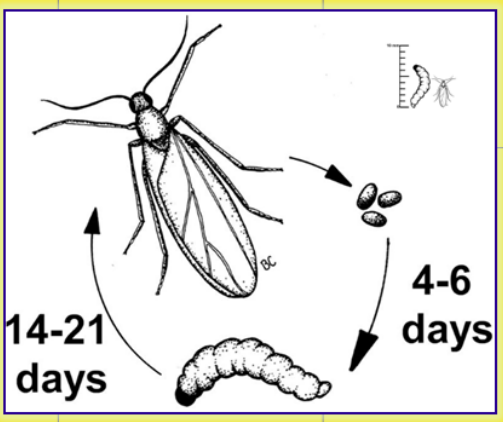
Integrated Pest Management Strategy

Fungus gnat *Bradysia spp.*

Adults (mosquito-like) 3-5mm long



Adult lays 100-150 eggs in its 3 day life

Larvae 10 - 8mm shiny black head

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/

Crop monitoring

- Sticky traps for adults, potato baits for larvae
- Keep records for future reference
- Choose intervals for monitoring that suit crop susceptibility and know how to identify

+

Thresholds for adult gnats in weekly sticky trap monitoring

< 20	20—50	50 +
Low	Medium	High

+

Cultural management

- Production areas free draining, free of algae and organic waste?
- Crop in good health?
- Quarantine / treat / dispose of infested or suspect plants, inspect plant imports
- Growing media stored in a clean dry area?

+

Introduce biological controls at first sign of Fungus Gnats

Biological control

- *Hypoaspis* mites
- *Dalotia* rove beetles
- *S. feltiae* emtomopathogenic nematodes
- BT drench

+

Continue crop monitoring to gauge effectiveness of treatments applied

Chemical controls

- Spot spray rather than blanket
- Toxicity to beneficials?
- Residual?

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Images courtesy of QDAF

Developed by the GIA National Nursery Industry Biosecurity Program Team 2020

Fungus Gnats (*Bradysia* spp., Sciaridae)

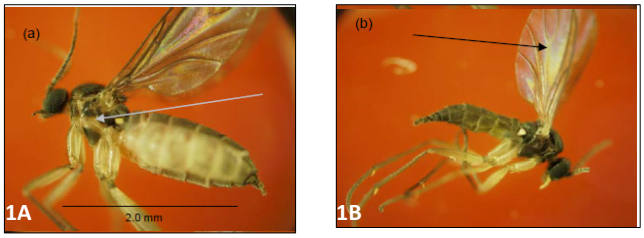
The following information is summarised from Manners, A, n.d., '*Fungus gnat pest management plan for production nurseries*' unless otherwise stated.

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

Adult fungus gnats are **small mosquito like insects 3-5mm long**. They are weak flyers that can usually be found resting on plants or growing media. When disturbed they tend to fly in a zig zag pattern. They are similar in appearance to shoreflies.

Larvae are 10-8mm long white maggots with a shiny black head. They can be found in the top 3cm of growing media.



1. A and B. Adult fungus gnats from the genus *Bradysia* have a yellow band running below their wing (see arrow in photo (a)) and are relatively large, species in the genus *Lycoriella* are smaller and do not have the yellow band (b). All fungus gnats have a prominent 'Y-shaped' wing vein (see arrow in photo (b)). Photos by Afsheen Shamshad

Life cycle

Adult females lay 100-150 eggs over their 3-day lifespan, eggs take 4 days to become larvae. The larval stage which causes damage to plants lasts 15-30 days at temperatures between 18 and 25°C, dependant on the species. Temperatures outside 10-32/35°C are unfavourable for the pest.

2.Fungus gnat larvae. Photo from: University of New Hampshire Cooperative Extension, 2018, Fungus gnats (fact sheet), Viewed 30th November 2020, Fungus Gnats | UNH Extension

Damage to plants

Damage to plants is caused by the **larval stages of fungus gnats cause damage**. Fungus gnats feed on root hairs, fungi, root callus and organic matter. Feeding on plant roots and root callus happens when there are no fungi to feed on, this can slow down or prevent root development. Plants highly susceptible to fungus gnats are those with succulent type stems. Larvae are not attracted to inorganic types of growing media such as vermiculite and perlite.

3. Fungus Gnat larvae. Photos from: The Center for Agriculture, Food, and the Environment, Fungus Gnats and Shore Flies, viewed 30th November 2020, Greenhouse & Floriculture: Fungus Gnats and Shore Flies | UMass Center for Agriculture, Food and the Environment

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 underpinned by trained and informed personnel, consistent crop monitoring that is structured 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 management choices 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

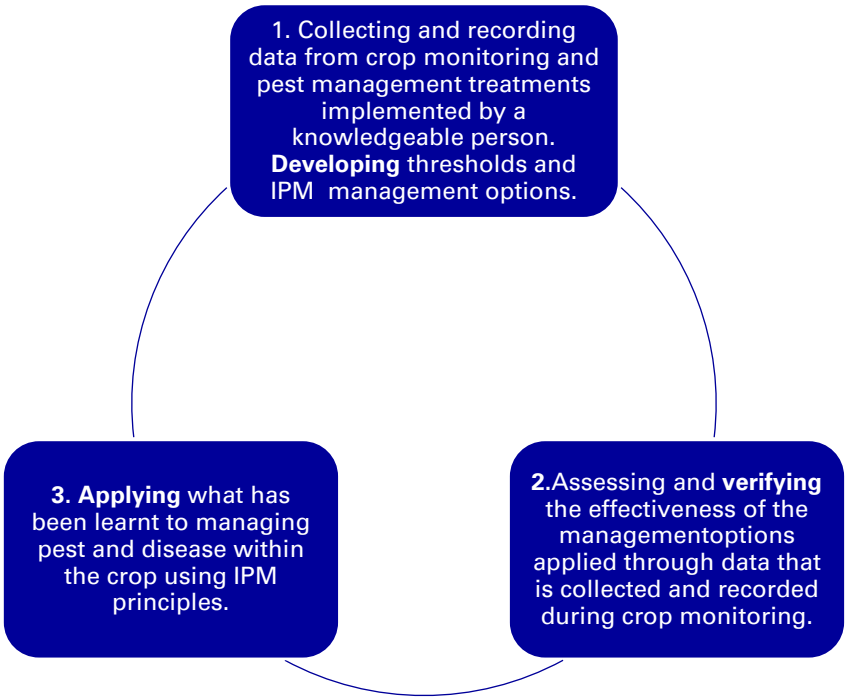
At the centre of any successful IPM program is **structured**, **consistent crop monitoring** (Newman, et. Al. 1999, LeBude, A.V., et. al, 2012)). Consistent monitoring means that the crop monitoring is performed on a schedule that suits the crop age and type. If you are producing seedlings then this 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

a 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.

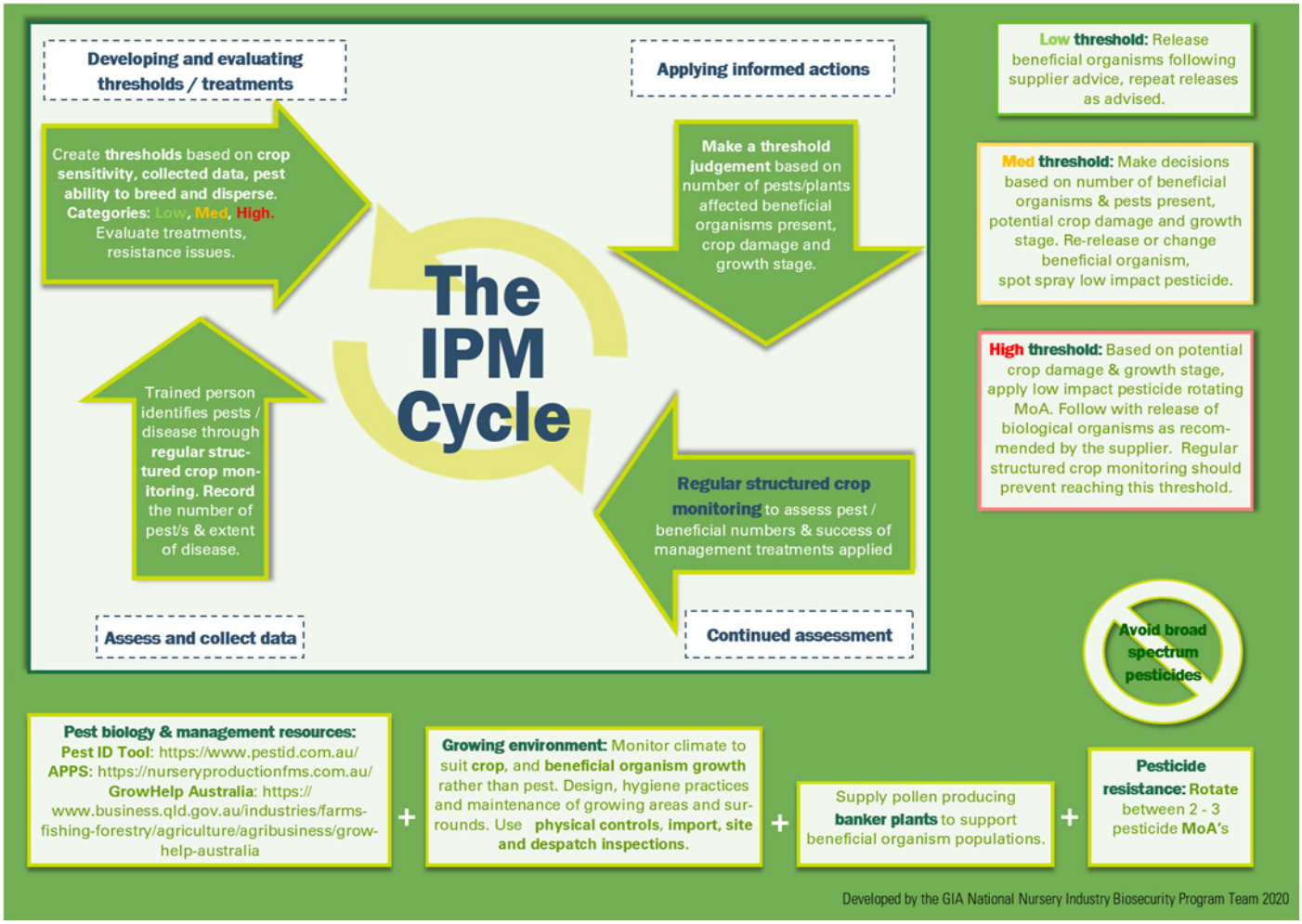
Many studies worldwide on broadacre cropping have found that intercropping to include flower strips or planting nectar-producing plants supports biological control parasites and predators by providing plant-based food, shelter, and alternative prey, increasing their abundance, while pest populations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



Managing Fungus Gnats

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 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 aren't 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 Fungus Gnat larvae

Ensure scouts are familiar with the identifying features of fungus gnat larvae. Larvae of Fungus gnat are found up to 3cm below the surface of the growing media. Inspecting this top layer of growing media can be time consuming and not suitable to all crop life stages such as where disturbance may affect the strike the rate for newly propagated material.

Potato baits can assist in identifying areas of infestation without disturbing the growing media. Place segments of raw peeled potato onto the growing media surface for a 24 to 48-hour period. After this time, look for larvae hiding beneath the potato. Dispose of the potato after 48 hours to ensure it does not attract pests (Manners A. n.d.).

Equipment List	
Hand lens (at least x10 or greater).	Marking pen.
'Crop Monitoring Record' and clipboard.	Knife/ secateurs.
Flagging tape and stake.	Disinfectant (spray bottle) – 70% Methylated Spirits/30% Water or disinfectant/detergent.
Small brush.	Disposable gloves.

Equipment List	
Small container with secure lid for collecting suspect organisms/samples.	Minimum/maximum thermometer or access to climate data.
Small plastic bags (e.g. zip lock).	Pest, disease and weed identification materials (e.g. the Pest ID Tool – www.pestid.com.au) **AND** a Beneficial insect guide (if applicable).
White container/paper plate/plastic lid/or similar white surface.	'Beneficial Organism Release Record' (if applicable).

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

Monitoring for adult Fungus Gnats

The best method for monitoring populations of adult fungus gnats, is to use sticky traps. Either blue or yellow sticky traps. Yellow is the best for detecting fungus gnats. Place traps out to monitor areas of growing beds, greenhouses or polyhouses using the density of traps per m^2 provided in the following table (Greenlife Industry Australia, 2019).

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.

Placement of sticky traps should be elevated 10 cm above the crop, near to entryways such as doors and vents. Inspect the traps for fungus gnat presence weekly. Less than 20 gnats per trap per week may be under the economic threshold, this is dependent on the crop susceptibility. Change traps every 1 to 2 weeks dependant on their condition (Manners, A, n.d.).

Cultural management of Fungus gnats

Effective cultural practices in the production nursery can reduce Fungus gnat populations in production nurseries by making the environment unfavourable for establishment, reproduction, dispersal, and survival of Fungus gnats. Good practices that support reduced Fungus gnat populations include:

- Training staff to identify Fungus gnat adults and larvae. 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.
-
- Excluding populations from greenhouses with insect proof glasshouses/tunnels.
- Quarantining incoming stock and monitoring for signs of infestation prior to moving the stock into production areas.
- Check deliveries of growing media to ensure it is not infested. Seek NIASA accredited providers or steam sterilise/pasteurise growing media before use.

- Use potting media that is low in organic matter content where possible. Examples include vermiculite and perlite.
- Store media in a clean dry area. Any moisture in the stored growing media will increase fungal load making it more enticing to fungus gnats.
- Grow resistant cultivars.
- Identify infestations through regular structured monitoring. Early identification and treatment are the key to success for controlling any pest or disease (Manners, A., n.d.).

Also practice good hygiene in the growing areas by:

- Regularly disinfesting the growing area to remove algae and clean bench surfaces.
- Ensure all areas are free draining.
- Keep organic waste away from growing areas by removing weeds and waste, and unsaleable crops.
- Avoid broad spectrum highly residual chemicals that will kill off natural predators or parasitoids (Manners, A., n.d.).

Biological management options for managing Fungus gnats

Biological control organisms are very effective control options for controlling Fungus gnat larvae. 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.

The following beneficial organisms are available for release to control Fungus gnats in Australia.

- Hypoaspis soil dwelling predatory mites, 2 species:
  - *Geolaelaps aculeifer* (FKA *Hypoaspis aculeifer*) slower moving with darker harrier legs, more rounded and,
  - *Stratiolaelaps Scimitus* (FKA *Hypoaspis miles*)
- *Dalotia coriaria* (FKA *Atheta coriaria*) – predatory rove beetle
- *Steinernema feltiae – entomopathogenic nematode*
- *Bacillus thuringiensis* subsp. *israelensis* (Bti) entomopathogenic bacteria (Manners, A. n.d.)

4. Hypoaspis adult. Images from: Bugs for Bugs, 2015, Hypoaspis, Viewed 30th November 2020, https://bugsforbugs.com.au/product/hypoaspis/

Hypoaspis mites *Geolaelaps aculeifer (Hypoaspis aculeifer)*

Habitat: Lives in moderately moist soils rich in organic matter. Soil temperatures outside 16-30°C adversely affect its survival.

Feeds on: 'Nymphs and adults feed of *G. aculeifer* feed on fungus gnat larvae, thrips pupae and other soil organisms, including nematodes, springtails, root aphids and mites' (Manners A., n.d.).

Life cycle: Females lay 3-4 eggs per day in good conditions. Development from egg to adult is complete in 12 days at 27°C and 40 days at 16°C. Can survive long periods without prey.

Appearance: Adults are light brown, about 0.6 mm long, nymphal stages are paler and smaller ([2]Biological Services, 2015).

5. Hypoaspis adult. Images from: Bugs for Bugs, 2015, Hypoaspis, Viewed 30th November 2020, https://bugsforbugs.com.au/product/hypoaspi

Stratiolaelaps Scimitus *(Hypoaspis miles)*

Habitat: Live in top 1-2 cm of soil

Feeds on: Fungus gnat larvae. Preferring a soil temperature of 20-30°C, they become inactive at temperatures below 12°C but will live, below 10°C they will die.

Life cycle: Entire life cycle varies dependant on temperature from about 10 - 18 days at 25/20°C to 30 or more days at 15°C days. Can survive up to 7 weeks without prey by feeding on organic matter such as plant debris (Llewellyn, R 2002).

Appearance: Predatory mite about 0.5 -1mm long, females are larger and more common (Llewellyn, R 2002).

Hypoaspis release: Preventative treatment:15,000 per 150-300 x 150mm pots or 15000 per 100-150m2. For curative treatment double the rate (Llewellyn, R 2002).

Tips for release

- Even distribution gives best results.
- Insect spread via crawling; pots touching will assist them to travel.
- Do not mix into potting media and ensure media is not waterlogged as they will die due to lack of air.
- Expect a reduction of numbers of Fungus gnats over a 2-3-week period, perform crop monitoring to confirm numbers.
- Hot spots of activity may need further applications.
- Compatible with Steinernema feltiae – entomopathogenic nematode which also controls fungus gnat larvae.
- Pyrethroids (particularly soil drenches) are especially toxic to all Hypoaspis (Llewellyn, R 2002).

Dalotia coriaria *(Atheta coriaria)*

Habitat: Temperature range for survival 15-32°C with an optimal temperature of 27°C

Feeds on: "Feeds heavily on fungus gnat/shorefly eggs and larvae, and thrips pupae. Will eat western flower thrip larvae and shorefly larvae however prefer fungus gnats. Eggs and small larvae of a wide range of insects are consumed" (Manners, A., n.d.)

Life cycle: Lifespan – 21 days, lays up to 8 eggs per day, consume up to 150 fungus gnat larvae per day

6. Adult Dalotia: Buglogical Control Systems Inc, n.d., Rove beetle, Viewed 30th November 2020, https://www.buglogical.com/beetles/rove-beetle-dalotia-coriaria/

Appearance: Adults are slender, fast moving glossy blackish-brown beetles that are 3-4 mm long, larvae are thin pale to light brown in colour 3-4mm long, adults have wings and will fly in search of a food source

Release rates: 1000 (usually per litre) per 200m^2, two introductions 7 days apart, double the rate for hotspots ([1]Biological Services, 2015).

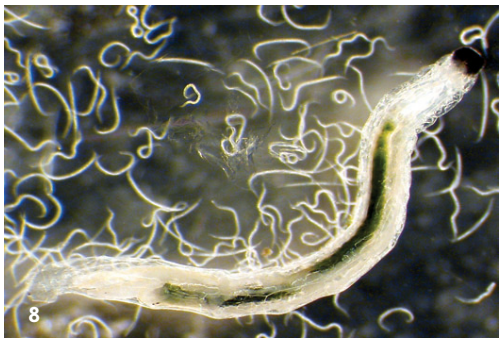
Tips for release: Early repeated releases work best, adults fly so will distribute themselves, spoon small piles onto the tops of potting media to distribute through the growing area, concentrating on hot spot areas(Biological Services, 2015).

7. Adult Dalotia spp. Eating: Everwood Farm Supply, n.d. DALOTIAforce – rove beetle adults, viewed 30th November 2020, https://www.everwoodfarm.com/Organic_Pest_Control/Beneficial_Insects_Listing/Dalotia/coriaria/DALOTIAforce

Steinernema feltiae

Habitat: Optimal soil temperature range: 10-30°C with prolonged temps above 25°C reducing effectiveness.

Feeds on: Fungus gnats (*Bradysia* spp.), shore flies, western flower thrips, leafminers (Tofangsazi, N, Arthurs, S.P, Giblin-Davis, R.M., 2012)



8. S. Feltiae emerging from Fungus gnat larvae. Image from: Ferguson, G, Murphy, G, Shipp, L, 2020, Fungus Gnats and Shoreflies in Greenhouse Crops, Viewed 30th November 2020, http://www.omafra.gov.on.ca/english/crops/facts/14-003.htm

Life cycle: *S. feltiae* kill fungus gnat larvae by entering the larvae through body openings, this releases a bacteria in the larvae which breaks down the host larvae's body tissue into food, killing the fungus gnat larvae within about 48hrs from infection and releasing a new generation of nematode as it decomposes.

Appearance: Nematodes are microscopic wormlike soil dwelling organism less than 1mm in length.

Application rates: Ecogrow gives rates for their product as 15 Million nematodes per 30 m^2 for a curative treatment or 15 Million nematodes per 60 m^2 as a preventative treatment. Rates will differ according to supplier (Ecogrow, n.d.).

Tips for release: *S. feltiae* are applied as a drench to growing media.

- Apply using high-volume low-pressure spray (with removal of fine filters) to drench nematodes into the media preferably not in direct sunlight. *S. feltiae* are compatible with most insecticides and miticides, however nematacides will kill them (Nemassist, n.d.).
- Fill application equipment with tepid with water 10-20°C and allow 15-20 minutes for the nematodes to re-hydrate (Ecogrow, n.d.).
- Apply evenly to pre-moistened soil, ensuring that the suspension is agitated or stirred at 5-minute intervals, as the nematodes will settle to the bottom of the vessel.
- For best results, lightly irrigate after application to help flush the nematodes into the upper layers of the media from foliage.
- Growing media should be treated as soon as possible after sowing seed or inserting cuttings (Ward, C., 2014).

Bacillus thuringiensis subsp. *israelensis* (Bti)

Bacillus thuringiensis (Bti) is an entomopathogenic bacteria used for the control of fungus gnats and various other pests. Research has shown that Bti is mainly effective against first instar fungus gnat larvae, not larger second or third instars. If using Bti apply the product when fungus gnats first appear. Bti may require multiple applications and is UV sensitive. Bti is available from most agricultural supply outlets.

Biological management combinations

Fungus gnat populations taken from weekly sticky trap monitoring			
Biological management options	**Low < 20 per week**	**Moderate 20-50 per week**	**High 50+ per week**
1	Release one of *G. aculeifer*, *S. scimitus* or *D. coriaria* on a regular basis at a preventative rate [i]. Preferably, release when potting up and once two weeks later.	Release one of *G. aculeifer*, *S. scimitus* or *D. coriaria* at moderate rate [i] weekly for three consecutive weeks.	Release *S. scimitus* or *G. aculeifer* AND nematodes at a relatively high rate [i,ii] for three consecutive weeks
2	Apply nematodes [ii] or Bti on a regular basis at a preventative rate [ii], preferably starting when first potting up. Alternate between Bti and nematodes at fortnightly intervals.	Release nematodes for 3 consecutive weeks at moderate rates [ii].	If the population is particularly high, apply Bti once per week in addition to predatory mites and nematodes.

i Spread 1L of *G. aculeifer*, *S. scimitus* or *D. coriaria* over 100-150 m2 for preventative rates, 50-75 m2 for moderate rates and 30 m2 for high rates.

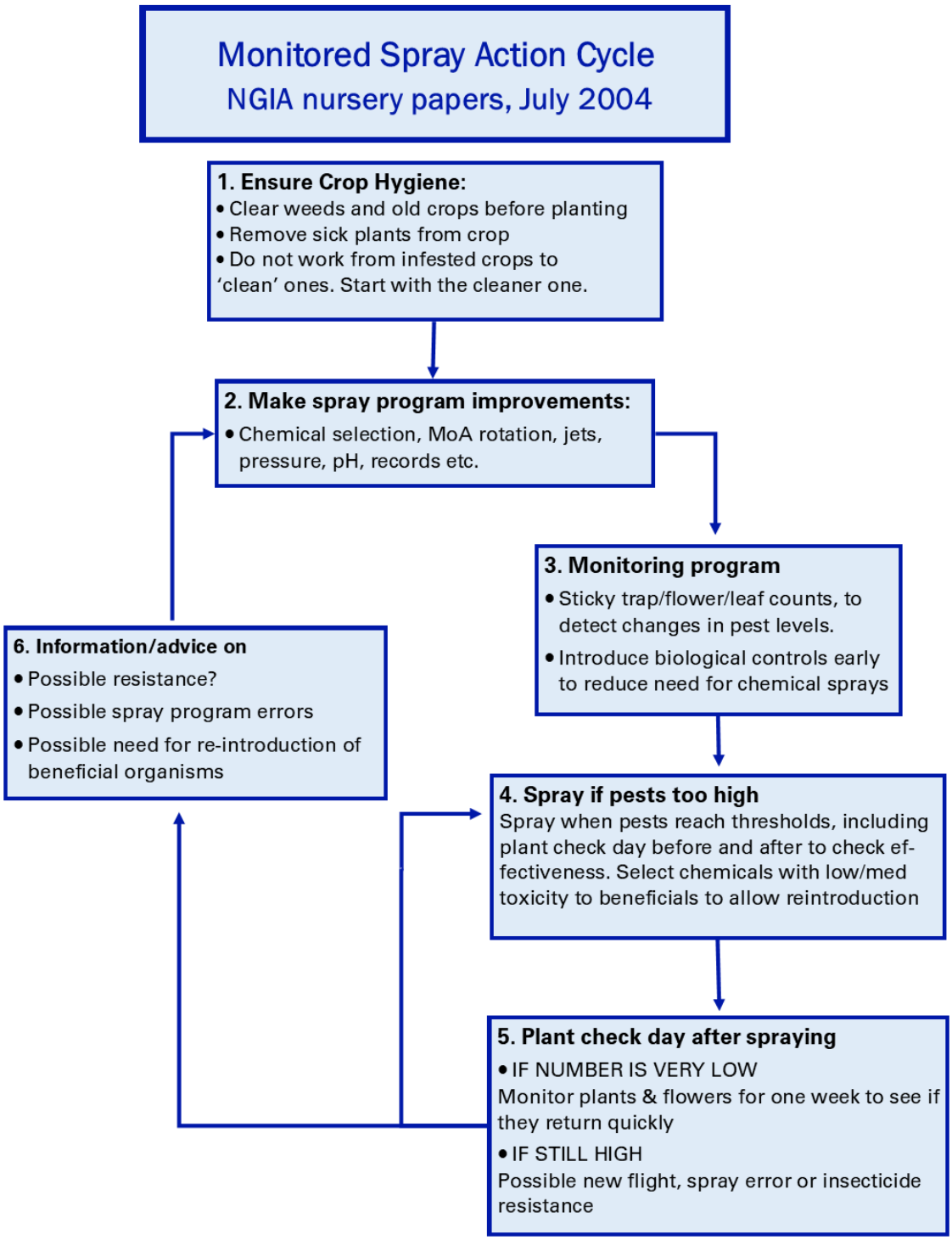
ii Spray nematodes in a drench using low pressure. Use one 55 million pack of nematodes in 100-200 litres of water covering 200, 150 and 100 m2, respectively, at low, medium, and high rates. Refer to your supplier's guidelines before applying nematodes. Please note that Becker Underwood and Ecogrow differ in their recommended rates of release, probably due to the different formulation of the nematodes they supply. Nematodes may also be applied through irrigation lines, but filters must be removed. Taken from: Manners, A, n.d., 'Fungus gnat pest management plan for production nurseries', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

Chemical Management

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.

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

Mode of action group	Toxicity to beneficials	Active ingredient	Example product	Registration information	Mode of action	Limits on application	Other information
11	**None** Non-residual	*Bacillus thuringiensis* subsp. *israelensis*	VectoBac, Bactivate	Permit 11472 allows use against fungus gnats in protected capsicums, cucumber, eggplants, herbs, lettuce, ornamentals (including potted plants) and tomatoes.	I	None	Refer to label for application instructions. See section on biological control for more details. **Most effective against small larvae**
22A	**L** Non-residual	Azadirachtin A and B	Eco-neem; Azamax	Registered against fungus gnats for potting soil of floriculture and ornamentals.	C, I	None	Some sensitive plants have had minor phytotoxic effects. Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. **Only effective against larvae.**
7C	**L - M** 1-week residual.	Pyriproxyfen	Admiral	Permit 81707 allows use against fungus gnats on nursery stock (non-food): including seedlings and plugs, potted colour trees and shrubs, foliage plants, palms, grasses and fruit trees (non-bearing).	C, T	Once per crop cycle	Use as drench to saturate top 2-4 cm of soil. **Only effective against larvae.**
4A	**M** Probably 1-2 weeks residual.	Acetamiprid	Crown	Registered against fungus gnats and shore fly on ornamental plant potting mixes, applied as a drench after potting and plant up.	C, I, S, T	Repeat in 6-8 weeks if pest activity reappears.	Refer to label for application instructions. **Only effective against larvae.**
1B	**M** 1-2 weeks residual.	Diazinon	Diazinon, Diazol	Registered against fungus gnats in ornamental potted plants but only in Qld.	C, I V	None	Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. **Effective against larvae.**
1B	**M – H** Likely to have a very long residual period greater than 12 months.	Chlorpyrifos	Suscon green	Registered for fungus gnats and shorefly for ornamental nursery plants (rooted cutting or seedlings or direct seed or unstruck cuttings) but only if in a peat based growing media.	C, I, V	Incorporate into growing media before young bare root plants, seeds or cutting are planted, sown, or struck.	Refer to label for application instructions. **Effective against larvae**
1A	**H** - Probably 4-8 weeks residual.	Methiocarb	Mesurol	Registered against fungus gnats on ornamental crops.	C, I	None	Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. Refer to label for application instructions. **Effective against larvae.**

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

1. https://portal.apvma.gov.au/pubcris
2. **Mode of Action: C = contact; S = systemic; I = ingestion; T = translaminar; V = vapour**.
3. In the context of the table, beneficials refers to *G. aculeifer*, *S. scimitus*, *D. coriaria* and *S. feltiae*. Summarised primarily from *The Good Bug Book* 16, http://www.koppert.com/,
4. For the production nursery full list of minor use permits https://nurseryproductionfms.com.au/minor-use-permits-mups-for-pesticides/

Taken from: Manners, A, n.d., 'Fungus gnat pest management plan for production nurseries', Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

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/
2. IPM in Ornamentals = Integrated Pest Management in Ornamentals Information Guide - http://era.daf.qld.gov.au/id/eprint/2208/
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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