markings
- A number of methods have been proposed for the monitoring of Tarnished plant bug including direct tree examinations, jarring or beating tray counts, sticky traps, orchard floor sweep sampling and fruit damage counts (Polk *et al*. 1995; Boivin *et al.* 1982). Points to note are:
    - Visual examination of trees is tedious and time consuming
    - Beating tray sampling can be used which comprises using a framed white sheet placed on the ground beneath the tree or with a hand held square canvas beating tray. Use a rubber mallet or heavy stick wrapped in rubber hose to beat one or two branches 3 to 4 times. Any insects landing will fly away if not counted quickly

  - Sweep sampling can be used to indicate the insects present in the ground cover. This method will select nymphs and adults and could therefore be used as a method to predict population growth. Sampling should include taking 50 sweeps across a site and be biased towards the thicker ground cover and weeds that are blooming or have flowered
  - In the USA, fruit damage is monitored by assessing 200 units of fruit per block. This type of sampling is done for management rather than eradication purposes
  - White sticky boards have been used in apple orchards but not successfully in peach orchards. Traps should be placed in the outer one or two rows with the trap colour mimicking bloom colour. Traps should be placed approx. 0.5 m above ground on the tree or on stakes near weeds with the ground cover cleared around the traps. Traps should be monitored and replaced weekly, or cleaned weekly and when needed replace adhesive
  - The preferred method for detection of plant bugs species is to beat the leaves with a small heavy trowel over a clean plastic surface or sweep nets to collect adults and nymphs
  - For nurseries, depending on the size of the business, beating tray, sweep or white sticky board sampling methods would be most suited
- Targeted surveillance should be focussed on high-risk areas. These include commercial propagators and production nurseries involved with the import and export of cut flowers and other nursery produce

If an incursion of *L. lineolaris* is to be eradicated in a production nursery, it must be detected early, before the insect has had the opportunity to disperse over a large area. It is therefore necessary to consider pathways and plan surveys accordingly. Important points to consider when developing early detection surveys are:

- The greatest entry risk currently comes from importation of host plants or other goods. Ongoing surveys at importing production nurseries and ports are therefore recommended
- Awareness information should be targeted at people who are in regular close contact with potential hosts in high risk areas or movement vectors (e.g. production nursery operators)
- Systematic and careful inspection of production nursery crops and propagative plant material is essential to prevent introduction of Tarnished plant bug and limit its spread within, and from infested production nurseries. Early detection of the pest, while at very low levels, will provide the best chance of eradication
- An inspector must be trained to recognise the basic identification of all stages of Tarnished plant bug, including adults, eggs and larvae, as well as other endemic pests for comparison (see Section 4.3). A production nursery layout map that includes approximate locations of known host species will be required to develop a strategy for surveys. A survey map should include species and cultivar names, locations, approximate quantity and sources of targeted plants within the area. During the survey walkthrough, record the date, observations, and sampling information directly onto the survey map. The recorded information should be reviewed and used to develop the most efficient survey strategy each time the production nursery is inspected
- Begin the inspection with an overview of the area from the crop perimeter or with a quick walk-through. If suspicious symptoms or stages of Tarnished plant bug are apparent, immediately examine them more closely and collect samples if required. If no symptoms are

apparent from the overview inspection, start the complete inspection by walking a systematic path through the crop. A common survey technique is to move relatively quickly down a walkway and scan both sides of adjacent production beds/benches, back and forth. If suspicious symptoms are seen, inspect plants more closely. A good-quality 10x magnification hand lens can help identify many pest symptoms. If plants are found with suspicious symptoms or stages of Tarnished plant bug, a sample should be taken and the plant marked with plastic tape or a flag with the location noted on the survey map. Also, a few plants can be selected at random to closely inspect for Tarnished plant bug life stages or plant damage. Surveys can be prioritised to highest risk stock

- New stock or cuttings of hosts should be monitored closely. Note also outside sourced plants on survey maps for weekly examination

5.2.3 Delimiting surveys in the event of an incursion

- In the event of an incursion, information from delimiting surveys will be used in the decision-making process
- The size of the survey area will depend on the size of the known infested area and the severity of the infection, as well as prevailing winds and movement of plant material during the period prior to detection (Figure 9). Other considerations are for example, movement of people or plant material equipment as a result of trace-forward and trace-backs
- Tarnished plant bugs can readily fly and also can spread long distances by floating with the wind or being transported on infested plants
- Initial surveys should be carried out in a 1.5 km radius of the initial detection but as the Tarnished plant bug is an active flier the survey radius should be expanded to a 30 km radius as the delimitation progresses. It should be noted this will only take into account natural dispersal and survey range may need to be extended if human assisted dispersal is considered a factor
- All potential host species (refer to Section 4.2 and 9.1) should be surveyed including the species to which the pest was initially detected
- In addition to inspection of possible host plants, material should be collected for diagnostic purposes (refer Section 4.3)
- If the incursion is in a populated area, publication and distribution of information sheets and appeals for public assistance may be helpful

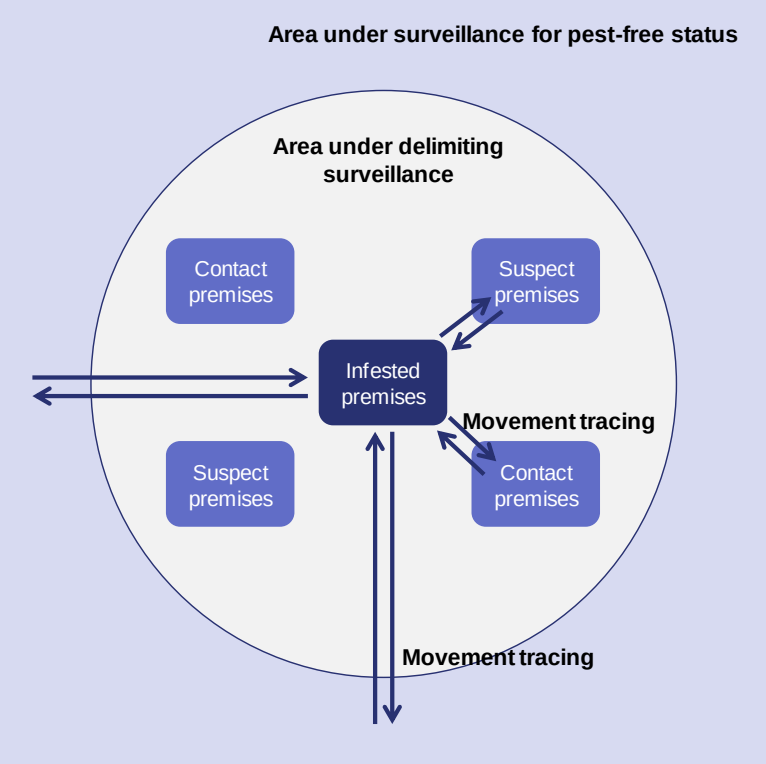

Figure 9. *Diagram of a delimiting survey showing surveillance activities from the infected premises*

5.2.4 Collection and treatment of samples

Protocols for the collection, transport and diagnosis of suspect Emergency Plant Pests (EPPs) must follow PLANTPLAN (Plant Health Australia, 2010). Any personnel collecting samples for assessment should notify the diagnostic laboratory prior to submitting samples to ensure expertise is available to undertake the diagnosis.

5.2.4.1 COLLECTION OF SPECIMENS

Sampling procedures

Samples can be collected by hand using a sweep net or beat sheet, along with white sticky traps (see Section 5.2.2). All life stages are found on the plant material except for eggs (eggs are inserted into flowerets of blossoms) which are found within plant material.

Number of specimens to be collected

Where possible, collect multiple specimens representative of all life stages of the population available. Adult Tarnished plant bugs are preferred, as the adult life stage is the easiest with which to confirm identification.

Record the identity of the host plant where the plant bugs were collected. Record the location, preferably as GPS co-ordinates, or alternatively, a map reference or distance and direction from a suitable landmark. If the land is privately owned, record the owner's details including contact telephone numbers.

How to collect and send plant samples with eggs, larvae or pupae

Samples should be treated in a manner that allows them to arrive at the laboratory in a fresh, well preserved state. Leaf samples containing Tarnished plant bug nymphs and if possible adults are to be placed in a specimen container and placed in a portable fridge of insulated container with cool packs to prevent the insect and leaf samples from drying out.

Adults are the preferred stage for identification. However, if an adult is not available for collection, the pupae can be used for identification (should be packed between sheets of dry newspaper (for stem etc.) or moist paper (for leaves) and sealed in a plastic bag. Each sealed bag should be placed in a second bag along with additional paper to absorb excess moisture. Bagged samples should then be placed in a non-crushable container with paper, bubble or foam to fill the remaining space and protect samples during transit.

All sample containers should be clearly labelled with the name, address and contact phone number of both the sending and receiving officers. In addition containers should be clearly labelled in accordance with the requirements of PLANTPLAN (Plant Health Australia, 2010; Appendix 3). Containers should then be carefully sealed to prevent loss, contamination or tampering of samples. The Chief Plant Health Manager will select the preferred laboratory. Additional labelling includes the identification of plant species/parts affected, location of affected plant (where available include GPS reading) as well as symptoms and an image if available.

Refer to PLANTPLAN for packing instructions under IATA 650.

How to preserve insects

Prior to beginning the identification process, place specimens in the freezer for at least 24 hours to kill them. Alternatively, they may be placed in ethyl alcohol to kill and preserve them. Specimens stored in alcohol for more than 3-5 days will become brittle (Mueller *et al*. 2003).

How to transport insects

Vials containing the samples in a preservative should be sealed to avoid leakage and packed in a manner to minimise shock to the vials (i.e. with cushioning material in a strong box). It is important to ensure that vials are completely 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:

- 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. Contact the relevant transport authority or company for advice

Precaution

Overheating or desiccation of samples prior to despatch should be prevented. Samples may be stored in a fridge (4-10°C) for a few days if necessary.

Receipt

On receipt of the samples the diagnostic laboratory should follow strict quarantine and processing guidelines. In keeping with ISO 17025 refer to PLANTPLAN (Plant Health Australia, 2010).

5.2.5 Epidemiological study

The extent of infestation in a production nursery, on a property or within a region will depend on the initial population size and whether conditions have been favourable for the pest to spread from the initial location. Sampling should be based upon the origins of the initial suspect sample(s). Factors to consider will be:

- The proximity of other susceptible plants to the initial infestation source, including both current and previous crops. This will include crops in the production nursery or on the property with the initial detection and those on neighbouring properties
- Machinery or vehicles that have been into the infested area or in close proximity to the infestation source
- The extent of human movements into and around the infested area. A possible link to the recent importation of plant material from other regions should also be considered
- The source of any production nursery stock propagation material and whether any other crops have been propagated from the same source and/or distributed from the affected nurseries
- If any other crops have been propagated from the same source and/or distributed from the affected production nurseries
- Plant bugs are highly mobile and depending on the temperature and environmental conditions Tarnished plant bug can have multiple generations per year
- Tarnished plant bugs have an extremely wide host range feeding on agricultural crops, weeds and other herbaceous plants

5.2.6 Models of spread potential

No models of spread potential have been developed for Tarnished plant bug.

5.2.7 Pest Free Area guidelines

Determination of Pest Free Areas (PFAs) should be completed in accordance with the International Standards for Phytosanitary Measures (ISPMs) 8 and 10 (IPPC 1998a, 1999).

General points to consider are:

- Design of a statistical delimiting field survey for the presence of the insect on host plants (see Section 5.2 for points to consider in the design)
- Surveys should be completed as described in the BioSecure *HACCP* manual (Nursery and Garden Industry Australia, 2008), including monitoring processes (summarised in Table 8 and Table 9), indicator plants and weed monitoring
- Surveys should also consider alternative hosts (see Sections 4.2.1 and 9.1) and not be limited to the primary infested host
- Information (including absence of the pest) should be recorded

Table 8. *Summary of monitoring processes for protected production areas as described in BioSecure HACCP Guidelines*

Wear protective clothing when handling suspect samples
Walk at random through the area in a zigzag pattern
Take at least 10 minutes to inspect 10-20 plants or plug trays per 100 m^2 of production area
Inspect the tops and bottoms or leaves, looking for any direct evidence of insects
Inspect the entire plant if it has less than six leaves, or from larger plants select six leaves from all parts of the plant (upper, lower, middle) and examine them individually
Inspect the length of all stems and branches for insects and symptoms
During individual plant inspection, strike the foliage over a white sheet of paper, or a paper or plastic plate to dislodge small insects for easier viewing
If any plants show suspect symptoms or evidence of eggs or larvae (refer to Section 4.2.3) take a sample (refer to Section 5.2.4) to be formally diagnosed (refer to Section 4.3)
Check for a problem that have occurred regularly in the past, until you are certain it is not present
Record on the 'Crop Monitoring Record' sheet the presence or absence of the pest
Routinely inspect growing areas and remove alternate hosts and reservoirs of the pest, including weeds, crop residues and old plants that will not be marketed

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).

Table 9. *Summary of monitoring processes for field production areas as described in BioSecure HACCP Guidelines*

Wear protective clothing when handling suspect samples
Pay particular attention to areas on the windward side, the sides bordering ditches, canals or other uncultivated areas and growing block centres
Place a flag or other marker at the entrance to the block or sampling area at the beginning of each inspection
Vary the entrance point in the sampling area (1 m to 3 m) for each subsequent sampling so that the same plants are not inspected each time
Walk at random through the area in a zigzag pattern
The scout should follow the same general pattern at each sampling
Make an effort to select those plants that appear less healthy for visual inspection
Take at least 10 minutes to inspect 10-20 plants or plug trays per 100 m^2 of production area
Inspect the tops and bottoms or leaves, looking for any direct evidence of insects
Inspect the entire plant if it has less than six leaves, or from larger plants select six leaves from all parts of the plant (upper, lower, middle) and examine them individually
Inspect the length of all stems and branches for insects and symptoms
During individual plant inspection, strike the foliage over a white sheet of paper, or a plastic or paper plate to dislodge small insects for easier viewing
If any plants show suspect symptoms or evidence of eggs or larvae (refer to Section 4.2.3) take a sample (refer to Section 5.2.4.1) to be formally diagnosed (refer to Section 4.3)
Check for a problem that has occurred regularly in the past, until you are certain it is not present
Record on the 'Crop Monitoring Record' sheet the presence or absence of the pest
Routinely inspect growing areas and remove alternate hosts and reservoirs of the pest, including weeds, crop residues and old plants that will not be marketed

5.3 Availability of control methods

5.3.1 General procedures for control

- Keep traffic out of affected areas and minimize movement in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest
- After surveys are completed, and permission has been obtained from the Chief Plant Health Manager or OCPPO, destruction of the infested plant material is an effective control
- On-going surveillance of infested areas is required to ensure the pest is eradicated
- Do not use any material from infested plants for propagation

5.3.2 Chemical control

Tarnished plant bug is controlled by a range of chemical products across a number of crop species overseas. While none of these chemicals are registered for Tarnished plant bug in Australia, several

of these products are available for the control of other insect pests across many crops in Australia (Listed in Table 10), and may be pursued for an Emergency Use Permit should Tarnished plant bug enter the country. In recent years *Lygus* populations in North America have developed resistance to insecticides (Grafton-Cardwell *et al.* 2000). Thus, use of a range of chemical groups may be necessary in an eradication effort and should Tarnished plant bug become established in Australia, rotation of insecticide groups will be essential in management of the pest.

Table 10. *Chemical control options for Tarnished plant bug*

Active ingredient	Group	Reference
Acephate	1B	Bagwell *et al.* (2005)
Bifenthrin	3A	Brust (2010)
Deltamethrin	3A	Kharboutli *et al.* (2000)
Dimethoate	1B	Bagwell *et al.* (2005)
Endosulfan	2A	Brust (2010)
Fipronil	2B	Kharboutli *et al.* (2000), Scott and Snodgrass (2000)
Imidacloprid	4A	Bagwell *et al.* (2005), Kharboutli *et al.* (2000), Scott and Snodgrass (2000)
Indoxacarb	22A	Kharboutli *et al.* (2000)
Oxamyl	1A	Bagwell *et al.* (2005)
Thiamethoxam	4A	Bagwell *et al.* (2005), Kharboutli *et al.* (2000)

Any chemicals used for the eradication or control of Tarnished plant bug in Australia must be registered for use through the Australian Pesticides and Veterinary Medicines Authority (APVMA). For information regarding this process visit the APVMA website (**www.apvma.gov.au**).

5.3.3 Biological control

Several parasitoids are known to be effective at parasitising *Lygus* spp., Hymenoptera including the egg parasite *Anaphis iole* (Girault) and the nymphal parasites *Leiophron uniformis* (Gahan), *Peristenus pallipes* (Curtis) and *P. pseudopallipes* (Loan), are thought to be relatively important for biological control. In the USA, native parasites are more effective at parasitising *Lygus* on weed hosts than on crops. Capinera (2001) showed that the parasitoid *Peristenus digoneutis* (Loan) decreased Tarnish plant bug abundance by 75% without affecting native parasitoid populations.

The braconid wasp *Peristenus pallipes* attacks nymphs, and the mymarid wasp *Anaphes ovijentatus* attacks eggs. Big-eyed bugs, damsel bugs, assassin bugs and crab spiders are important natural enemies and can help control lygus bug nymphs on host plants outside orchards or in the cover crop (**http://jenny.tfrec.wsu.edu/opm/displaySpecies.php?pn=180**).

Parasitoids, mainly species of *Peristenus* originating from Europe, have been imported and released in Canada and the USA (Kelleher and Hulme, 1981; Day, 1987). Evidence suggests that the entomopathogen *Beauvaria bassiana* also has promise as a biocontrol agent (Steinkraus and Tugwell, 1997).

Figure 10. *A quarter-inch-long parasitic wasp, Peristenus digoneutis, prepares to lay an egg in a tarnished plant bug nymph, Lygus lineolaris. Image courtesy of Scott Bauer, USDA Agricultural Research Service, Bugwood.org*

5.3.4 Physical and cultural control

Cultural practices may provide the best defence against Tarnished plant bugs. These practices include the removal of weeds and the elimination of trash that provide overwintering sites for the plant bugs. As a number of weeds and crops such as mustard play host to Tarnished plant bugs they have been used as trap crops to control *Lygus* numbers (CABI 2011).

5.4 Market access impacts

Within the AQIS PHYTO database (**www.aqis.gov.au/phyto**), there is currently no additional phytosanitary statement required that declares Tarnished plant bug is not known to occur in Australia (as at April 2011). Should Tarnished plant bug be detected or become established in Australia, countries may require a specific declaration or supplementary measures upon export. Latest information can be found within PHYTO, using an Advanced search “Search all text” for *Lygus lineolaris.*

6 Course of action

Additional information is provided by the IPPC (1998b) 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 PFA) or a measure to eliminate an established pest (establish a PFA). The eradication process involves three main activities: surveillance, containment, and treatment and/or control measures.

6.1 Destruction strategy

6.1.1 Destruction protocols

General protocols:

- No plant material should be removed from the infested area unless part of the disposal procedure
- Disposable equipment, infested plant material or growing media/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
- Machinery used in destruction processes need to be thoroughly washed, preferably using a detergent or farm degreaser

6.1.2 Decontamination protocols

Machinery, equipment and vehicles in contact with infested plant material or growing media/soil, or present within the Quarantine Area, should be washed to remove plant material and growing media/soil using high pressure water or scrubbing with products such as a degreaser or a bleach solution (1% available chlorine) in a designated wash down area. When using high pressure water, care should be taken not to spread plant material. High pressure water should be used in wash down areas which meet the following guidelines:

- 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, growing media/soil or plant residues should be contained (see Appendix 18 of PLANTPLAN [Plant Health Australia, 2010])
- Disposable overalls and rubber boots should be worn when handling infested plant material or growing media/soil in the field. Boots, clothes and shoes in contact with infested plant material or growing media/soil should be disinfected at the site or double-bagged to remove for cleaning
- Skin and hair in contact with infested plant material or growing media/soil should be washed

Procedures for the sterilisation of plant containers and growing media are provided within the BioSecure *HACCP* Guidelines, however, in the event of a Tarnished plant bug incursion, additional or modified procedures may be required for the destruction of the pest. Any sterilisation procedure must be approved for use in the endorsed Response Plan.

6.1.3 Priorities

- Confirm the presence of the pest
- Limit movement or people and prevent movement of vehicles and equipment through affected areas
- Stop the movement of any plant material that may be infested with the pest
- Determine the strategy for the eradication/decontamination of the pest and infested host material
- Determine the extent of infestation through survey and plant material trace back and trace forward

6.1.4 Plants, by-products and waste processing

- Any growing media/soil or infested plant material removed from the site should be destroyed by (enclosed) high temperature incineration, autoclaving or deep burial
- As the pest can be mechanically transmitted, plant debris from the destruction zone must be carefully handled and transported for destruction
- Infested areas or production nursery yards should remain free of susceptible host plants until the area has been shown to be free from the pest

6.1.5 Disposal issues

- Particular care must be taken to minimize the transfer of infested plant material or insects from the area
- Host material, including leaf litter, should be collected and incinerated or double bagged and deep buried in an approved site

6.2 Containment strategies

For some exotic pest incursions where eradication is considered impractical, containment of the pest may be attempted to prevent or slow its spread and to limit its impact on other parts of the state or country. Containment is currently being considered for inclusion within the Emergency Plant Pest Response Deed (EPPRD). The decision on whether to eradicate or contain the pest will be made by the National Management Group, based on scientific and economic advice (see Section 3, page 8).

6.3 Quarantine and movement controls

Consult PLANTPLAN (Plant Health Australia, 2010) for administrative details and procedures.

6.3.1 Quarantine priorities

- Plant material and growing media/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 growing media/soil, or present in close proximity to the site of infestation to be subject to movement restrictions

6.3.2 Movement controls

Movement controls need to be put in place to minimise the potential for transport of the pest, and this will apply to all plant material, growing media and other items within the quarantined area.

Movement of people, vehicles, equipment and plant material, from and to affected properties or areas, must be controlled to ensure that the pest is not moved off-property. Movement controls can be achieved through the following, however specific measures must be endorsed in the Response Plan:

- Signage to indicate quarantine area and restricted movement into and within these zones
- Fenced, barricaded or locked entry to quarantine areas
- Movement of equipment, machinery, plant material or growing media/soil by permit only. Therefore, all non-essential operations in the area or on the property should cease
- Where no dwellings are located within these areas, strong movement controls should be enforced
- Where dwellings and places of business are included within the Restricted and Control Areas movement restrictions are more difficult to enforce, however limitation of contact with infested plants should be enforced
- If a production nursery is situated within the Restricted Area, all nursery trading must cease and no material may be removed without permission, due to the high likelihood of pest spread. Movement restrictions would be imposed on both host and non-host material
- Residents should be advised on measures to minimise the inadvertent transport of Tarnished plant bug from the infested area to unaffected areas

- Clothing and footwear worn at the infested site should either be double-bagged prior to removal for decontamination or should not leave the site until thoroughly disinfected, washed and cleaned
- Plant material or plant products must not be removed from the site unless part of an approved disposal procedure
- All machinery and equipment should be thoroughly cleaned down with a high pressure cleaner (see Section 6.1.2) or scrubbing with products such as a farm degreaser or a 1% bleach (available chlorine) solution, prior to leaving the affected area. Machinery should be inspected for the presence of insects and if found, treatment with insecticide may be required. 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. When using high pressure water, care should be taken to contain all plant material and mud dislodged during the cleaning process

6.4 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. This will be determined by the National Management Group during the production of the Response Plan. Further information on quarantine zones in an Emergency Plant Pest (EPP) incursion can be found in Appendix 10 of PLANTPLAN (Plant Health Australia, 2010). These zones are outlined below and in Figure 11.

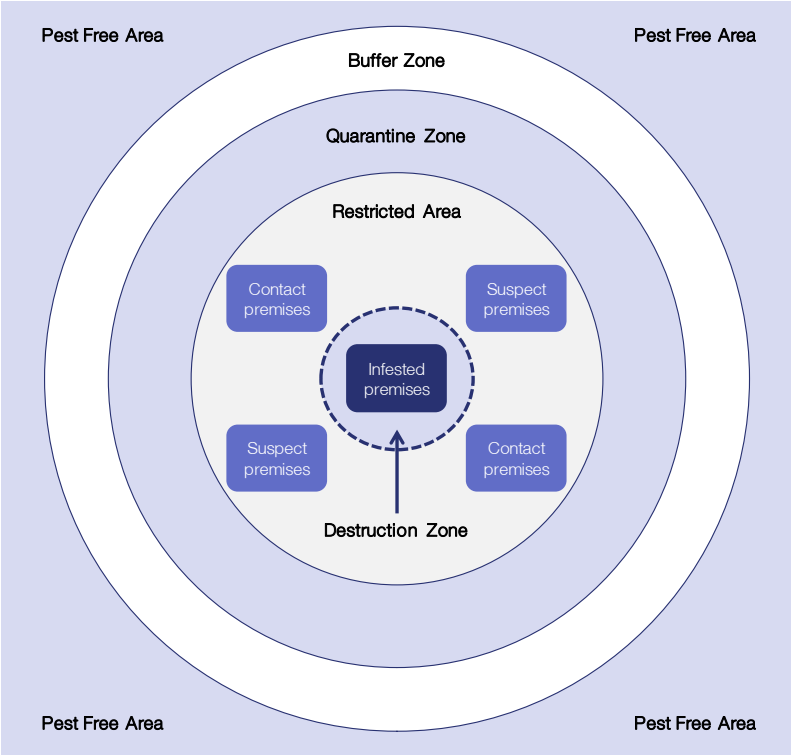

Figure 11. *Schematic diagram of quarantine zones used during an EPP incursion (not drawn to scale)*

6.4.1 Destruction Zone

The size of the destruction zone (i.e. zone in which the pest and all host material is destroyed) will depend on the ability of the pest to spread, distribution of the pest (as determined by delimiting surveys), time of season (and part of the pest life cycle being targeted) and factors which may contribute to the pest spreading.

All host plants should be destroyed after the level of infestation has been established. The delimiting survey will determine whether or not neighbouring plants are infested and need to be destroyed. Non-host plant material within this zone may be destroyed, based on recommendations in the Response Plan. The Destruction Zone may be defined as contiguous areas associated with the same management practices as, or in contact with, the infested area (i.e. the entire production nursery, property or area if spread could have occurred prior to the infection being identified).

Particular care needs to be taken to ensure that plant material (including non-hosts) is not moved into surrounding areas.

6.4.2 Restricted Area

The Restricted Area is defined as the zone immediately around the infested premises and suspected infested 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.

6.4.3 Quarantine Zone

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

6.4.4 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.

6.4.5 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.

6.5 Decontamination and property clean up

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

6.5.1 Decontamination procedures

General guidelines for decontamination and clean up:

- Refer to PLANTPLAN (Plant Health Australia, 2010) for further information
- Keep traffic out of affected area and minimize it in adjacent areas
- Adopt best-practice property hygiene procedures to retard the spread of the pest between growing areas/fields and adjacent properties
- Machinery, equipment, vehicles in contact with infested plant material or growing media/soil present within the Quarantine Zone, should be washed to remove growing media/soil and plant material using high pressure water or scrubbing with products such as a degreaser or a bleach solution in a designated wash down area as described in Section 6.1.2
- Only recommended materials are to be used when conducting decontamination procedures, and should be applied according to the product label
- Infested plant material should be disposed of by autoclaving, high temperature (enclosed) incineration or deep burial

6.5.2 General safety precautions

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

6.6 Surveillance and tracing

6.6.1 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 and businesses in the pest quarantine area
- Surveying all properties and businesses identified in trace-forward or trace-back analysis as being at risk
- Surveying all host growing properties and businesses that are reliant on trade with interstate or international markets which may be sensitive to Tarnished plant bug
- Surveying production nurseries selling at risk host plants
- Surveying other host growing properties and backyards

6.6.2 Survey regions

Establish survey regions around the surveillance priorities identified above. These regions will be generated based on the zoning requirements (see Section 6.4), 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. Detailed information regarding surveys for Tarnished plant bug have been outlined elsewhere in this plan (refer to Section 5.2).

Steps outlined in Table 11 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 11**. 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 the pest. Contact premises may be determined through tracking movement of materials from the property that may provide a viable pathway for spread of the pest. Pathways to be considered are: • Items of equipment and machinery which have been shared between properties including bins, containers, irrigation lines, vehicles and equipment • The producer and retailer of infested material if this is suspected to be the source of the outbreak • 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) • Movement of plant material and growing media/soil from controlled and restricted areas
Phase 5	Surveillance of production and retail nurseries, gardens and public land where plants known to be hosts of the pest are being grown
Phase 6	Agreed area freedom maintenance, post control and containment

6.6.3 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 growth conditions, the previous level of infestation, the control measures applied and the pest biology.

Specific methods to confirm eradication of Tarnished plant bugs may include:

- Monitoring of sentinel plants that have been grown at the affected sites. Plants are to be grown *in situ* under quarantine conditions and monitored for symptoms or other indications of Tarnished plant bug presence

- If symptoms or suspect insects are detected, samples are to be collected and stored and plants destroyed
- Targeted surveys for Tarnished plant bug should be undertaken within the Quarantine Zone to demonstrate pest absence
- Alternate non-host crops should be grown on the site and any self-sown plants sprayed out with a selective herbicide

7 Technical debrief and analysis for stand down

Refer to PLANTPLAN (Plant Health Australia, 2010) for further details

The emergency response is considered to be ended when either:

- Eradication has been deemed successful by the lead agency, with agreement by the Consultative Committee on Emergency Plant Pests and the Domestic Quarantine and Market Access Working Group
- Eradication has been deemed impractical and procedures for long-term management of the pest risk have been implemented

A final report should be completed by the lead agency and the handling of the incident reviewed.

Eradication will be deemed impractical if, at any stage, the results of the delimiting surveys lead to a decision to move to containment/control.

8 References

Anonymous (1988) *Lygus* bug trapping results. Auburn University, Southern. Forest Nursery Management Cooperative Newsletter. Spring 1988. 8 p.

Anthon EW (1993) Lygus bugs (tarnished plant bug). Orchard Pest Management Online, Washington State University. **http://jenny.tfrec.wsu.edu/opm/displaySpecies.php?pn=180**.

Bagwell RD, Leonard BR, Burris G, Stewart S, Pinnell-Alison C, Erwin T, Farris M, Micinski S (2005) Cotton Insect Control 2005. Louisiana Cooperative Extension Service. Publication 1083. 6 pp.

Bancroft JS (2005) Dispersal and abundance of *Lygus hesperus* in field crops. *Environmental Entomology,* 34: 1517–1523.

Biosecurity Australia (2009) Draft import risk analysis report for fresh apple fruit from the United States of America Pacific Northwest states. Biosecurity Australia. Canberra, ACT.

Biosecurity Australia (2010) Final import risk analysis report for fresh stone fruit from California, Idaho, Oregon and Washington. Biosecurity Australia. Canberra, ACT.

Blackmer JL, Naranjo SE, Williams LH (2004) Tethered and untethered flight by *Lygus hesperus* and *Lygus lineolaris* (Heteroptera: Miridae). *Enviornmental Entomology,* 33: 1389–1400.

Boivin G, Stewart RK, Rivard I (1982) Sticky traps for monitoring phytophagous mirids (Hemiptera: Miridae) in an apple orchard in southwestern Quebec. Environmental Entomology, 11(5): 1067-1070.

Broadbent AB, Lachance S, Sear MK, Goulet H (2006) Native braconid parasitism of the tarnished plant bug (Hemiptera: Miridae) in Southern Ontario. *Biocontrol Science and Technology,* 16: 687–698.

Brust G (2010) Tarnished plant bug management. University of Maryland extension publication. **http://mdvegetables.umd.edu/entomology/Tarnished%20plant%20bug%20in%20strawberry%20.pdf**.

Bryan H (1989) Control of the tarnished plant bug at the Carters Nursery. *Tree Planters' Notes,* 40(4): 30-33**.**

CABI (2011) Crop Protection Compendium CAB Internt. **www.cabi.org/compendia/cpc/index.htm**

Capinera JL (2001) Handbook of Vegetable Pests. Academic Press, San Diego. p. 729.

Caprile JL, Wunderlich LR, Vossen PM, Coates WW, Andris HL, Varela LG, Bentley WJ (2006) Insects and Mites. In *UC IPM Pest Management Guidelines: Apple.* pp. 6-54.

Cleveland TC (1982) Hibernation and host plant sequence studies of tarnished plant bugs, *Lygus lineolaris*, in the Mississippi delta. *Environmental Entomology,* 11: 1049-1052.

Cleveland TC (1987) Predation by tarnished plant bugs (Heteroptera: Miridae) of *Heliothis* (Lepidoptera: Noctuidae) eggs and larvae. *Environmental Entomology*, 16(1): 37-40.

Day WH (1987) Biological control efforts against Lygus and Adelphocoris spp. infesting alfalfa in the United States, with notes on other associated mirid species. In: Hedlund R, Graham HM, eds. Economic importance and biological control of *Lygus* and *Adelphocoris* in North America. Washington, USA: USDA, Agric. Res. Publ. ARS, 64: 20-39.

Dixon WN (1989) The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois) in conifer nurseries (Heteroptera: Miridae). Entomology Circular (Gainesville). 320. p. 2.

Fletcher M (2007) Plant bugs. Primefacts 508. **www.dpi.nsw.gov.au/primefacts**

Grafius E, Morrow EA (1982) Damage by the tarnished plant bug and alfalfa plant bug (Heteroptera: Miridae) to asparagus. *Journal of Economic Entomology*, 75(5): 882-884.

Grafton-Cardwell B, Goodell PB, Montez G (2000) Trends in pesticide use and pesticide resistance in San Joaquin Valley cotton. *California Cotton Review,* 56: 4-7.

Handley DT (1991) Strawberry fruit development and the effects of feeding by the tarnished plant bug (*Lygus lineolaris*). The strawberry into the 21st century. Proceedings of the Third North American Strawberry Conference Houston, Texas 14-16 February 1990. Portland, Oregon. Timber Press, pp. 209-216.

Haseman L (1918) The tarnished plant-bug and its injury to nursery stock. University of Missouri, College of Agriculture, Agricultural Experiment Station Research Bulletin. 29. p. 26.

IPPC (1995) Requirements for the Establishment of Pest Free Areas. International Standards for Phytosanitary Measures (ISPM) No. 4.

IPPC (1998a) Determination of pest free status in an area. International Standards for Phytosanitary Measures (ISPM) No. 8.

IPPC (1998b) Guidelines for Pest Eradication Programmes. International Standards for Phytosanitary Measures (ISPM) No. 9.

IPPC (1999) Requirements for the establishment of pest free places for production and pest free production sites. International Standards for Phytosanitary Measures (ISPM) No.10.

Kelleher JS, Hulme MA, eds. (1981) Biological control programmes against insects and weeds in Canada 1969-1980. Slough, UK: Commonwealth Agricultural Bureaux.

Kelton LA (1975) The Lygus bugs (genus *Lygus* Hahn) of North America (Heteroptera: Miridae). *Memoirs of the Entomological Society of Canada*, No. 95.

Kelton LA (1980) The plant bugs of the prairie provinces of Canada. Heteroptera: Miridae. The insects and arachnids of Canada. Part 8. Canadian Government Publishing Centre. Hull, Quebec. p. 408.

Kharboutli MS, Allen CT, Capps C, Earnest LD (2000) Insecticides for early-season tarnished plant bug control. AAES special report 198, University of Arkansas Cooperative Extension Service.

Knight HH (1941) The plant bugs, or Miridae, of Illinois. Bull. *Illinois Natural History Survey*, Vol. 22, Art. 1. p. 234.

Layton MB (2000) Biology and damage of the tarnished plant bug, *Lygus lineolaris,* in cotton. *Southwestern Entomologist*, 23: 7-20.

Merriman P, McKirdy S (2005) Technical guidelines for the development of pest specific response plans. Plant Health Australia. Canberra, ACT.

Mueller SC, Summers CG, Goodell PB (2003) A field key to the most common *Lygus* species found in agronomic crops of the central San Joaquin Valley of California. University of California, Agriculture and Natural Resources. Publication 8104.

Nursery and Garden Industry Australia (2008) Biosecure *HACPP*: guidelines for managing biosecurity in nursery production.

Pickel C, Bentley WJ, Hasey JK, Day KR, Rice RE (2006) UC IPM: UC Management guidelines for plant bugs on peach. University of California, Agriculture and Natural Resources.

Plant Health Australia (2010) PLANTPLAN Australian Emergency Plant Pest Response Plan (Version 2). Plant Health Australia. Canberra, ACT.

Plant Health Australia (2008) Industry Biosecurity Plan for the Nursery and Garden Industry (Version 2). Plant Health Australia. Canberra, ACT.

Polk DF, Hogmire HW, Felland CM (1995) Peach direct pests in 'Mid-Atlantic Orchard Monitoring Guide', published by NRAES, Ithaca, New York, (607), 255-7654.

Rakickas RJ, Watson TF (1974) Population trends of *Lygus* spp. and selected predators in strip-cut alfalfa. *Environmental Entomology*, 3: 781-784.

Ridgeway RL, Gyrisco GG (1960) Studies on the biology of the tarnished plant bug, *Lygus lineolaris*. *Journal of Economic Entomology*, 53: 1063-1065.

Sapio FJ, Wilson LF, Ostry ME (1982) A split-stem lesion on young hybrid *Populus* trees caused by the tarnished plant bug, *Lygus lineolaris* (Hemiptera (Heteroptera): Miridae). *Great Lakes Entomologist*, 15(4): 237-246.

Schwartz MD, Foottit RG (1992) Lygus bugs on the prairies. Biology, systematics, and distribution. Technical Bulletin - Agriculture Canada, No. 4E, 1-44.

Scott WP, Snodgrass GL (2000) A review of chemical control of the tarnished plant bug in cotton. *Southwestern Entomologist,* 23: 67-81.

Smith TM (2009) University of Massachusetts. www.umass.edu/umext/floriculture/fact_sheets/pest_management/tpb_cutf_pests.htm

Snodgrass GL, McWilliams JM (1992) Rearing the tarnished plant bug (Heteroptera: Miridae) using a tissue paper oviposition site. *Journal of Economic Entomology,* 85: 1162-1166.

Sohati PH, Boivin G, Stewart RK (1992) Parasitism of *Lygus lineolaris* eggs on *Coronilla varia*, *Solanum tuberosum*, and three host weeds in southeastern Québec. *BioControl,* 34: 515-523.

Stahl FJ, Luepschen NS (1977) Transmission of *Erwinia amylovora* to pear fruit by *Lygus* spp. *Plant Disease Reporter*, 61(11): 936-939.

Steinkraus DC, Tugwell NP (1997) *Beauveria bassiana* (Deuteromycotina: Moniliales) effects on *Lygus lineolaris* (Hemiptera: Miridae). *Journal of Entomological Science*, 32(1): 79-90.

Sutherland JR, Shrimpton GM, Sturrock RN (1989) Diseases and insects in British Columbia forest seedling nurseries. Canada, British Columbia Forestry Resource Development Agreement Report 065. p. 85.

Wardle AR, Borden JH (2003) Sexual attraction among *Lygus* (Hemiptera: Miridae) species.Canadian Entomologist 135: 733–735.

Wilson LF, Moore LM (1985) Vulnerability of the hybrid *Populus* nursery stock to injury by the tarnished plant bug, *Lygus lineolaris* (Hemiptera: Miridae). *Great Lakes Entomologist*, 18(1): 19-23.

Young OP (1986) Host plants of the tarnished plant bug, *Lygus lineolaris* (Heteroptera: Miridae). *Annals of the Entomological Society of America*, 79(4): 747-762.

Zalom FG, Phillips FA, Toscano NC, Bolda M (2008) UC IPM: UC Management Guidelines for Lygus bug on strawberry. University of California, Agriculture and Natural Resources.

8.1 Related Websites

CABI Compendium (**www.cabicompendium.org**)

Center of Invasive Species and Ecosystem Health – Bugwood Network (**www.bugwood.org**)

Pest and Disease Image Library (PADIL) (**www.padil.gov.au**)

http://www.virginiafruit.ento.vt.edu/tpb.html

Washington State University, Tree Fruit Research & Extension Centre, Orchard Pest Management Online **(http://jenny.tfrec.wsu.edu/opm/displaySpecies.php?pn=180)**

Penn State University (**http://ento.psu.edu/extension/factsheets/tarnished-plant-bug**)

9 Appendices

9.1 Appendix 1: Genera of plants from which *Lygus lineolaris* has been recorded

Table 12. *List of taxa known to be hosts of Lygus lineolaris. (CABI 2010**)***

Species	Common name
Amaranthus cruentus	Redshank
Anethum graveolens	Dill
Apium graveolens	Celery
Apium graveolens var. dulce	Celery
Asparagus officinalis	Asparagus
Aster	
Aster pilosus	White heath aster
Bellis perennis	Common daisy
Beta vulgaris	Beetroot
Brassica napus var. napus (rape)	Rape
Brassica oleracea var. botrytis	Cauliflower
Brassica oleracea var. capitata	Cabbage
Calendula officinalis	Pot marigold

Species	Common name
Cosmos	
Cucumis sativus	Cucumber
Dahlia hybrids	
Daucus carota	Carrot
Erigeron	Fleabane
Fragaria ananassa	Strawberry
Gladiolus hybrids	Sword lily
Glycine max	Soybean
Gossypium hirsutum	Bourbon cotton
Helianthus	Sunflower
Lespedeza cuneata (Sericea lespedeza)	
Malus	Ornamental species apple
Medicago sativa	Lucerne
Papaver nudicaule	Iceland poppy
Phaseolus lunatus	Lima bean
Phaseolus vulgaris	Common bean
Pinus echinata	Shortleaf pine
Polyphagous (polyphagous)	
Populus	Poplars
Prunus persica	Peach
Pyrus communis	European pear
Rubus	Blackberry, raspberry
Salvia officinalis	Common sage
Sinapis alba	White mustard
Solanum tuberosum	Potato
Tragopogon porrifolius	Oysterplant
Trifolium incarnatum	Crimson clover
Verbena	Vervain
Vicia sativa	Common vetch
Zea mays subsp. mays	Sweet corn
Zinnia elegans	Zinnia

9.2 Appendix 2: Resources and facilities

Table 13 provides a list of diagnostic facilities for use in professional diagnosis and advisory services in the case of an incursion.

Table 13. 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	110 Natimuk Rd Horsham VIC 3400 Ph: (03) 5362 2111; Fax: (03) 5362 2187
Industry and Investment 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
I&I New South Wales – Tamworth Agricultural Institute	NSW	4 Marsden Park Road Calala NSW 2340 Ph: (02) 6763 1100; Fax: (02) 6763 1222
I&I 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