Integrated Pest Management Strategy

Aphids *(Family: Aphididae)*

Adult Green Peach Aphid (left) courtesy QDAF**, Winged green peach aphid (right)** image from: Scott Bauer, USDA Agricultural Research Service, Bugwood.org

Crop monitoring

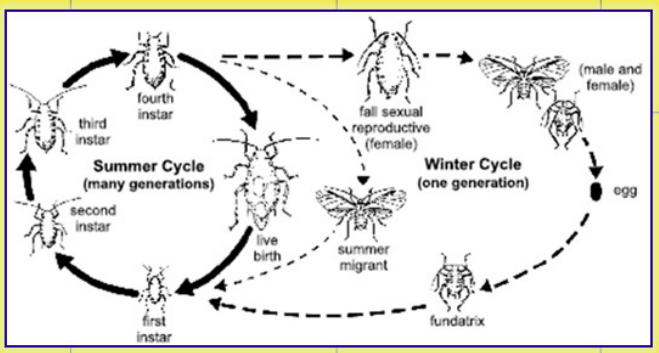
- Yellow sticky traps for flying adults
- Plant beating
- Keep records for future reference
- Choose intervals for monitoring that suit crop susceptibility and know how to identify aphids and the damage they cause
- For further information consult **BioSecure HACCP** guidelines

Aphid damage on Abelia (left) and Eucalypt (right). Images from: [3]Manners, A, 2018, 'Pest management plan for aphids in production nurseries', Nursery levy at work: Building resilience and biosecurity capacity.

Cultural management

- Staff trained to identify aphids and symptoms or damage
- Crop in good health?
- Quarantine / treat / dispose of infested or suspect plants, inspect plant imports
- Avoid moving infested material
- Grow resistant varieties

Introduce biological controls at first sign of aphids



Aphid lifecycle Image from: Flint, M. L., 2013. 'Integrated Pest Management for Home Gardeners and Landscape Professionals Aphids', University of California Agriculture and Natural Resources Integrated Pest Management program

Biological control

- Green lacewings
- Orius tantillus (minute pirate bug)
- Predatory wasps (Aphidius spp., aphelinus sp.)
- Predatory ladybeetles (Harmonia spp.)

Continue crop monitoring to gauge effectiveness of treatments applied

Chemical controls

- Many chemicals registered for use
- Check mode of action groups
- Toxicity to beneficials?
- Residual toxicity?
- Use spot spraying over blanket sprays

For pest ID and information on best management practices go to:

Pest ID tool: https://www.pestid.com.au/

Australian plant production standard: https://nurseryproductionfms.com.au/

Hort Innovation | NURSERY FUND

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Developed by the GIA National Nursery Industry Biosecurity Program Team 2020

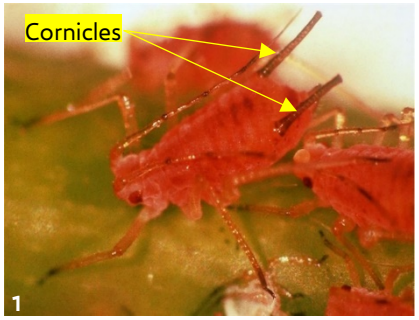
Aphids (Family: Aphididae)

The following information is summarised from [1]Manners, A, n.d., 'Aphids – A rapidly reproducing problem' unless otherwise stated.

To make best use of this integrated pest management strategy, use the information provided on pest biology and all the management options, and combine those with information on your crop in the **'Integrated pest management plan'** template found at the back of this document. An excel version of the template is found here: https://nurseryproductionfms.com.au/download/pest-management-plan-template/

Morphological features of aphids

Small soft bodied, bulbous, oval shaped insects 1- 2 mm long (with a few species being an exception at 6-7mm long). Coloured light to dark green, brown, red, black, yellow dependant on life stage, species and food source. Some species (i.e., cow pea aphid) and aphids that are winged (adult aphids only) are darker in colour than immature aphids.



1.Wingless rose aphid adult. Image courtesy of QDAF

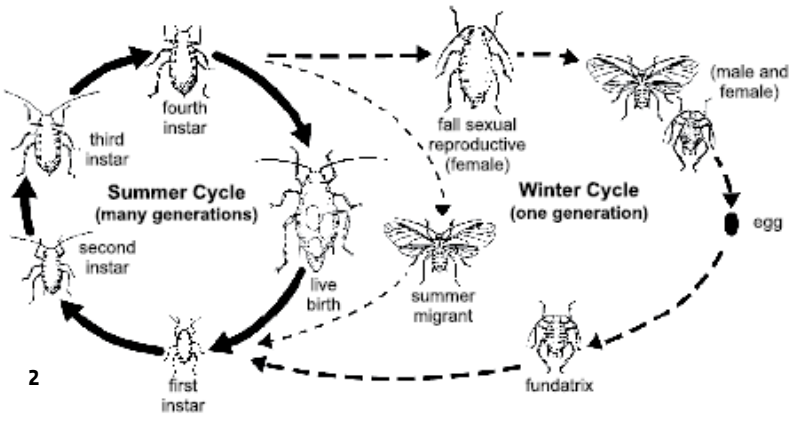
Aphids have long piercing and sucking mouthparts that they use to pierce plant parts and suck out sap. With most species having a set of two tubelike structures called cornicles protruding backward from their abdomen a key identifying feature.

Some aphid species can appear to have a woolly or waxy white/grey substance over their body (Flint, M. L., 2013).

Life Cycle of aphids

Aphids can rapidly reproduce and disperse once in a crop. This is because most aphids are female, they do not need to mate, they give birth to live offspring.

The exception to this is in the cooler months where some species produce male aphids which mate with females to produce eggs. These overwinter producing a new generations when temperature increases. In controlled conditions such as glasshouses where temperatures are consistently warmer this may not occur.



2. General life cycle of aphids. Image from: Flint, M. L., 2013. 'Integrated Pest Management for Home Gardeners and Landscape Professionals Aphids', University of California Agriculture and Natural Resources Integrated Pest Management program.

Aphid populations increase rapidly with the aphid life cycle completed in 5 – 10 days, and females laying 1 – 2 nymphs per day. Nymphs moult about four times before becoming adults.

Damage to plants

Typically prevalent during the spring and autumn months. Most species of aphids are host specific. With a small number of the species highly polyphagous (feed on a variety of plant species).

Damage to plants is caused by the insect sucking on plant tissue, the injection of salivary secretions into the plant while feeding, and through the production of honeydew which encourages the growth of black sooty mould. Aphids tend to feed on young leaves and soft new plant growth. They can often be found on the

undersides of these leaves. Leaves that have been fed upon will appear distorted and stunted as they expand. Expanded leaves that have been fed upon by aphids may become chlorotic, wilt, and drop. Large infestations will greatly affect plant growth rates.

A small number of aphid species feed on plant roots, this will cause wilting and reduced growth and vigour in the plant.

Aphids are also common vectors of viruses in plants. For example, green peach aphid (GPA) which is known to feed on up to 400 different species of plant, can vector over 100 plant viruses. 'Some of the more common viruses transmitted by GPA include *Cucumber* and *Celery mosaic virus*, *Potato leaf roll virus*, *Potato virus Y*, *Beet western yellows virus* (and other beet yellow viruses), *Papaya ringspot virus* and *Lettuce mosaic virus*' ([2]Manners, A, n.d.).

3. Foxglove aphid damage on capsicum. Image courtesy of QDAF.

Spread of aphids

Wings will aid dispersal of the pest, as will wind. Winged adults tend to occur when populations on a host are high or the host plant begins to die.

Integrated Pest Management (IPM)

Extensive use of conventional broad spectrum chemicals for pest control has resulted in resistance issues in pest populations, the destruction of beneficial arthropods and chemical residues in food, soil water and air. Integrated Pest Management (IPM) is a strategy that was developed to control pests and diseases of crops while at the same time combat the effects of chemical use on the environment and human health (Curkovic. T.S. 2015).

IPM has been described in many ways since it's inception. Stenberg (2019) describes it as 'a holistic 'approach' or 'strategy' to combat plant pests and diseases using all available methods, while minimising applications of chemical pesticides'. Which while accurate, oversimplifies the investment and dedication required of a business integrating an IPM system into their pest management system, particularly if it is solely dependent on chemicals for control of pests.

What is IPM?

IPM is a holistic approach to pest management. It relies on the use of judicious combinations of control options for management of pests and disease. An IPM system is underpinned by trained and informed personnel, consistent crop monitoring to inform on pest and beneficial populations within the crop, minimising the use of chemicals particularly broad-spectrum chemicals and using data collected from crop monitoring and other record keeping to inform decisions and identify thresholds.

IPM is not a one size fits all process. Many growers would like to have a handbook of pest thresholds to advise them of when to act and what to use. No production nursery has the same environment, climate, facilities, surrounds, crops, pest or beneficial species as another. The creation of action or economic thresholds to inform management decisions can only be derived from the collection of data through consistent crop monitoring informing site-specific thresholds. To be successful a business must realise the dedication and mindset required for the implementation of IPM (Newman, et. Al. 1999).

IPM requires an investment over the long term. A commitment to implementation and committing the time required for a new healthier equilibrium within the crop ecosystem to be reached. Once this point has been reached IPM is sustainable and profitable (Mueller, D.S., et.al 2020, Mauceri M et.al n.d).

Why IPM works

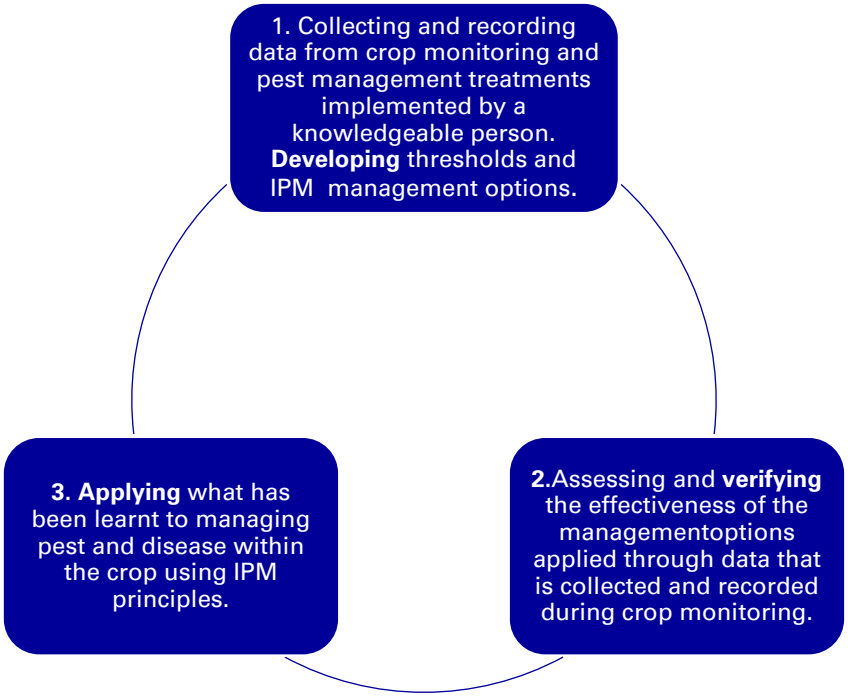
At the centre of any successful IPM program is **structured**, **consistent crop monitoring** (Newman, et. Al. 1999, LeBude, A.V., et. al, 2012)). Consistent monitoring means that the crop monitoring is performed on a schedule that suits the crop age and type. If you are producing seedlings then this would mean weekly monitoring, for more advanced crops this may mean fortnightly crop monitoring. Structured monitoring means following a methodology that suits your crop type and site design. It means creating a site map to ensure all growing areas are covered consistently and that an employee responsible for monitoring can plan their monitoring to be comprehensive and to move from high risk zones to low risk zones within the growing areas.

IPM programs centred on crop monitoring programs 'assist growers in the adoption of pest management practices that are more environmentally friendly and safer for workers, consumers and the community at large (Newman, et. Al. 1999)'. Crop monitoring provides the earliest possible indication on pest presence within a crop and allows the choice of less toxic measures of control such as, throwing out affected plants, releasing beneficial organisms or spot spraying with low toxicity chemicals. Crop monitoring also allows better timing for pesticide applications making their use more effective. In systems reliant on chemicals for control of pests, 'timing of pesticide applications is often mismanaged as pesticides are frequently not applied until populations are too high or are applied when pests are not present' contributing to pest resistance issues and a shortage of chemicals that are efficacious (Newman, et. Al. 1999).

Elements of a good IPM system

A systematic approach

IPM is a strategy of integrating management options informed by crop monitoring. Any 'decision support system has a natural lifecycle of development, verification, application' (Gent. D. H., 2009). For example:



Good IPM systems rely on employing all management options available, using the safest least toxic option for management at initial sightings of a pest, escalating to least safe option based upon pest and beneficial organism numbers gathered through crop monitoring.

Communication and information

For any system to succeed in a business it must be endorsed from the top down. To get the full benefit of IPM there must be a commitment to production nursery operators becoming knowledgeable about the biology of both pests and beneficial organisms, their options for control and sources of information. This knowledge must be supported by being provided time to perform crop monitoring, collect and analyse data. This knowledge should then be shared throughout the organisation.

A study by Newman et. al. (1999) implementing IPM in the floriculture industry found "best results were realised when growers and others involved in pest management in the nursery worked together with the scout (crop monitor) as a team, good communication was critical to the overall success of the IPM program."

Biological control options

Biological control options for pest management include both parasites and predators, pheromone traps and pathogen-based sprays such as BT sprays. Biological controls are best introduced at the first sighting of the pest. Suppliers of biological controls are an excellent source of advice for options available, release rates and methods.

Physical control

Physical control can include any measures that excludes pests from the crop or any actions that cause the environment or climate to be unsuitable for pest survival. Physical controls are extensive and can include but is not limited to excluding pests using insect proof facilities, creating a climate that unsuitable for pest

survival, import inspections of any Greenlife to prevent pest entry, using banker plants, throwing out or quarantining infested stock.

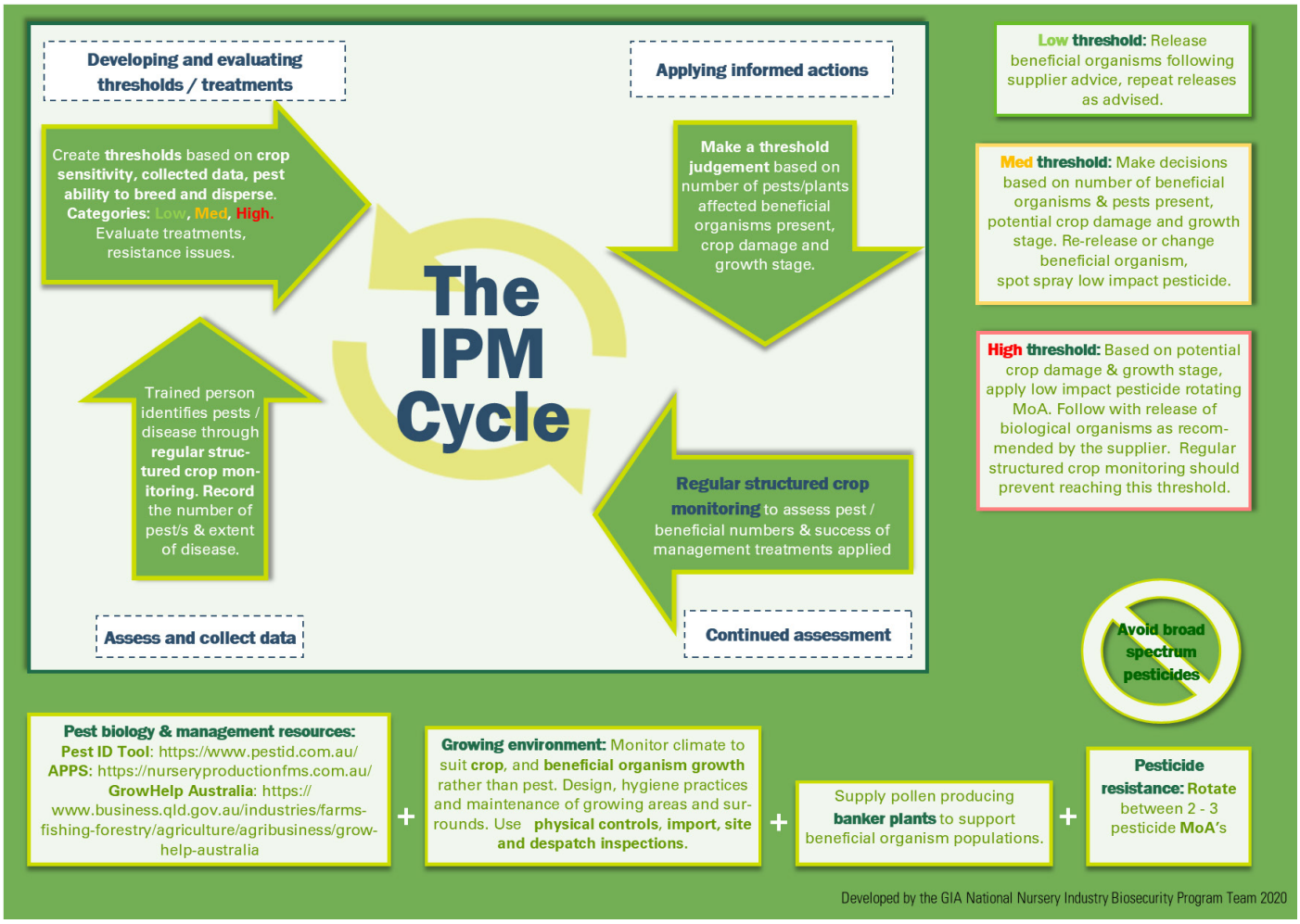
Many studies worldwide on broadacre cropping have found that intercropping to include flower strips or planting nectar-producing plants supports biological control parasites and predators by providing plant-based food, shelter, and alternative prey, increasing their abundance, while pest populations are reduced (Stenberg, J., 2017).

Chemical

It is preferential that any chemical applications within an IPM system is chosen for its narrow spectrum of control, low toxicity to beneficial insects and low residual capacity in the environment. Soaps and detergents have little toxicity, while broad spectrum pesticides such as organophosphates have high toxicity and should be avoided where possible (Curkovic, T.S., 2015).

Any chemical treatments applied should in succession for a pest should be rotated to alternate between 2 - different Mode of Action (MoA) chemical groups.

All chemical treatments for pests and disease must be registered for use by the APVMA on a crop, pest or disease. This can be checked through the PUBCRIS database.



Management of Aphids

Crop monitoring

This crop monitoring procedure is taken from the Greenlife Industry Australia BioSecure HACCP guidelines 4th edition, unless otherwise stated.

For any management method to be successful, monitoring must be performed routinely, consistently and findings recorded. Knowledge of the plants produced across the cropping system and their associated pests and diseases form the background for successful crop monitoring. The **frequency** of crop monitoring is determined by **crop type** and **periods of pest susceptibility** and **potential impact**. Always consult historical crop monitoring records, biological release records, and spray records to inform the crop monitoring event. By doing this the scout can predict areas of concern, judge the effectiveness of treatments, and monitor beneficial populations.

- Begin each crop monitoring process in sterile or clean areas or those of high risk, such as propagation facilities or crop hardening off areas, and move progressively into less high risk areas such as hardened finished crops ready for despatch or known hardy crops.
- Pay close attention to crops around entry ways such as doors, gates, curtains, etc. and along main thoroughfares such as access roads, paths, or laneways.
- Vary the entrance point to the crop monitoring area (1 to 3 m) for each subsequent crop monitoring activity to avoid inspecting the same plants each time.
- Walk at random through the area in a zigzag pattern. Visually inspect plants for abnormal plant growth and pest and disease symptoms or weed growth. Pick up and inspect at least 35 plants from within each plant group selecting those plants that appear less healthy for inspection.
- Thorough visual inspection will include looking for signs of pests and disease on tops and undersides of leaves, flowers, stem, leaf axils, and where appropriate the roots of plants. If problems are identified increase the number of plants inspected from 35 to judge the extent of the pest and disease population.
- Make an estimate of the prevalence of the pest or disease and record this in the crop monitoring record.
- Collect samples of pest and disease if they are not able to be identified immediately, ensuring that samples are stored in a sealed container or plastic bag to prevent spread during the rest of the monitoring.

Cropping System	Monitoring Frequency
• Seedings, plugs and **annual** potted colour.	At least once every **7 days**.
• All plants during the propagation phase.	At least once every **14 days**.
• **Perennial** potted colour.	At least once every **14 days**.
All others- including: • Trees and shrubs. • Palms. • Indoor / houseplants. • Ornamental grasses. • Succulents.	September to May At least once every **14 days.** June, July, August – Winter months At least once every **28 days.**

Table taken from: Greenlife Industry Australia, 2019, BioSecure HACCP Guidelines 4th edition, Sydney Australia.

Monitoring for aphids

Visual examination: Regularly monitor for aphids by examining all plant parts especially soft new growth, flowers, and the undersides of leaves. Inspect any new growth that is stunted, chlorotic or deformed. Monitor for ants because they are attracted to the honeydew produced by aphids so are an indicator of aphid presence. Be aware that the presence of winged aphids will indicate possible population expansion to other growing areas.

Plant beating can assist to identify populations of aphids and other pests within a crop. Plant beating involves gently hitting foliage over a uniformly coloured (black or white) tray or bucket and checking the tray for insects and mites that are dislodged. Then identifying and counting the number of pests' present using a x10-15 hand lens where required and recording the information.

Yellow sticky traps can be used for a monitoring for the presence of a variety of flying insects. Place traps out to monitor areas of growing beds, greenhouses or polyhouses using the density of traps per m^2 provided in the following (Greenlife Industry Australia, 2019) table.

Place sticky traps elevated 10 cm above the crop, near to entryways such as doors and vents. Inspect the traps for pest presence weekly. Change traps every 2 to 4 weeks dependant on their condition ([3]Manners, A, 2018).

If plant stage of growth allows, check roots of plants that are wilting or have reduced vigour for root aphids.

Open field / growing beds		Greenhouse / Polyhouse/ Glasshouse	
Total area (ha)	**No. of traps**	**Total area m2**	**No. of traps**
<0.5	6	0 - 200	1
0.5 - 1	10	200 – 500	2
1 – 5	12	500 – 1000	4
5 – 10	15	1000 – 5000	6
>10	20	5000 - 10,000	10

Table taken from: Greenlife Industry Australia, 2019, BioSecure HACCP Guidelines 4th edition, Sydney Australia.

Managing Aphids

Cultural management of aphids

"Monitoring is a critical component of a successful IPM program" (Liburd, O & Rhodes, E., 2019). Growers should look to combine their management options (cultural, biological and chemical) to suit the population density of the pest or disease, ability to colonise a crop, and the crop type.

This is particularly true for aphids, which can drastically increase in population size within a week during optimal conditions. Cultural management options that will support the management of aphids and other insects in the nursery include:

- Training staff to identify aphids.
- Identify infestations through regular structured monitoring. Early identification and treatment are the key to success for controlling any pest or disease.
- Excluding populations from greenhouses with insect proof glasshouses/tunnels particularly for susceptible crops.
- Quarantining incoming stock and inspecting for signs of infestation prior to moving the stock into production areas.

- Throw out, destroy or quarantine heavily infested plants. If throwing an infested plant out, ensure the plant is placed in a covered bin, away from growing areas, alternatively bag throw outs if practical and leave in the sun for several hours to kill pests.
- Reduce staff movement through infested areas.
- Use pesticides discerningly to preserve natural predators. This is enabled by frequent crop monitoring to inform pesticide usage.
- Control weeds around the nursery as they will harbour pest populations.
- Propagate from uninfested material.
- Avoid moving infested plant material within the growing areas.
- Use of wind breaks will assist in preventing the spread of many pest species including aphids.
- Prune moderate and high infestations prior to chemical treatment to allow for better pesticide penetration.
- In the instance of persistent populations, consider growing alternative resistant varieties or rotate crops with non-host species to break the cycle of infestation.
- For assistance in identification of aphids, make use of professional diagnostic services such as Grow Help Australia https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/agribusiness/grow-help-australia.

Biological management of aphids

Biological control organisms are very effective control options for controlling aphids. Successful integration of biological organisms into a management regime relies on good knowledge of the pest, the beneficial organism, regular structured crop monitoring and selective and informed use of chemicals. Consultation with suppliers of beneficial organisms is recommended before use. For best results release beneficials early in the season or when pests are first observed.

3. Green lacewing eggs

Green lace wings *(Mallada signata)*

Habitat: Well adapted to warm conditions, they become inactive in cool conditions.

Feeds on: Larvae are very effective control for aphids eating up to 60 aphids in an hour (Llewellyn, R (ed.) 2002). They also feed on two spotted mite, greenhouse whitefly, scales, mealybug, moth eggs and small caterpillars. Adults feed on pollen and nectar.

Lifecycle: Eggs which are white and laid on thin stalks, take about 4 days to hatch. Larvae are about 1mm in length at hatching and increase in size through three moults up to 8mm before they pupate into adults. Adults live for 3- 4 weeks (Llewellyn, R (ed.) 2002).

4. Green lacewing larvae with trash package

Appearance: Adults are green with four clear wings. Larvae have small spines on their back where they impale the remains of prey, these are called trash-packages which they use for camouflage (Llewellyn, R (ed.) 2002).

Application rate: Adult lacewings are recommended for release into outdoor cropping situations like orchards and vineyards, whereas larvae are recommended for protected cropping in situations such as nurseries ([2]Bugs for Bugs, 2015).

5. Green lacewing adult.
Images 3 – 5 taken from: [2]Australasian Biological control, Green lacewing: Mallada signata, general predator,

Situation	Release rate	No. of releases	Interval between releases
Outdoor crops	400-600 adults /ha	1 - 3	2 weeks
Hotspot treatments (outdoor or protected)	10 - 50 larvae/ m2	As required	1 – 2 weeks

[2]Bugs for Bugs, 2015, Lacewing, Viewed 7th December 2020, https://bugsforbugs.com.au/product/lacewing/

Tips for release: Sensitive to persistent or broad-spectrum chemicals. Release at first signs of pests. Banker plants that produce pollen can provide a food source for adults, sustaining populations when pest numbers are low.

Aphidius and Aphelinus – Parasitic wasps *(Aphidius colemani) (Aphidius ervi) (Aphelinus abdominalis)*

Habitat: Banker plants will aid in establishing populations as these wasps will feed on pollen in between feeding or parasitising pests. 'Ideal temperatures are between 15°C and 30°C. *Aphelinus abdominalis* can survive temperatures up to 36°C, optimal temperatures range between 15 and 32°C ([2]Manners, A, n.d.)'.

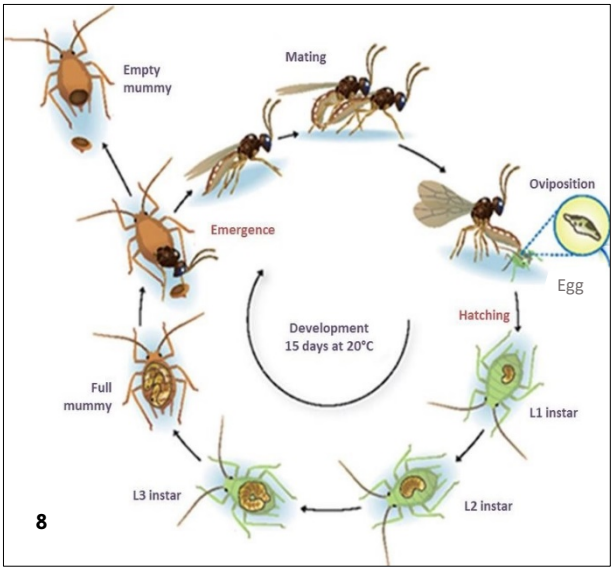
Feeds on:

Beneficial Species	Preys on
Aphidius colemani:	Many aphid species, particularly green peach aphid, cotton/melon aphid and wheat aphid.
Aphidius ervi:	Many species, particularly foxglove aphid, potato aphid and pea aphids.
Aphelinus abdominalis:	Over 200 aphid species, mainly large species such as potato/foxglove aphid, green peach aphid, pea aphid, potato aphid. Lays eggs into aphids and may also cause considerable impact by feeding on other aphids.

Table from: [3]Manners, A, 2018, 'Pest management plan for aphids in production nurseries', Nursery levy at work: Building resilience and biosecurity capacity.

Life cycle:

Female wasps lay their eggs inside aphids. Wasps emerge from the aphid and begin feeding on the aphid, leaving behind the aphid body which is referred to as a 'mummy'. These look different depending on the wasp species that has parasitised the aphid. *Aphidius ervi* and *Aphidius colemani* leave behind a bronze inflated looking aphid with an exit hole, *Aphelinus abdominalis* however leaves a distinctive black aphid mummy with an exit hole.



8. Aphid parasite lifecycle. Image taken from: Tougeron,, K, (2017). [EN] Diapause variability in aphid parasitoids in the context of climate changes; implications for biological control. 0.13140/RG.2.2.13917.92644

Beneficial Species	Description of lifecycle
Aphidius colemani:	Females mostly lay eggs inside young aphids, although any stage can be parasitised. Resultant wasps emerge after about 10 days at 25°C, and 14 days at 20 or 30°C.
Aphidius ervi:	Complete development time is temperature dependent but is about 12 days at 25°C'. ([1]Biological Services, 2015)
Aphelinus abdominalis:	After an aphid is parasitised, an adult wasp may take 2-3 weeks to emerge, depending on temperature, and adults may live up to 60 days under good conditions.

Information for this table was extracted from: [2]Manners, A, n.d., 'Managing green peach aphid in production nurseries', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

Appearance:

Beneficial Species	Description of appearance
Aphidius colemani:	Slender, 2–3mm long. Looks similar to small, winged, black ants, but with long antennae.
Aphidius ervi:	Slender, 4–5mm long. Similar to small, winged, black ants, but with long antennae.
Aphelinus abdominalis:	Stocky, about 3mm long, black head, yellow abdomen

Table from: [3]Manners, A, 2018, 'Pest management plan for aphids in production nurseries', Nursery levy at work: Building resilience and biosecurity capacity.

7. Parasitised aphid mummies. Image from: from: [2]Manners, A, n.d., 'Managing green peach aphid in production nurseries', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

9. Aphidius coleman parasitising an aphid. Image from: Australasian Biological Control, n.d., 'Aphidius – Aphidius colemani - Aphid parasitoid' viewed 15th January 2021, http://www.goodbugs.org.au/Good%20bugs/aphidius.html

10. Aphidius ervi parasitising aphid. Image from: [2]Biological Services, 2015, Ervi Aphidius ervi, viewed 15th January 2021, http://www.biologicalservices.com.au/products/ervi-18.html.

11. Aphelinus abdominalis parasitising an aphid. Image from: [3]Biological Services, 2015, 'Aphelinus Aphelinus abdominalis', viewed 15th January 2021, https://biologicalservices.com.au/products/aphelinus-2.html

Application rates:

Application rates may vary dependant on the species of aphid to be controlled. Consult with your supplier to ensure correct rates.

Aphidius colemani: '**Preventative**: 0.15 per m^2weekly **After aphid detection**: 0.5-1 per m^2 per week for at least 3 weeks. Return to preventative rate once control is achieved ([4]Biological Services, 2015)'.

Aphidius ervi: **'Preventative**: 0.1 per m^2 weekly **After aphid detection**: 0.5 per m^2 per week up to 10 per m^2 for hotspots, for at least 3 weeks ([2]Biological Services, 2015)'.

Aphelinus abdominalis: **'Preventative**: 0.5-2 per m^2 fortnightly, 3 applications. **After aphid detection**: 2-4 per m^2 weekly for at least 3 applications. Does not disperse well independently, place near infestations at releas ([3]Biological Services, 2015)'.

Tips for release: Sensitive to persistent or broad-spectrum chemicals particularly pyrethroids, organophosphates and neonicotinoids. Release at first signs of pests. Contact your supplier for further information on release rates and chemical sensitivity. The use of all three wasp species will provide coverage for a broad range of aphids ([3]Biological Services, 2015). Banker plants that produce pollen can provide a food source for adults, sustaining populations when pest numbers are low.

Harmonia – predatory ladybeetle *(Harmonia conformis* and *Harmonia octomaculata)*

Most information on *Harmonia* spp. a native Australian ladybeetle is available is on *H. conformis.* Therefore, most of the following information pertains to *H. conformis* unless otherwise specified.

Habitat: Above ground parts of plants.

9. Harmonia conformis eggs

Feeds on: *H. octomaculata* feeds mainly aphids and sometimes whiteflies whereas *H. conformis* feeds on aphids and psyllids. Most of the predation is done by the larvae of Harmonia, however adults will also feed on aphids ([1]Bugs for Bugs, 2015).

10. H. conformis larvae

Life cycle: Females lay yellow oval shaped eggs in clusters near infestations of prey such as aphids. Larvae hatch from eggs and moult through four instars. When fully grown the fourth instar pupates into an adult. The lifecycle is dependent on temperature, with the beetle overwintering in adult form before producing eggs again in spring (Martin, N. A., 2016).

Appearance: Adults are black and orange 5.5 – 7.0mm in length, their head and prothorax orange with black spots. Spots vary in size and can sometimes merge; beetles can also be completely dark grey or black. Their underside varies from dark brown to black (Martin, N. A., 2016). Adults are capable of dispersal through flying whereas larvae disperse by crawling.

11. H. conformis adults

Newly hatched larvae are dark grey in colour, as they mature, they develop through to the fourth instar they develop white/yellow scoli. They have three pairs of legs at the front of their body.

Application rates: One pack of beetles per 20 to 50 m^2 in enclosed situations ([1]Bugs for Bugs, 2015). For more accurate recommendations, please contact your supplier.

12. H. conformis dark coloured. Images 9 – 12 from: Martin, N. A., 2016, 'Large spotted ladybird - Harmonia conformis', viewed 20th January 2021, https://nzacfactsheets.landcareresearch.co.nz/factsheet/InterestingInsects/Large-spotted-ladybird---Harmonia-

Tips for release: 'Carbamate, organophosphate and synthetic pyrethroid insecticides are toxic. Some insect growth regulators (IGRs) are also toxic to predatory beetles ([1]Bugs for Bugs, 2015)'. Avoid releasing where bright lights may attract them away ([1]Bugs for Bugs, 2015).

Orius – minute pirate bug *(Orius tantillus)*

Predatory bugs are highly mobile flying through the crop for food.

Habitat: Above ground parts of plants, Orius will disperse via flying between plants.

Feeds on: Various species of thrips especially western flower thrips. It will also feed on thrips larvae, aphids, mites and moth eggs and pollen. Banker plants such as basil are useful to provide pollen (Bugs for Bugs, 2015).

6. Orius adult. Image from: [5]Biological Services, 2015, 'Orius Orius tantillus', viewed 19th January

Life cycle: At 25°C eggs will hatch and develop into an adult within 16 – 18 days. At 30°C eggs will hatch and develop into an adult within 12 days It has 5 larval stages before pupating to become an adult ([5]Biological Services, 2015).

Appearance: Predatory bugs that feed mostly on thrips.

Application rates: Contact your supplier for rates of release for Orius for aphid control.

Tips for release: Very sensitive to chemicals. Can be released preventatively if there is adequate pollen to feed on. Release early morning or afternoon / early evening ([5]Biological Services, 2015).

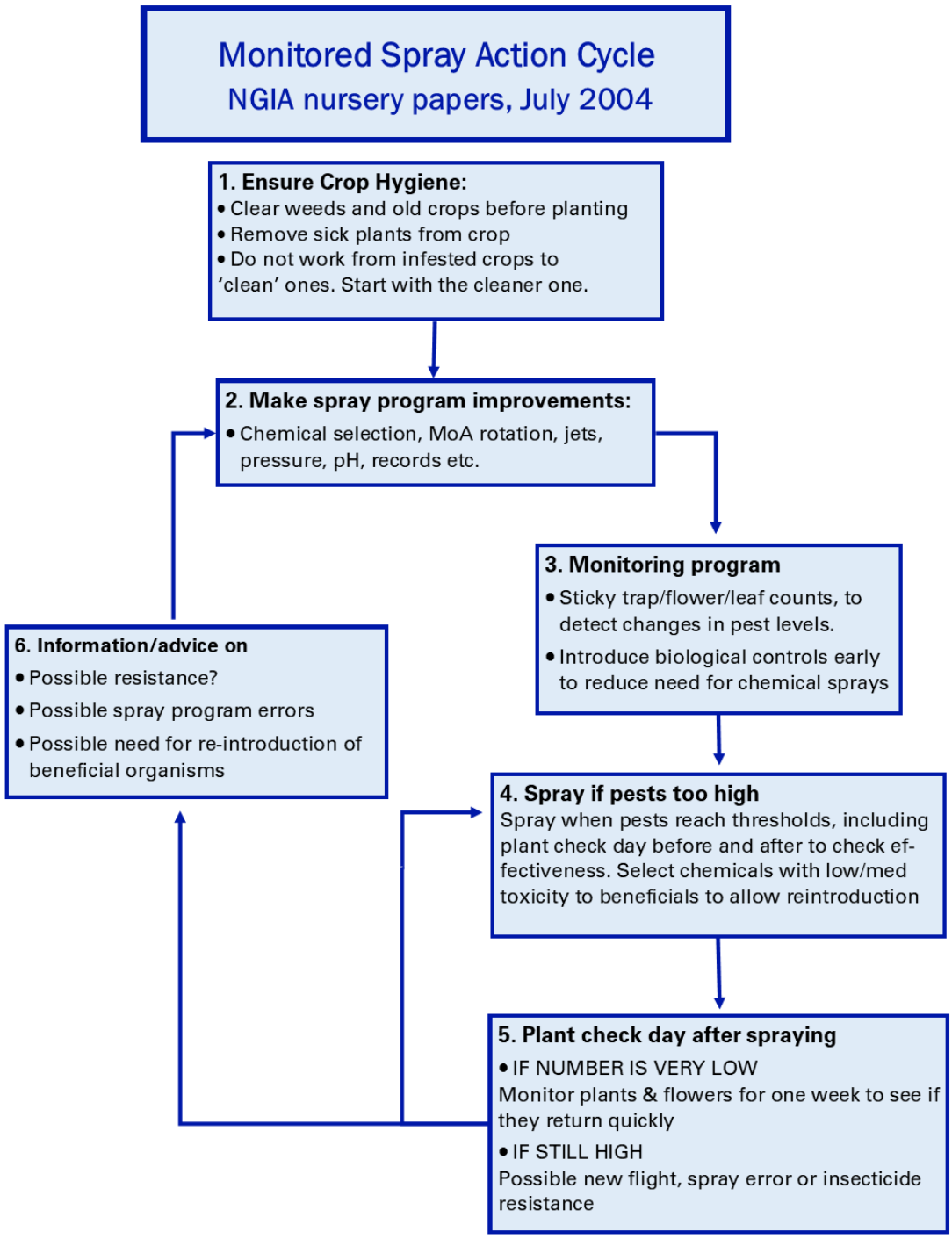
Chemical management of aphids

For successful use of chemicals be aware of the following:

- The mode of action (MoA) group of the chemical active ingredient. This provides detail on how the chemical acts upon the insect to kill it.
- Rotating the MoA group to help prevent instances of resistance.
- **Continual use of a single MoA increases the risk of insect resistance**.
- Know how each product comes into contact with the pest: **contact** (chemical must make contact with the pest), s**ystemic** (insect eats plant material which has absorbed the chemical), **translaminar** (limited systemic effect).
- Residual toxicity of the chemical control for mites to beneficial species.

There are many pesticides registered for use against aphids. Use structured routine crop monitoring to inform on pest populations and locations for more targeted pesticide use.

Implement a spray program following the "Monitored Spray Action Cycle" (taken from (NGIA, 2004)) below, with a view to using the least toxic chemicals for beneficial organisms. This promotes improved biodiversity and allows the re-introduction of beneficial organisms sooner to the crop.



Pesticide mode of action table for pesticide use against aphids:

Low risk products	Broad spectrum and highly residual products
1A products	1B products
Group 9 products	3A products
12A products*	4A products
Group 23 products	
Oil products	
K salts*	

Products marked with * can cause high mortality in other beneficial insects present in the crop.

Table taken from: [3]Manners, A, 2018, 'Pest management plan for aphids in production nurseries', Nursery levy at work: Building resilience and biosecurity capacity.

Information resources

- Businesses engaged in the APPS can be supported by APPS technical advisors appointed by GIA.

  APPS technical advisors must meet a number of criteria including but not limited to:

  - tertiary qualifications appropriate to horticulture, plant science agriculture or environmental management (majoring in plant-based content)
  - technical competence in production nursery practices,
  - chemical application certification.

  APPS technical advisors may be able to assist businesses in a number of ways such as preparing to meet audit requirements or through the provision of technical advice to improve on site operations.

  Technical advisors may be available through levy funded mechanisms or through a fee for service basis. Greenlife Industry Australia Plant Protection Officer contact details are found here: https://nurseryproductionfms.com.au/technical-service-providers/

- The **Australian Plant Production Standard** (APPS) website. Technical information and best management practices produced specifically for the nursery production industry on everything including pest and disease management, water management and more: https://nurseryproductionfms.com.au/
- The **Pest ID Tool** is an initiative by Nursery and Garden Industry Queensland (NGIQ) The tool is provided to assist the horticultural industries in identifying and treating pest insects, diseases, disorders, and weeds. It also includes information on beneficial insects as biocontrol treatments.: https://www.pestid.com.au/
- Access the **E-learning website** for specific training modules on managing the top 5 SARP pests and other training such as how to perform crop monitoring or import inspections: https://ngia.talentlms.com/index
- To view **videos** of webinars on topics such as telling the difference between bacterial and fungal leaf spots and other plant health and production nursery operations and training topics please see the videos listed here: https://nurseryproductionfms.com.au/videos/
- **Grow Help Australia** is a service offered through the Queensland Department of Agriculture which provides pest and disease diagnostic services for all horticultural crops. APPS accredited businesses are eligible for ten free diagnostic tests each year with further tests available at a significant discount. For further information on the services available to production nurseries through Grow Help Australia please visit the website below: https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/agribusiness/grow-help-australia
- **Supply and consultation** for using **beneficial organisms** in your nursery:
  - https://biologicalservices.com.au/
  - https://bugsforbugs.com.au/

    - http://www.ecogrow.com.au/index.html
- Agrilink Integrated Pest Management in ornamentals information guide: http://era.daf.qld.gov.au/id/eprint/2208/
- The **Insecticide Resistance Action Committee** (IRAC). A specialist technical group of the industry association CropLife, providing a coordinated industry response to prevent or delay the development of resistance in insect and mite pests: https://irac-online.org/about/irac/

Record sheet templates

Videos on how to perform the procedures for the following record sheet templates: https://nurseryproductionfms.com.au/videos/

Record sheet templates are provided as a part of the NIASA and BioSecure HACCP guidelines available here: https://nurseryproductionfms.com.au/

A copy of the Greenlife Industry Australia "Integrated Pest Management Plan" is available in excel format at: https://nurseryproductionfms.com.au/download/pest-management-plan-template/

Materials Import Inspection Record

(For the inspection of risk materials received by the business)

NOTE – A corrective action form must be completed for materials that do not pass inspection and are rejected or require treatment.

Business name:

Business address:

Date received	Supplier	Material type and quantity	Invoice, batch, number/ identifier	Inspection sampling rate e.g. 600 or 2%, all, etc	Inspection Results	IMPORT DECISION ☑			Signature of authorised inspection person
						Approved	Reject / return	Treat	

Crop Monitoring Record

(For recording the results of monitoring within and around crops)

NOTE – Crop weed monitoring may be recorded on this form or separately using the Weed Monitoring Record form.

Business address: Authorised Inspection Person (name): Date:

Crop area monitored (Site Plan reference)	Crop (type/number in area)	Number inspected	Pest/diseases/ weeds detected? (record NO or describe)			Comments / actions (Include physiological issues if applicable)
			Insects/pests	Diseases/disorders	Weeds	

Sticky Trap Register

(To document the number of traps used in each area and inspection and replacement frequency)

NOTE - Each sticky trap must be marked with the ID number and date installed

Business name:

Business address:

Trap Monitoring area description (Site Plan reference)	Size of area (specify ha or m^2)	Number of traps installed in area	ID numbers/codes or ID range (e.g. Trap 001- Trap 030)	Inspection interval (must be no > than 7 days)	Maximum replacement interval (must be no > than 14 days)

Sticky Trap Monitoring Record

(To record trapping results)

Business name:

Business address: Authorised Inspection Person (name): Date:

				Number of each pest detected on trap							
Monitoring area (Site Plan Reference)	Crop description	Trap ID	Placement date	Fungus gnat	Shore flies	Whiteflies	Thrips	Aphids	Other pests	Beneficial	Comments / actions

Biological Organism Release Record

Business name:

Business address:

Date	Time	Organism released	Location (Site Plan reference)	Crop (if applicable)	Name of Authorised Person who made the release

Site Surveillance Record

(For areas outside of the production area)

NOTE – The entire site must be surveyed and surveillance must be conducted at intervals of not more than 14 days.

Business name:

Business address: Authorised Inspection Person (name/s): Date:

Area surveyed (Site vegetation map or Site Plan reference- OR entire site)	Pests/diseases detected? Y/N	Weed species detected? Y/N	Name of pest, disease or weeds detected, approximate numbers (if applicable), and a description of where found within the area	Comments / actions including details of any other issue or risk identified if applicable

Materials Despatch Inspection Record

(For the inspection of risk materials to be despatched from the business)

NOTE – A corrective action form must be completed for materials that do not pass inspection as a result of a biosecurity risk being identified.

Business name:

Business address:

Date inspected	Consignee name	Invoice, batch, number/ identifier	Inspection sampling rate e.g. 600 or 2%, all, etc	Free of pests, diseases, weeds? Y/N	Signature of authorised inspection person	DESPATCH DECISION ☑		Reason Not Approved (if applicable) e.g. Pest, disease or weed name/ description of problem
						Approved	Not Approved	

Integrated Pest Management Plan

Pest name		Comments and *information source*
Pest significance		High medium or low significance relative to your situation. *Own knowledge.*
Life cycle description		Stages in life cycle. Reproduction methods of weeds. *Pest ID tool.*
Life cycle days to complete		Range of days life cycle to complete. *Pest ID tool.*
Symptoms/ description		Description of damage or description of weeds. *Pest ID tool.*
Conditions favoured		Favourable environmental conditions. *Pest ID tool.*
Transmitted by		Insect transmission (relevant to your situation). *Pest ID tool.*
List of susceptible plants grown		Susceptible plants (relevant to your situation). *IPM in Ornamentals.*
Weed and other hosts		Other hosts (relevant to your situation). *IPM in Ornamentals.*

Quarantine/ isolation		
Neighbouring environments		Are neighbouring environments a likely source of the pest. *Own knowledge.*
Prevailing wind direction		Which direction is the prevailing wind. What effects might this have. *Own knowledge.*
Stock quarantine and treatment		Should incoming stock be quarantined and treated? *IPM in Ornamentals.*
Type of quarantine		Isolation and/or screening? *IPM in Ornamentals.*
Quarantine/ Isolation period		Length of quarantine period. Lifecycle length. *IPM in Ornamentals.*
Proximity of new stock to old stock		Isolation distance for new stock. *IPM in Ornamentals. BioSecure HACCP guidelines - A1 18*
Isolation of first infested stock		Isolation of first infected stock? *IPM in Ornamentals.*
Staff and visitor movement restrictions		Staff and visitor movement restrictions required. *IPM in Ornamentals.*
Varietal management		
Resistant crops/ varieties		Are there resistant crops/ varieties. *IPM in Ornamentals.*

Cultural management		
Landscape habitat for pests & biocontrols		*IPM in Ornamentals.*
Propagation/ planting material		Is propagation or potting stock a source of pests? *IPM in Ornamentals.*
Organisation of growing areas		Organising growing areas to reduce spread. *Own knowledge.*
Spacing crops		Effect of spacing crops on pest and Biocontrol spread. *IPM in Ornamentals.*
Irrigation management		What are the optimal irrigation requirements to reduce pest levels. *IPM in Ornamentals.*
Weed management		Weed management strategies to reduce alternative hosts for pests. *Pest ID/ IPM in Ornamentals.*
Nutritional management		Nutritional strategies to reduce problems. *IPM in Ornamentals.*
Crop waste management		Removing crop waste to reduce levels of pests. *IPM in Ornamentals.*
Temperature control		Temperature management strategies to reduce pest incidence. *IPM in Ornamentals.*
Relative humidity control/		Relative humidity control to minimise pests or encourage

		Biocontrol. *IPM in Ornamentals.*
Condensation control		Condensation control to reduce pest problems. *IPM in Ornamentals.*
Ventilation		Ventilation to reduce pest incidence. *IPM in Ornamentals.*
Light/ shading		Light can affect development of pests. *IPM in Ornamentals.*
Fallow/ rotating growing areas		Resting growing areas to reduce incidence. *Own knowledge.*
Physical management		
Protective structures		Screening of growing areas? *Pest ID tool/ IPM in Ornamentals.*
Physical removal		Physical removal of pests e.g. hand weeding. *Pest ID/ IPM in Ornamentals*
Dust control		Dust control strategies to reduce pests. *IPM in Ornamentals.*
Hygiene and disinfestation procedures		Hygiene procedures to reduce pest levels. *IPM in Ornamentals. NIASA Guidelines Section 1. BioSecure HACCP A1.5.*
Water disinfestation		Is the problem spread by water? Irrigation disinfestation methods. *NIASA Guidelines 1.1.1 Water.*

Drainage water management		Minimise pooling of water around plants for disease control. *IPM in Ornamentals.*
Monitoring		
Crops to inspect - including mother stock and crop indicator plants		Crops to inspect. *Own knowledge.*
Inspection procedure		Refer to symptoms/ weed description to decide parts of plants to inspect. *BioSecure HACCP A1.8 Pest, Disease & Weed Crop Monitoring.*
Monitoring interval		Life cycle days to complete. *BioSecure HACCP A1.8 Pest, Disease & Weed Crop Monitoring.*
Action Threshold		At what level of pests are control actions applied. *IPM in Ornamentals/ own knowledge*
Sticky Traps		
Monitoring interval		*BioSecure HACCP A1.10.7 Inspection of sticky traps.*
Action Threshold		At what level are control actions to be applied. *Own knowledge.*
Biocontrol management		
Refer to biocontrol suppliers, IPM in Ornamentals Information Guide and Pest ID tool website for specific information.		
Naturally occurring biocontrols		List naturally occurring biocontrols are there. *Pest ID tool.*

Strategies to encourage naturally occurring biocontrols		Strategies to encourage naturally occurring biocontrols. *IPM in Ornamentals/ Biocontrol suppliers.*
Banker plants		Can banker plants be used to enhance biocontrols. *Biocontrol suppliers.*
Biocontrol option and supplier		List biocontrol options. *Pest ID tool/ Biocontrol suppliers.*
Other target pests		Other pests the biocontrol targets. *Pest ID tool/ Biocontrol suppliers.*
Description		Is the biocontrol a predator or parasite. General description. *Pest ID tool.*
Optimal conditions		Optimal conditions for the biocontrol. *Pest ID tool/Biocontrol suppliers.*
Release instructions		When, how and how often should the biocontrol be released. *Biocontrol suppliers.*
Pesticide compatibility		Susceptibility of the biocontrol to pesticides. *Biocontrol suppliers.*

Pesticide management				
	Pesticide 1	Pesticide 2	Pesticide 3	Specify registered pesticides for pest and crop. *APVMA - Download label or permit*
Mode of action group				Specify mode of action group. *Product label or permit.*
Rate				Mixing and application rates. *Product label or permit.*
Instructions for use				Summary of instructions for use. *Product label or permit.*
Timing				When to apply the pesticide - time of day, crop stage, problem stage. Product label or permit.
Application equipment				What application equipment is required. *Product label or permit.*
Rotation strategies for resistance management				Explain resistance management strategies. *Product label or permit.*
Effect on biocontrols				What effect does the Pesticide have on biocontrols. *Biocontrol suppliers.*

Comments		
Integrated Pest Management		
How does this plan integrate with other pest management plans?		Consider the integration of this plan with other pest management plans. *Other pest management plans.*
Comments		

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3. NIASA guidelines = Nursery Industry Accreditation Scheme, Australia. Best Management Practice Guidelines - available for purchase at http://nurseryproductionfms.com.au/
4. BioSecure HACCP guidelines = BioSecure HACCP Guidelines for Managing Biosecurity in Nursery Production - available for purchase at http://nurseryproductionfms.com.au/
5. Product labels and permits = Pesticide labels and minor use permits - Australian Pesticides and Veterinary Medicines Authority (APVMA).

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