Integrated Pest Management Strategy
Hard and soft scale insects

Hard scale with unattached shell lifted. Image from: John. A. Davidson, Univ. Md, College Pk, Bugwood.org

Underside of soft scale with attached shell and eggs under shell. Image from: John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org

Black sooty mould caused by scale infestation. Image from: University of Florida, Citrus Whitefly, viewed 8th December 2020, http://entnemdept.ufl.edu/creatures/citrus/citrus_whitefly.htm

Common scale insects of production nurseries

- **Soft scales**: Pinks wax scale, white wax scale, soft brown scale, black scale, *Saissetia* spp.
- **Hard scales**: Oleander scale, white louse scale, rose scale, fern scale, san jose scale, white palm scale, red scale, oriental scale, latania scale.

Crop monitoring

- Crop monitor regularly looking for signs of damage / presence
- Staff performing crop monitoring are trained to identify scale insects?
- Collect samples for identification if needed
- Keep records for future reference
- For further information consult BioSecure HACCP guidelines

Cultural management

- Crop in good health?
- Staff trained to identify?
- Quarantine / treat / dispose of infested or suspect plants, inspect plant imports
- Reduce movement through infestations
- Control ants

Introduce biological controls at first sign of mites

Predator	Scale controlled
Cryptolaemus	Mealybug, soft scale, felt scale
Green lacewing	Various scales
Red chilocorus	White louse scale, oriental scale, red scale
Blue chilocorus	Oleander scale, oriental scale, various hard scale

Continue crop monitoring to gauge effectiveness of treatments applied

Chemical controls

- Rotate MoA group of chemical
- Toxicity to beneficials?
- Residual?

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/

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Developed by the GIA National Nursery Industry Biosecurity Program Team 2020

Scale (Superfamily *Coccoidea*)

The following information is summarised from [1]Manners, A, n.d., 'Scale insects: A difficult problem that can be managed' 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

Scale insects cause damage to plants by sucking plant sap. Scale insects are divided into two groups. **Hard scales** (sometimes known as armoured scales) and **soft scales**. Their classification is not to do with the hardness of their shell, rather whether the shell is attached to the organism or not.

1

1. Hard scale with shell lifted. Image from: John. A. Davidson, Univ. Md, College Pk, Bugwood.org https://www.invasive.org/browse/detail.cfm?imgnum=1635287

Males when they occur are generally smaller than females and similar in appearance to fungus gnats or whitefly. Most males of scale insects have two pairs of wings, (only the front pair is functional) and legs. Males do not feed and are therefore short-lived.

The colour, shape and texture of scale insects varies with species.

Hard Scale

'Armoured or hard scales have a hard, shield-like cover composed of shed skins and wax that conceals the body but is not attached to the body of the insect' (ISU Extension and research, 2020).

Soft Scale

'Soft scales produce a soft, thin, cottony, powdery or waxy layer over themselves that cannot be separated from the insect body. These scale insects often produce copious amounts of honeydew' (ISU Extension and research, 2020).

2

2. Soft scale overturned with eggs under shell. Image from: John A. Weidhass, Virginia Polytechnic Institute and State University, Bugwood.org, https://www.invasive.org/browse/detail.cfm?imgnum=1626023#

Life Cycle of Scale

Many scale species can reproduce without mating as they are either hermaphroditic or parthenogenetic (have both male and female reproductive parts or can reproduce without mating).

Most species lay and carry their eggs underneath their shells. The eggs hatch into nymphs (or nymphs are born live) which are about 0.5-0.1mm long. The first nymphal stage is known as the first instar. Nymphs are referred to as crawlers because they have legs and antennae and can move around dispersing the population.

After moulting (second instar), the scale insect becomes immobile due to their legs reducing in size or becoming absent. Female scale insects generally have 2 – 3 instars, and males have 4.

Damage to plants

Scale insects have piercing and sucking mouthparts they use to feed by sucking sap from plants. When feeding on young parts of plants they cause distorted or yellowed growth. In severe infestations die back of stems or branches occurs. The excretion of honeydew often leads to development of black sooty mould on the infested plant.

3

Sooty mould on citrus. Image from: University of Florida, Citrus Whitefly, viewed 8th December 2020, http://entnemdept.ufl.edu/creatures/citrus/citrus_whitefly.htm

Spread of Scale

Nymphs being very small and having functional legs are the life stage at which the insect is spread. Apart from walking, nymphs are spread by wind, on clothing and tools, with some hitchhiking on other insects.

Common soft scales of Australia

Common & Scientific name	Brief Description	Geographic region	Host Range
Saissetia spp. – S. coffeae, S. oleae and S. miranda. Common names include black scale, black shield scale, brown olive scale, citrus black scale, olive soft scale, hemispherical scale, coffee scale, mexican black scale and many others	Brown to black, convex scales. Nymphs often have light and dark patches or bands.	Key pests in Qld, NSW, NT, Vic and WA, minor pest in SA and Tas	Mostly hardwood plants from more than 20 plant families, mainly Moraceae, Myoporaceae, Myrtaceae, Oleaceae, Rosaceae and Rutaceae including such species as apple, apricot, ash, citrus, daphne, fig, hibiscus, holly, magnolia, oleander, olive, passionfruit, pear, photinia, pistachio, plum, poplar, quince, tamarisk and many others.
Pink wax scale: *Ceroplastes rubens*	Edges are flattened with convex and globular hump in the middle. Light to bright pink, sometimes very pale. Often with white lobes.	Key pests in NSW and Qld, minor pest in NT, Vic and WA	Reported from over 80 plant families, mainly Anacardiaceae, Apocynaceae, Araliaceae, Musaceae, Myrtaceae, Rutaceae and Sapindaceae including avocado, banana, citrus (particularly mandarin), coffee, custard apple, fern, frangipani, holly, ivy, ixora, lilly pilly, mango, pittosporum and many other species.
White wax scale, white scale, citrus white scale: *C. destructor*	White and globular, often with dark circular areas in the middle or at the edge.		Reported from over 15 plant families, mainly Asteraceae, Rosaceae and Rutaceae including acacia, avocado, citrus, coffee, dodoneae, gardenia, guava, hibiscus, lilly pilly, persimmon, rosemary, stone fruit and other species.
Soft brown scale: *Coccus hesperidum*	Discoid, relatively flat. Mostly light brown and slightly transparent, with some dark patches.	Key pest in Qld, NSW, NT and Vic, minor pest in SA, Tas and WA	Reported from over 50 plant families, mainly Anacardiaceae, Caesalpiniaceae, Caricaceae, Hydrangeaceae, Malvaceae, Myrtaceae, Pinaceae, Rosaceae, Rubiaceae, Rutaceae and Solanaceae including blue spruce, citrus, coffee, fern, gardenia, hibiscus, hydrangea, lychee, mango, Moneterey pine, orchid, palms, papaw and many other plants.
Black scale or hibiscus shield scale: *Parasaissetia nigra*	Circular to elongate, black to dark brown; younger nymphs lighter brown. Convex bodies.	Key pest in Qld, NSW and Vic, minor pest in NT, SA and WA	Reported from over 20 plant families, mainly Anacardiaceae, Apocynaceae, Araceae, Euphorbiaceae, Myrtaceae, Rutaceae and Sapindaceae including avocado, cassava, citrus, ficus, frangipani, guava, ginger, hibiscus, lillypilly, mango, poinse a and many other plants.

Table taken from: [1]Manners, A, n.d., 'Scale insects: A difficult problem that can be managed', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

4. Pink wax scale and parasite

5. Soft brown scale

6. Black scale

7. White wax scale

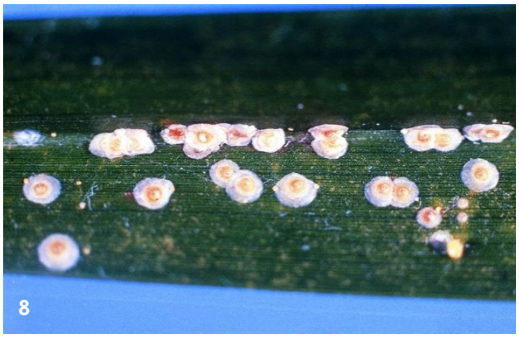
Images courtesy of QDAF.

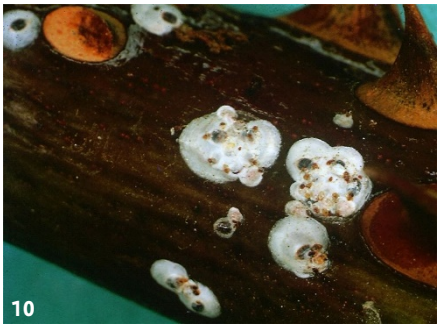
Common hard scales of Australia

Common & Scientific name	Brief Description	Geographic region	Host Range
Latania scale: Hemiberlisia lataniae	Light to dark brown, darker in the centre. Mostly concentric circles, sometimes off-centre.	Mainly found in Qld and NSW. May be found in NT and WA.	Reported on over 25 plant families, mainly, Actinidiaceae, Anacardiaceae, Arecaceae, Fabaceae, Lauraceae, Moraceae, Myrtaceae, Proteaceae, Rosaceae, Rutaceae and Sapindaceae including avocado, banana, grape, grevillea, hakea, kiwifruit, liquid amber, macadamia, mango, palms, pawpaw, poplar, privet, pear, plums, quince, Wollemi pine and many other plant species.
Oleander scale: *Aspidiotus nerii*	Similar to Latania scale, but less regular in shape and lighter in colour.	Key pest in Qld, also found throughout, NSW, Tas and Vic. May also be found in WA, NT and parts of SA.	Reported on over 40 plant families, mainly Araliaceae, Arecaceae, Aucubaceae, Elaeocarpaceae, Ericaceae, Euphorbiaceae, Fabaceae, Grossulariaceae, Mimosaceae, Moraceae, Myrtaceae, Orchidaceae, Proteaceae, Rutaceae, Sapindaceae and Zamiaceae including, acacia, boxwood, citrus, eucalyptus, ferns, grape, ivy, macadamia, macrozamia, oleander, olive, orchid, persimmon and many others.
White louse scale: *Unaspis citri*	Oval and elongate. White lobed section with a dark brown region on one end.	Key pest in Qld and NSW, minor pest in NT and Vic.	Reported on only 2 plant families Chenopodiaceae and Rutaceae, mainly on citrus.
Rose scale: *Aulacaspis rosae*	Smaller individuals with elongate, white scale. Adults circular. Both have darker brown area at one end.	Key pest in Vic and Tas, minor pest in NSW	Blackberry, loganberry, raspberry and rose.
Fern scale: *Pinnaspis aspidistrae*	Similar to rose and white louse scale, but adults are more elongate.	Minor pest in Qld and NSW	Reported on over 15 plant families, mainly Arecaceae, Aspleniaceae and Polypodiaceae including many fern and palm species, but also can infest Chinese hibiscus, citrus, croton, cycads, dracaena, geranium, mango, orchids and African violet.
San Jose scale: *Diaspidiotus perniciosus*	Dark brown and produces regular symmetrical to slightly asymmetrical concentric circles.	Minor pest in Qld, Vic and WA	Mainly plants from the family Rosaceae in Australia, but many other host plants from other families have been reported overseas. Main hosts are pome and stone fruit, rose, berries and quince but may also include a large number of minor hosts including

			aloe, citrus, daphne, eucalyptus, ficus, periwinkle and many other species.
White palm scale: *Pseudaulacaspis eugeniae*	Mainly white or off-white, oblong scale with a small dark brown region at one end.	Minor pest in Qld, NSW, Vic, SA and WA	Over 10 plant families, mainly Arecaceae, Lomandraceae, Magnoliaceae, Moraceae, Myrtaceae and Proteaceae including many palm species, banksia, eucalyptus, ficus, leptospermum, lomandra, melaleuca and many other species.
Red scale: Aonidiella aurantii	Orange, brown or red, roughly circular scale.	Major pest in Qld, NSW and NT, Vic and WA. Minor pest in SA.	Over 50 plant families, mainly Arecaceae, Cucurbitaceae, Euphorbiaceae, Fabaceae, Moraceae, Rosaceae and Rutaceae including most citrus, olive, passionfruit and squash.
Oriental scale *A. orientalis*	Light orange to brown, roughly circular scale	Major pest in Qld, NT and northern WA.	Over 60 plant families, mainly Apocynaceae, Arecaceae, Caricaceae, Meliaceae and Solanaceae including banana, camelia, citrus, dracaena, guava, frangipani, oleander and pawpaw.

Table taken from: [1]Manners, A, n.d., 'Scale insects: A difficult problem that can be managed', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.





8. Oleander scale. Image courtesy of QDAF

9. White louse scale. Image courtesy of QDAF.

10. Rose scale. Image courtesy of QDAF.

11. Fern scale Taken from: John. A. Davidson, Univ. Md, College Pk, Bugwood.org, viewed 8th December 2020, https://www.invasive.org/browse/detail.cfm?imgnum=1635058#

12. San jose scale Taken from: United States National Collection of Scale Insects Photographs , USDA Agricultural Research Service, Bugwood.org, viewed 8th December 2020, https://www.invasive.org/browse/detail.cfm?imgnum=5109045#

13. Red scale. Taken from: Dennis Navea, ControlBest, Bugwood.org, viewed 8th December 2020, https://www.insectimages.org/browse/detail.cfm?imgnum=5439740

14.Oriental scale. Taken from: Charles Olsen, USDA APHIS PPQ, USDA APHIS PPQ, Bugwood.org, viewed 8 the December 2020, https://www.invasive.org/browse/detail.cfm?imgnum=5485895

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 guide pest 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 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.

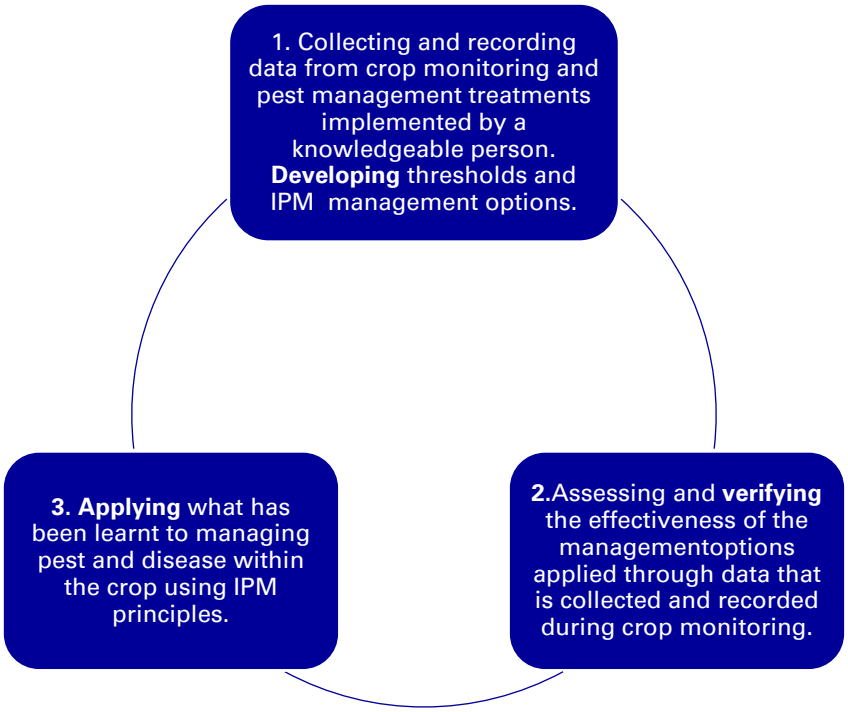
IPM programs centred on crop monitoring programs 'assist growers in the adoption of pest management practices that are more environmentally friendly and safer for workers, consumers and the community at large (Newman, et. Al. 1999)'. Crop monitoring provides the earliest possible indication on pest presence 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 survival, import inspections of any Greenlife to prevent pest entry, using banker plants, throwing out or quarantining infested stock.

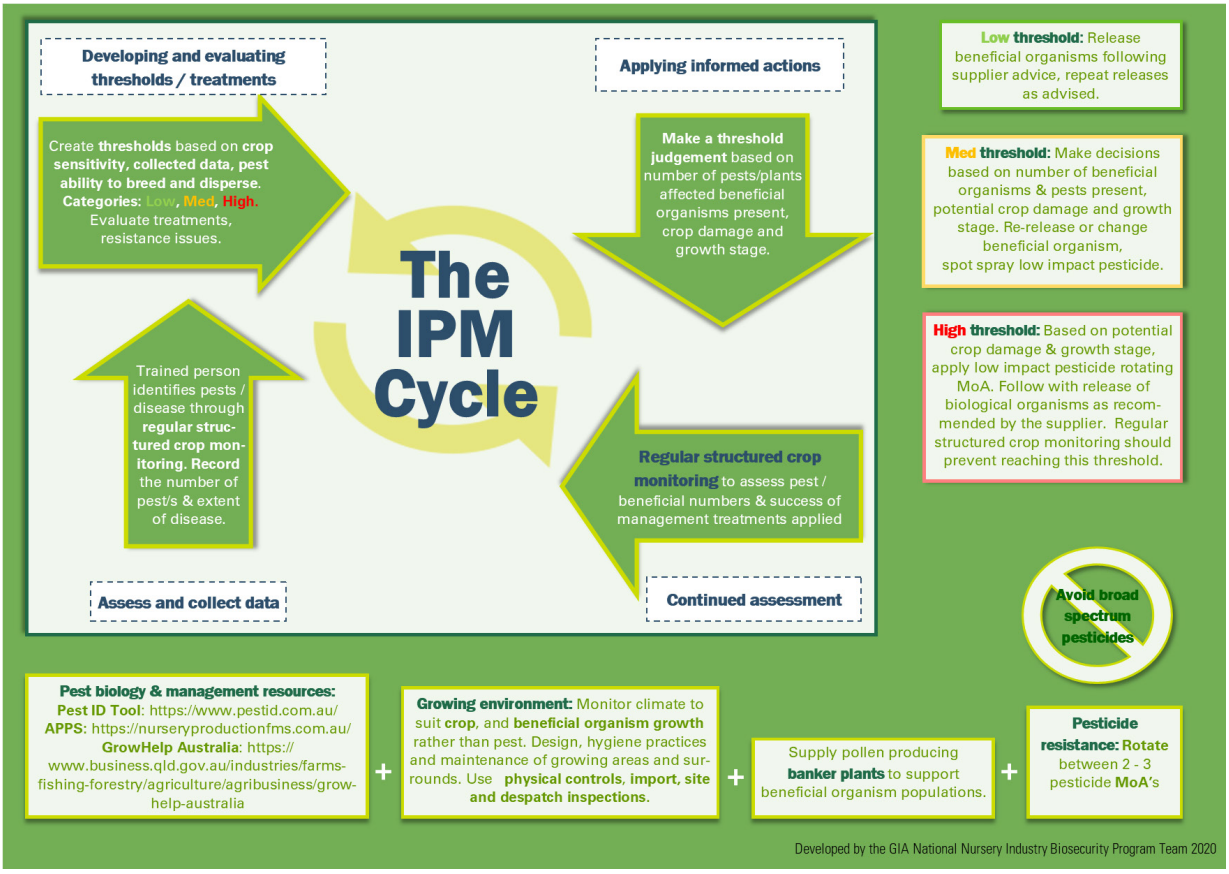
Many studies worldwide on broadacre cropping have found that intercropping to include flower strips or planting nectar-producing plants supports biological control parasites and predators by providing plant-based food, shelter, and alternative prey, increasing their abundance, while pest populations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



Managing Scale

Crop Monitoring

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

For any management method to be successful, monitoring must be performed routinely, consistently and 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. ucculents.	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 scale

Examine any plants that look unhealthy for signs of pests when performing crop monitoring. Examine leaf undersides and along stems for scale, the presence of black sooty mould or ants. Use of a x10 or x 20 hand lens will aid identification of scale. **The presence of crawlers or egg mases under the shells of female scale indicates a rapid rise in population**, finding scale with a circular exit hole on the back is evidence of the presence of natural predators.

Cultural management of scale

Effective cultural practices in the production nursery can reduce scale populations in production nurseries by making the environment unfavourable for establishment, reproduction, dispersal, and survival. Good cultural management practices that will support the management of scale and other insects in the nursery include:

- Train staff to identify scale, especially those species that are pertinent to the crop grown and the region of the production nursery. To ensure correct identification, 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.
- Identify infestations through regular structured monitoring. Early identification and treatment are the key to success for controlling any pest or disease.
- Exclude populations from greenhouses with insect proof glasshouses/tunnels particularly for susceptible crops.
- Quarantine incoming stock and inspecting for signs of infestation prior to moving the stock into production areas.
- Throw out 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.
- 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 scale populations.
- Propagate from uninfested material.
- Avoid moving infested plant material within the growing areas.
- Control ants so they cannot spread crawlers and protect scale from predators.
- Disinfest recycled pots thoroughly.
- Ensure adequate plant spacing to detect scale and increase pesticide coverage.

Biological management of scale

Biological control organisms are very effective control options for controlling hard and soft scales. Successful integration of biological organisms into a management regime relies on good knowledge of the pest, the beneficial organisms, 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 when pests are first observed.

Green lace wings *(Mallada signata)*

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

Feeds on: Larvae feed on aphids, 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 silk 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).

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.

16. Green lacewing eggs

17. Green lacewing larvae with trash package

18. Green lacewing adult.

Images 16-18 taken from: [2]Australasian Biological control, Green lacewing: Mallada signata, general predator, viewed 8th December 2020, http://www.goodbugs.org.au/Good%20bugs/lacewing-green.html

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).

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. The presence of flowers after release will help keep adults within the crop by supplying them with pollen.

Red and Blue ladybeetles or Chilocorus beetles *(Chilocorus circumdatus* (red) and *C. baileyi* (blue))

19. Red chilocorus adult and larvae: : [3]Australasian Biological Control, n.d., Red Chilocorus Chilocorus circumdatus, viewed 8th December 2020, *http://www.goodbugs.org.au/Good%20bugs/chilocorus.html*

Habitat: Prefer warm humid conditions of about 28°C in a protected envirnment.

Feeds on: Both larvae and adults feed on scale. Scale species fed on by red chilocorus include white louse scale, oriental scale, and red scale. Blue chilocorus feed on oleander scale, oriental scale, and several hard scale species.

Lifecycle: At 25°C eggs hatch in about a week. Larvae of both are elongate, light brown in colour with black spikes covering their body. After about 10 days larvae pupate to adults, this takes about 7-9 days. Adult beetles then start laying eggs about 10 days after emergence. At their optimum temperature of 28°C the whole life cycle will take 4 – 8 weeks (Llewellyn, R (ed.) 2002).

Appearance: There are two species of chilocorus ladybeetles that feed on scale. Red chilocorus and blue chilocorus. Both species are small helmet shaped beetles, the red chilocorus is slightly larger than the blue at 5mm long with the blue chilocorus 3 mm long. The red chilocorus is orange while the blue chilocorus is a deep metallic blue.

20. Adult blue chilocorus adult. Image from: Llewellyn, R (ed.) 2002, The Good Bug Book, 2nd edn, Integrated Pest Management Pty Ltd, Australia.

Application rate:

Situation	Release rate	No. of releases	Interval between releases
Protected crops	1-10 beetles / 10m^2	2 - 3	3 - 6 weeks

Table taken from: [3]Bugs for Bugs, 2015, Chilocorus, viewed 8th December 2020, https://bugsforbugs.com.au/product/chilocorus/

Tips for release: Organophosphates, carbamates and synthetic pyrethroids are toxic to Cryptolaemus. A minimum gap of about four weeks is required before release after treatment with these chemicals (Llewellyn, R (ed.) 2002). Release at first signs of pests.

Aphytis species *(Aphytis lingnanensis* and *Aphytis melinis)*

Image 21. Aphytis laying eggs in red scale taken from: (Llewellyn, R (ed.) 2002)

Habitat: Optimal temperatures are 25 - 30°C, able to tolerate higher temperature up to 38°C for short periods. Prefer healthy well foliaged plants for shelter from extremes in climate (Llewellyn, R (ed.) 2002).

Feeds on: Armoured scale insects including red scale, oriental scale, and oleander scale.

Lifecycle: Wasps live for about 2 weeks and are capable of laying about 100 eggs in that time (Llewellyn, R (ed.) 2002).

Appearance: Small orange/yellow wasp about 1mm in length.

Application rate: 'Three releases (Spring/Summer/Autumn) per season to ensure constant parasite activity are advised per orchard. Where scale insect levels are high, an oil spray at high volume may also be advised' (Biological Services, 2015).

'Citrus: Minimum 25,000 wasps per hectare (2.5 cups per hectare)
Pawpaws/Passionfruit/Ornamentals: Minimum 50,000 wasps per hectare (5 cups per hectare)' (Biological Services, 2015).

For further information on application rates contact your supplier.

Tips for release: Very susceptible to chemical use. 'Aphytis should be released in September/October in mild spring conditions to restore parasite levels after winter. Releases can continue through summer after pesticide applications and heat waves. Releases in March/April after extreme heat has passed are also beneficial' (Biological Services, 2015).

Cryptolaemus *(Cryptolaemus montrouzieri)*

Habitat: Above ground plant parts. Do best at 28°C and will survive in temperatures between 16-33°C.

Feeds on: Adults and larvae feed on mealybug and felt scales, or soft scales when preferred food is not available.

Lifecycle: Takes between 4 and 7 weeks dependant on temperature. Females lay about 10 eggs per day.

Appearance: A type of ladybird the adult is about 4mm long and has an orange head and black wing coverings. The larvae look similar to mealybug as they are covered in white waxy filaments, however they are more mobile than mealybug, with older larvae larger (about 13mm long) than mealybug (Llewellyn, R (ed.) 2002) ([1]Bugs for Bugs, 2015).

15. Cryptolaemus adult and larvae feeding on citrus mealy bug: [1]Australasian Biological Control, n.d., Cryptolaemus: Cryptolaemus montrouzeri, viewed 8th December 2020, http://www.goodbugs.org.au/Good%20bugs/cryptolaemus.h

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Application rate:

Situation	Release rate	No. of releases	Interval between releases
Protected crops	1 - 5 beetles / m2	2 - 3	3 - 6 weeks
Hotspot treatments	10 - 50 larvae/ m2	As required	1 – 2 weeks

Table taken from: [1]Bugs for Bugs,2015, Cryptolaemus, viewed 7th December 2020, https://bugsforbugs.com.au/product/cryptolaemus/

Tips for release: Works best on large mealybug populations, combine with *Leptomastix* for control of citrus mealybug. Release at first sign of pests. It may be 2 – 3 weeks before larvae are seen feeding on pests. Adults may not be obvious after release. Organophosphates, carbamates and synthetic pyrethroids are toxic to Cryptolaemus. A minimum gap of about four weeks is required before release after crop is treated with these chemicals (Llewellyn, R (ed.) 2002).

Combination biological and chemical management of scale

Combination management options for Scale			
Scale absent	**Low population**	**Moderate population**	**High population**
Continue monitoring. If a particular species of scale insect consistently attacks the plant during a particular time of year, release predators or parasitoids at preventative rates.	Release at normal rate weekly until 80% of scale insects are parasitised or consumed. If hot spots occur within, add high rates to the hotspot.	Release at high rates weekly until 80% of scale insects are parasitised or consumed. If the plant species is highly susceptible to damage, application of a low risk insecticide may be warranted prior to release.	Remove as much highly infested plant material as is feasible. Apply a low risk insecticide (e.g. products with the active ingredients pyriproxyfen, buprofezin, Spirotetramat) to knock down scale insect numbers to a manageable level. Be aware of how long the product will be active against the biocontrol agent. Release when safe and numbers are low.

Table taken from: [1]Manners, A, n.d., 'Scale insects: A difficult problem that can be managed', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

Chemical management of scale

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.

Chemical rotations for use alongside a biological management program

- Spirotetramat
- Buprofezin
- Pyriproxyfen
- Fenoxycarb

Add an oil compound at label rates if feasible, particularly if crawlers are present.

Chemical rotations for chemical only management program

- 1B product (preferably a systemic product)
- 4A product
- Sulfoxaflor (see text below)
- Carbaryl (but only if the product will contact scale insects present)

The following table lists chemical products available for the treatment of scale insects in production nurseries. It includes information on the mode of action and the level of toxicity to beneficials to assist with implementing an IPM program. Toxicity to beneficials is just a guide based on current information and some products may differ in their impact to beneficial populations.

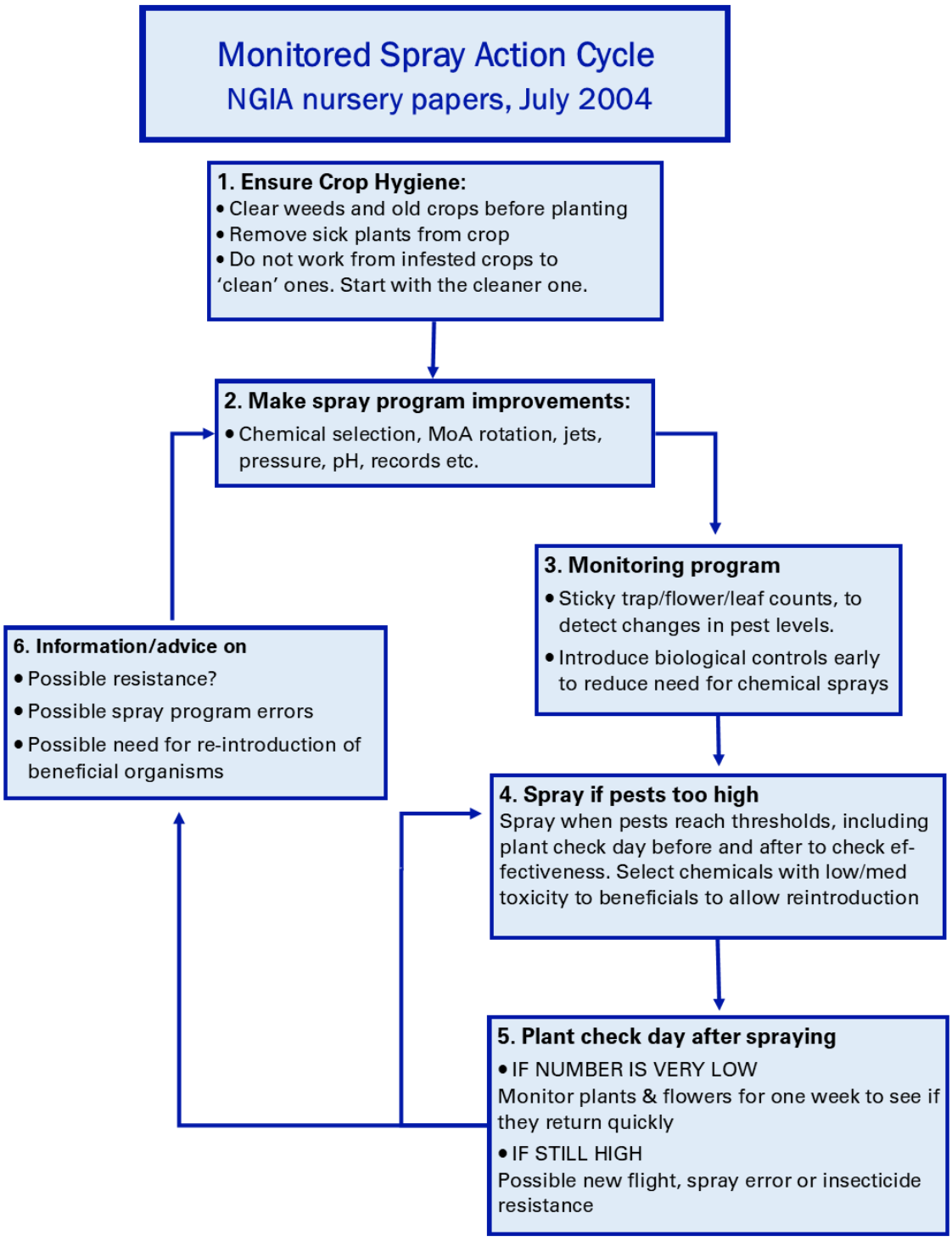
Action - C = contact, S = Systemic, T = Translaminar. Toxicity - H = High, M = Medium, L = Low.

Mode of action group	Active ingredient	Example product	Registration information	Action	Toxicity to beneficials
1A	Carbaryl	Bugmaster	Selected scale insects on oranges, lemons and mango.	C	H – 4+ weeks residual
1B	Chlorpyrifos	Lorsban	Selected scale insects on apple and pear, avocado, citrus, grape vines, mango, and stone fruit (not cherries).	C	H – 2-4 weeks residual
1B	Diazinon	Diazinon	All scale insects on nursery plants and selected scales on certain fruit crops.	C	M-H – 2-3 weeks residual
1B	Dimethoate	Dimethoate	All scales on Eucalyptus, kurrajongs, flame trees and umbrella trees only in WA only.	S	H – 4+ weeks residual
1B	Maldison	Maldison	Selected scales on citrus, grape vine, all scale insects on hardy ornamentals, eucalypts, and native plants.	C	H – 2-4 weeks residual
1B	Methidathion	Suprathion	San Jose scale on apple and pear, stone fruit, various scales on avocado, apricot, citrus, custard apple, grape, macadamia, mango, passionfruit, orchids; all scale insects on ornamental trees and shrubs in nurseries. Labels vary. All scales on lychee (PER14099) and persimmons (PER13694).	C	H – 2-4 weeks residual
1B	Omethoate	Folimat	Red scale on citrus only.	S	Probably H – 4+ weeks residual
4A	Acetamiprid	Crown	Scale insects including coffee scale, nigra scale, pulvinaria, but not white wax scale, on ornamental plants.	S	Probably M-H – 2 -3 weeks residual
4A	Imidacloprid	Confidor, Merit, Suscon Maxi Soil	PER81707 All scale insects on nursery stock (for inclusion in potting mix only). Soft scales on ornamental plants, pink wax scale and red scale on citrus. All scales on magnolias (Initiator tablets). Labels vary.	S	H – 2-3 weeks
4C	Sulfoxaflor	Transform	Certain scales on citrus only.	S	Probably L-H - unknown residual
7B	Fenoxycarb	Insegar	PER81707 All scales on nursery stock. San Jose scale on apple and pear only.	T	L-H – 1-3 weeks
7C	Pyriproxyfen	Admiral	Certain scales on citrus, mango, and olive.	T	Probably L-M – 1- 2 weeks residual
16	Buprofezin	Applaud	PER81707 All scale insects on nursery stock. Various scales on selected fruit crops.	T	L-M – 0-3 weeks residual
23	Spirotetramat	Movento	PER81707 All scale insects on nursery stock.	S	L – 0-1 week residual
NA	Paraffinic oil	Biopest paraffinic oil	Hard and soft scale on apple, all scales on pear, apricot, blueberry, olive, grape, cherry, plum, prune, pecan, avocado, kiwi, custard apple, mango, shade trees and shrubs and woody ornamentals, flowers and foliage plants. Labels vary.	C	L-M – 0-1 week residual
NA	Petroleum oils	Winter oil	PER81707 All scales on nursery stock. Most labels with selected scales on certain fruit crops, some with all scales on ornamentals.	C	L-M – 0-1 week residual
NA	Sulphur	Sulphur, lime sulphur	White louse scale on citrus and San Jose scale on apple and stone fruit. Labels vary.	C	Probably L-M – 1-2 weeks residual

Results presented were from queries of the APVMA pubcris searches. Notes on their use, toxicity to beneficial organisms and the level of resistance (which has been combined according to mode of action group) are also included. Check full product labels at http://services.apvma.gov.au/PubcrisWebClient/welcome.do

Table taken from: [1]Manners, A, n.d., 'Scale insects: A difficult problem that can be managed', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

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.


Monitored Spray Action Cycle
NGIA nursery papers, July 2004
1. Ensure Crop Hygiene:
• Clear weeds and old crops before planting
• Remove sick plants from crop
• Do not work from infested crops to 'clean' ones. Start with the cleaner one.
2. Make spray program improvements:
• Chemical selection, MoA rotation, jets, pressure, pH, records etc.
3. Monitoring program
• Sticky trap/flower/leaf counts, to detect changes in pest levels.
• Introduce biological controls early to reduce need for chemical sprays
4. Spray if pests too high
Spray when pests reach thresholds, including plant check day before and after to check effectiveness. Select chemicals with low/med toxicity to beneficials to allow reintroduction
5. Plant check day after spraying
• IF NUMBER IS VERY LOW
Monitor plants & flowers for one week to see if they return quickly
• IF STILL HIGH
Possible new flight, spray error or insecticide resistance
6. Information/advice on
• Possible resistance?
• Possible spray program errors
• Possible need for re-introduction of beneficial organisms

Information resources

1. 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:

   a. tertiary qualifications appropriate to horticulture, plant science agriculture or environmental management (majoring in plant-based content)
   b. technical competence in production nursery practices,
   c. 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/

2. 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/
3. 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/
4. 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
5. 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/
6. **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
7. **Supply and consultation** for using **beneficial organisms** in your nursery:

   a. https://biologicalservices.com.au/

b. https://bugsforbugs.com.au/
c. http://www.ecogrow.com.au/index.html

8. Agrilink Integrated Pest Management in ornamentals information guide: http://era.daf.qld.gov.au/id/eprint/2208/
9. 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				
References				

1. Pest ID tool = Pest Identification Tool - free registration - https://www.pestid.com.au/
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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/
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