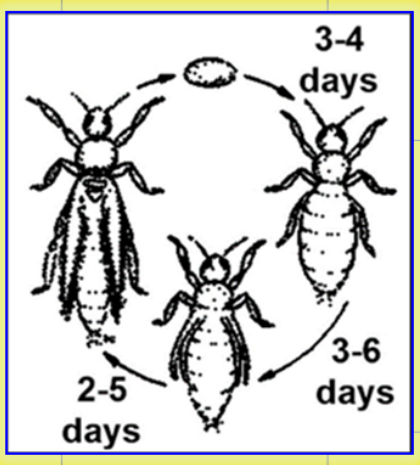
Integrated Pest Management Strategy

Western flower thrips (WFT) *(Frankliniella occidentalis)*

Adults WFT 1.5-2mm long. Image from: Jack T. Reed, Mississippi State University, Bugwood.org



WFT lifecycle Image courtesy of QDAF

WFT is a vector of TSWV. Characteristic ring lesions produced by tospovirus Image from: Elizabeth Bush, Virginia Tech, Bugwood.org)

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

- Blue sticky traps for adults
- Plant beating
- Keep records for future reference
- Choose intervals for monitoring that suit crop susceptibility and know how to identify WFT
- For further information consult **BioSecure HACCP** guidelines

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Cultural management

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

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Introduce biological controls at first sign of WFT

Biological control

- Cucumeris
- Montdorensis
- Green lacewing
- Hypoaspis
- Dalotia coriaria
- Entomopathogenic
- Orius

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Continue crop monitoring to gauge effectiveness of treatments applied

Chemical controls

- WFT chemical resistance issues are very common
- Toxicity to beneficials?
- Residual?

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Images courtesy of QDAF

Developed by the GIA National Nursery Industry Biosecurity Program Team 2020

Western flower thrips (WFT) *(Frankliniella occidentalis)*

The following information is summarised from [1]Manners, A, n.d., 'Managing western flower thrips in production nurseries' unless otherwise stated.

1. Western flower thrips. Image from: Jack T. Reed, Mississippi State University, Bugwood.org

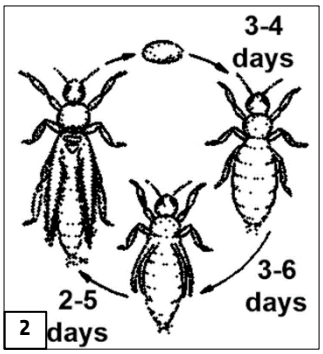
To make best use of this integrated pest management strategy, use the information provided on pest biology and all the management options, and combine those with information on your crop in the **'Integrated pest management plan'** template found at the back of this document. An excel version of the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

Morphological features of WFT

WFT **adults** are slender, cigar-shaped insects, pale yellow to dark brown, ranging between **1.5 - 2 mm**, with males being slightly smaller than females. **Larvae** are very small, ranging from **0.5 - 1 mm**, opaque and wingless. Pupae are largely immobile, non-feeding and are generally around 1 mm.

Life Cycle of WFT

About 70% of the WFT is female, they live up to 5 weeks (at 28°C) and will lay about 200 eggs in their lifetime. Eggs are laid in either foliage or flowers and at 25 - 30°C will hatch within 2 – 4 days. This is followed by two larval instars over a period of 8 – 10 days, the second of which pupates in the soil, on the plant or in crevices. WFT will pupate in the soil if the relative humidity (RH) is 80% or less, and on plants if RH is higher than 80%.



2. WFT lifecycle Image courtesy of QDAF

Damage to plants

WFT attacks a wide range of plant species. Damage to plants includes scarring, wilt and discolouration of growing tips and flower buds. Damage may also be seen as halo spotted dark marks on foliage. WFT is a vector of tomato spotted wilt virus which it contracts during the larval stage of its lifecycle and then spreads throughout the rest of its life.

3. Silver patches and die back from WFT. Image from Smith T.,2015, 'Western Flower Thrips, Management and Tospoviruses', Viewed 28th January 2021, https://ag.umass.edu/greenhouse-floriculture/fact-sheets/western-flower-thrips-management-tospoviruses

Spread of WFT

WFT do not spread via flight at temperatures below 15°C or above 45°C. Flight tends to be mostly in the 20 - 30°C temperature range. Movement of infested plant material or growing media and wind will also spread WFT.

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 is 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 inform management decisions can only be derived from the collection of data through consistent crop monitoring informing site-specific thresholds. To be successful a business must realise the dedication and mindset required for the implementation of IPM (Newman, et. Al. 1999).

IPM requires 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.

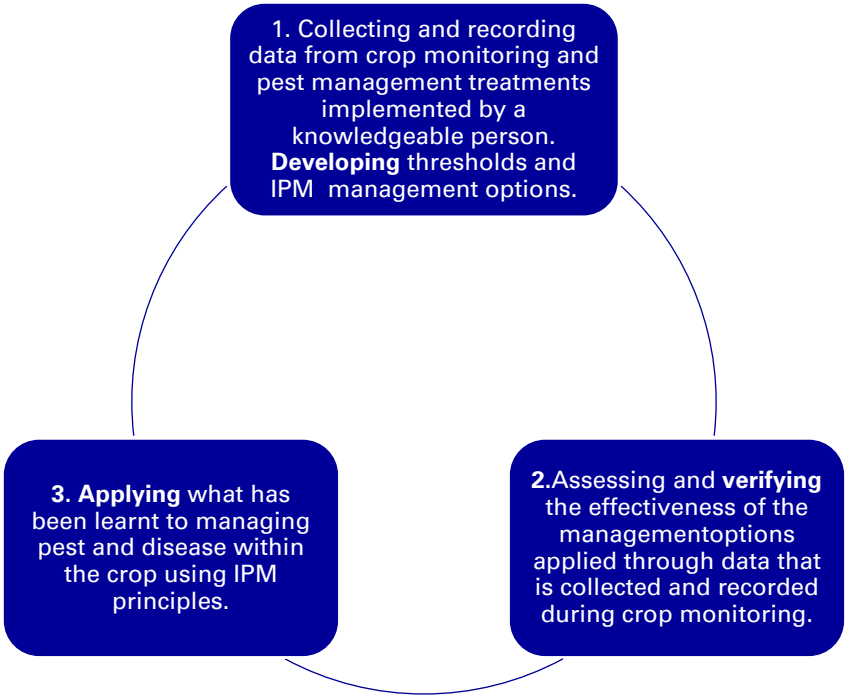
IPM programs centred on crop monitoring programs 'assist growers in the adoption of pest management practices that are more environmentally friendly and safer for workers, consumers and the community at large (Newman, et. Al. 1999)'. Crop monitoring provides the earliest possible indication on pest presence 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.

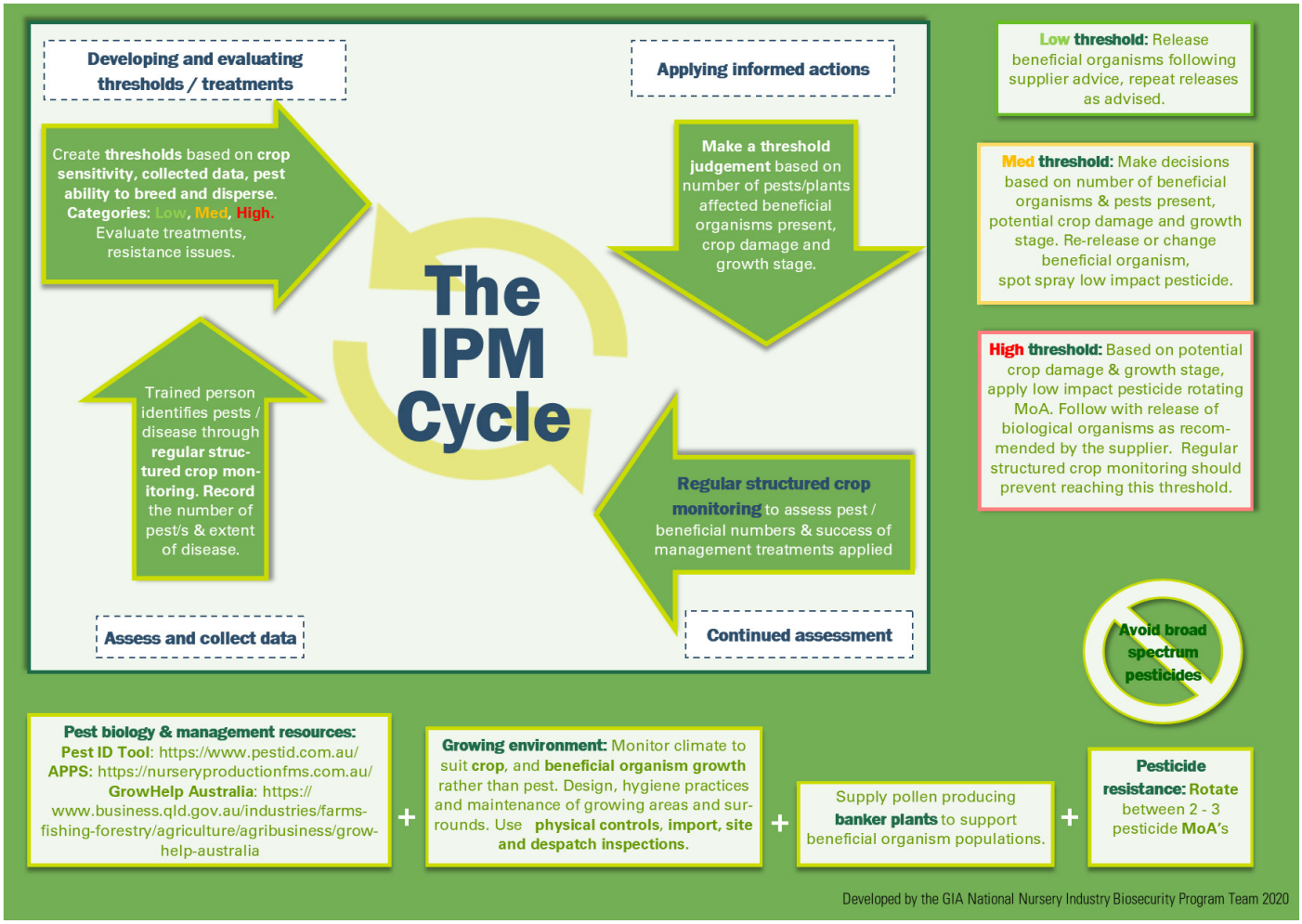
Many studies worldwide on broadacre cropping have found that intercropping to include flower strips or planting nectar-producing plants supports biological control parasites and predators by providing plant-based food, shelter, and alternative prey, increasing their abundance, while pest populations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

Crop monitoring

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

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

- Begin each crop monitoring process in sterile or clean areas or those of high risk, such as propagation facilities or crop hardening off areas, and move progressively into less high-risk areas such as hardened finished crops ready for despatch or known hardy crops.
- Pay close attention to crops around entry ways such as doors, gates, curtains, etc. and along main thoroughfares such as access roads, paths, or laneways.
- Vary the entrance point to the crop monitoring area (1 to 3 m) for each subsequent crop monitoring activity to avoid inspecting the same plants each time.

- Walk at random through the area in a zigzag pattern. Visually inspect plants for abnormal plant growth and pest and disease symptoms or weed growth. Pick up and inspect at least 35 plants from within each plant group selecting those plants that appear less healthy for inspection.
- Thorough visual inspection will include looking for signs of pests and disease on tops and undersides of leaves, flowers, stem, leaf axils, and where appropriate the roots of plants. If problems are identified increase the number of plants inspected from 35 to judge the extent of the pest and disease population.
- Make an estimate of the prevalence of the pest or disease and record this in the crop monitoring record.
- Collect samples of pest and disease if they are not able to be identified immediately, ensuring that samples are stored in a sealed container or plastic bag to prevent spread during the rest of the monitoring.

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

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

Monitoring for WFT

Plant beating and the use of sticky traps are effective means of monitoring for WFT populations. These work well when integrated with general plant inspections while crop monitoring.

Plant beating involves gently hitting foliage over a uniformly coloured (black or white) tray or bucket and checking the tray for insects and mites that are dislodged. Then identifying and counting the number of pests' present using a x10 or x15 hand lens where required and making a record of pest numbers.

Use of sticky traps for monitoring is effective for monitoring populations of flying insects. There are either blue or yellow sticky traps available. Blue is the best for detecting thrips. Place traps out to monitor areas of growing beds, greenhouses or polyhouses using the density of traps per m^2 provided in the following (Greenlife Industry Australia, 2019)

Place sticky traps elevated about 10 cm above the crop, near to entryways such as doors and vents. In unprotected are place on the side of the prevailing wind, vegetative areas, waterways and vegetative waste dumps. Inspect the traps for WFT presence weekly and record findings. Change traps every 1 to 2 weeks dependant on their condition.

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.

'**WFT breeds rapidly and virus transmission is also rapid**. Cultural and biological methods of control should be attempted before opting to use pesticides (Stavisky et al., 2002) (Reitz et al., 2003); (Momol et al., 2004)'. Chemical control is important and widely practised but is constrained by the knowledge on the habits of WFT, and because populations have been found to develop chemical resistance quickly" (CABI invasive species compendium, 2020).

Cultural management of WFT

"Monitoring is a critical component of a successful IPM program" (Liburd, O & Rhodes, E., 2019). This is particularly true for WFT, which can drastically increase in population size within a week during optimal conditions. Cultural management options that will support the management of mites and other insects in the nursery include:

- Train staff to identify thrips. To ensure correct identification of thrips, 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. Screens can be placed over vents and doors to help prevent entry by thrips.
- Quarantining 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 WFT populations.
- Propagate from uninfested material.
- Avoid moving infested plant material within the growing areas.
- Prune / thin plants with light infestations to increase airflow and the penetration of chemicals.
- Grow resistant plant varieties. For example, there are resistant varieties of capsicum, tomato and cucumber.

Biological management of WFT

Biological control organisms are very effective control options for controlling WFT. 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

Cucumeris *(Neoseiulus cucumeris)*

3. Cucumeris adult. Image courtesy of QDAF

Habitat: Lives in plant foliage. Prefer humidity above 65%, eggs will survive at 40% humidity ([3]Biological Services, n.d.).

Feeds on: Mainly larval stages of thrips but also tarsonemid mites and pollen. Bulb mites on leaves, flat mites, spider mites and eriophyid mites are consumed incidentally.

Lifecycle: Complete in about 8-11 days at 20-25°C, adults live for about 3 weeks. Survives but does not develop outside 13°C - 32°C. Like Californicus, Cucumeris feeds on pollen when other sources of food are unavailable, remaining in the crop when pest density is low.

Appearance: Adults about 0.5mm, teardrop shaped similar to Californicus. Moves rapidly along leaf undersides and in flowers ([3]Biological Services, n.d.). Eggs are clear and slightly oval (Llewellyn, R (ed.) 2002).

Application rate: Contact your supplier for application rates for WFT control.

Tips for release: Release at two-week intervals, starting at first sign of pest as preventative when pollen is an available food source. Leave an 8-week gap between spraying crop with synthetic pyrethroids or organophosphates. Not successful on tomatoes or geraniums due to leaf structure and toxic plant exudates (Llewellyn, R (ed.) 2002).

Montdorensis *(Typhlodromips montdorensis)*

4. Montodorensis. Image courtesy of QDAF

Habitat: Plant foliage

Feeds on: Mostly thrips, but also Broad mites and bulb mites present on foliage, whitefly, thrips larvae, other small insects, and mites. Eriophyid mites, flat mites and spider mites may be consumed incidentally.

Lifecycle: Lifecycle is complete in 6-7 days at 25°C (optimum temperature range 20-30°C) and they live for about four weeks. No activity will be noticed at low temperatures i.e., 11°C. Adults can tolerate greenhouse temperatures up to 45°C, but eggs and larvae will perish. Humidity of 70% will ensure a good hatch rate for eggs (Llewellyn, R (ed.) 2002).

Appearance: Adults are small pale pear shaped about 0.6mm long. Eggs are clear and oval, laid on leaf underside or flower sepals (Llewellyn, R (ed.) 2002).

Application rate:

Situation	Release rate	No. of releases	Interval between releases
Preventative	10 - 25/m2	3	2 weeks
Curative	50 -100 mites/ m2	As required	1-2 weeks
Hotspot	100 - 200 mites/ m2	As required	1-2 weeks

Table taken from:[2]Bugs for Bugs, n.d., Montodorensis tech sheet, viewed 3rd December 2020, https://bugsforbugs.com.au/wp-content/uploads/Tech-sheet-Montdorensis-060420.pdf

Tips for release: Sensitive to chemical residues such as synthetic pyrethroids and organophosphates (Llewellyn, R (ed.) 2002).

Green lace wings *(Mallada signata)*

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

Feeds on: Larvae feed on a variety of small insects and their eggs including thrips, 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 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. Trash packages provide larvae with camouflage (Llewellyn, R (ed.) 2002).

5. Green lacewing eggs

6. Green lacewing larvae with trash package

7. Green lacewing adult.
Images 5 – 7 taken from: [2]Australasian Biological control, Green lacewing: Mallada signata, general predator, viewed 8th December 2020,

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). See the table below for rates of release.

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. Banker plants that produce pollen can provide a food source for adults, sustaining populations when pest numbers are low.

Hypoaspis mites *Geolaelaps aculeifer (Hypoaspis aculeifer)*

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

Habitat: Lives in moderately moist soils rich in organic matter. Soil temperatures outside 16-30°C adversely affects survival of the mite.

Feeds on: 'Nymphs and adults feed of 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).

Dalotia coriaria *(Atheta coriaria)*

9. Adult Dalotia: Buglogical Control Systems Inc, n.d., Rove beetle, Viewed 30th November 2020, https://www.buglogical.com/beetles/rove-beetle-dalotia-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 thrips larvae and shorefly larvae however prefer fungus gnats. Eggs and small larvae of a wide range of insects are also consumed" (Manners, A., n.d.)

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

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).

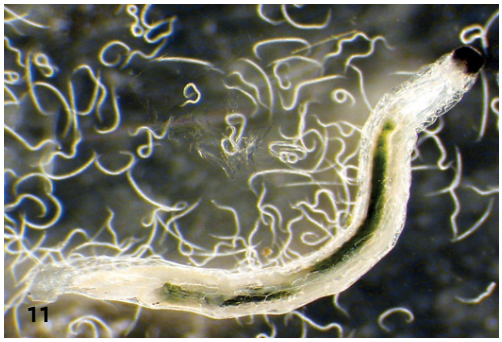
10. Adult Dalotia spp. Eating: Everwood Farm Supply, n.d. DALOTIAforce – rove beetle adults, viewed 30th November 2020, https://www.everwoodfarm.com/Organic_Pest_Control/Beneficial_Insects_Listing/Dalotia/coriaria/DALOTIAforce

Entomopathogenic nematodes *(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)

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.



11. 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

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).

Orius – minute pirate bug *(Orius armatus)*

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

Feeds on: Various species of thrips especially western flower thrips. It will also feed on thrips larvae, aphids, spider mites butterfly and moth eggs and pollen. 'At a temperature of 20°C, Orius can kill about 2 western flower thrips a day, and when the pest population is high, the Orius will kill more thrips than is required for its nutritional needs' (Australasian Biological Control, n.d).

Life cycle: At 25 - 30°C eggs will hatch and develop into an adult within 12 – 18 days. It has 5 larval stages before pupating to become an adult.

Appearance: Predatory bugs that feed mostly on thrips.

13. Orius adult left and nymph right. Image from: Chilman,L. 2012, Rearing Orius for vegetable industry, Horticulture Australia Ltd.

Application rates: 'The first release of 2-4 Orius per m^2 should be made at early flowering, and then repeated two weeks later. If thrips pressure is high, release between 10-20 Orius per m^2 over the two introductions, depending on thrips numbers. As the season progresses, further releases or top ups in hotspot areas may be required, or in areas adjacent to neighbouring farms which suffer from high thrips infestations' (Biological Services, 2015).

Tips for release: Very sensitive to chemicals. Can be released preventatively if there is adequate pollen to feed on.

Chemical management of WFT

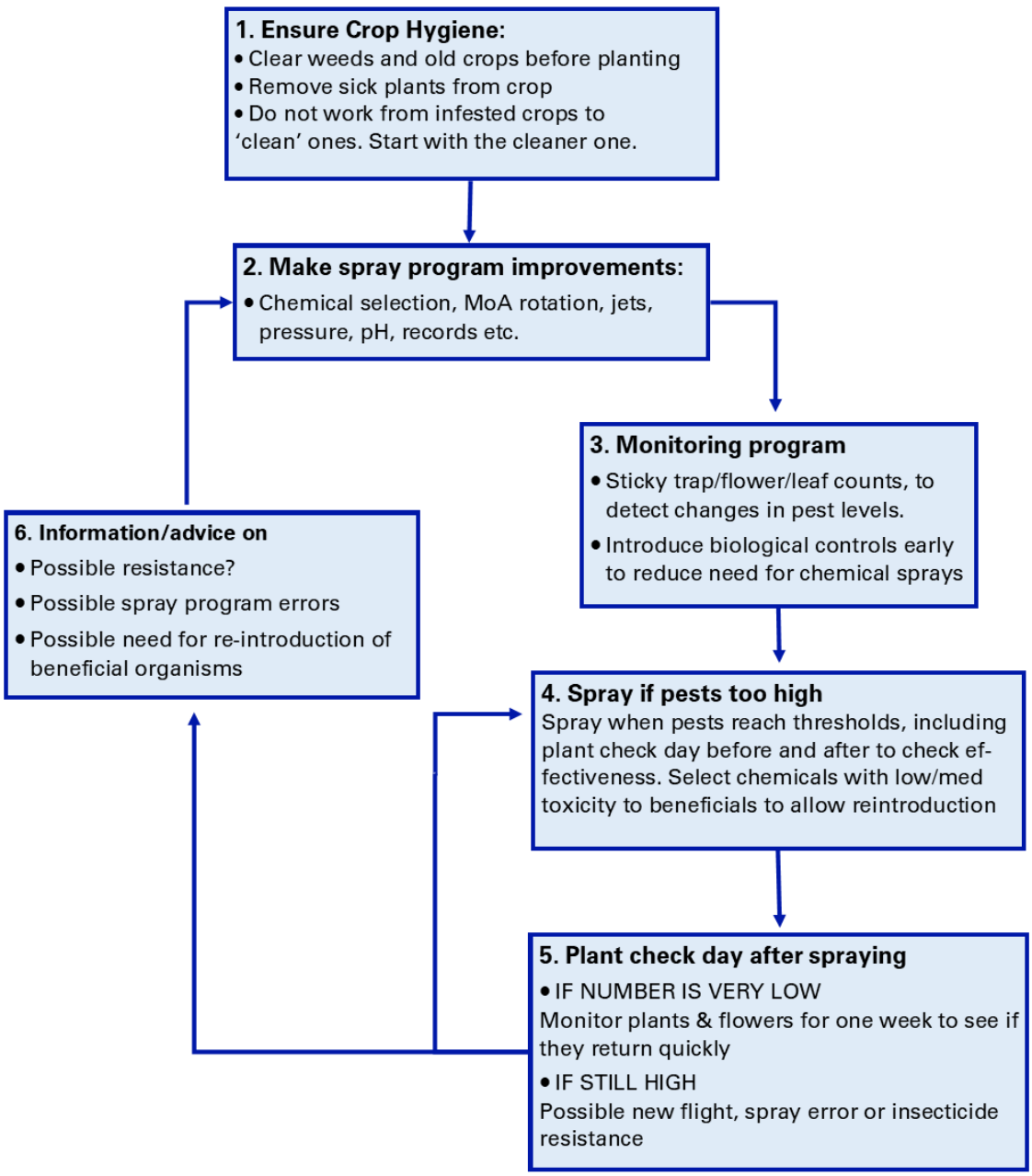
For successful use of chemicals be aware of the following:

- 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), **systemic** (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



Chemical management of WFT

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

Mode of action	Active ingredient	Example	Registration information	Limits on applications per season	Action	Other information	Toxicity to beneficials	Notes on WFT resistance/efficacy against WFT
1B	Acephate	Lancer	PER 12378 for non-bearing ornamental crops, tomatoes and peppers	Do not reapply if the first application does not exert control	C, S		**H** – 8-12 weeks residual	Low level resistance detected
1B	Diazinon	Diazinon	For all thrips species on nursery plants in NSW and Vic, sometimes also in ACT and WA. Also registered against certain thrips on beans, cucurbits, onions, garlic, Tomatoes and bananas.	No limits on label	C, I, V		**M-H** – about 3 weeks residual	Not known in Australia but low to high resistance has been detected overseas
1B	Dimethoate	Dimethoate	PER 13156 on nursery plants and flowers against all thrips species	No limits on label	C, S, I	Registration has been suspended. See the APVMA for further information.	**H** – 8-12 weeks residual	No resistance detected[6]. Not effective in Australian pepper field trials[9].
1B	Fenamiphos	Fenamiphos, Nemacur	For all thrips species in ornamental plants, some labels not registered in Tas.	No limits on label	C, S, I		Unknown, probably high toxicity with a relatively long residual	Not reported.
1B	Maldison	Maldison	Most products are registered for ornamental use against all thrips species, in all states except QLD.	No limits on label	C, S, I		**H** – at least 3 weeks residual.	Not reported.
1B	Methamidophos	Nitofol	For use on ornamentals against WFT only and all thrips species on gladioli.	No limits on label/permit.	C, S, I	Very toxic to human health.	**H** – at least 3 weeks residual.	Sporadic low to medium resistance when overused[7].
1B	Methidathion	Supracide	For use on ornamentals, trees, shrubs in nurseries, parks, gardens, and forestry situations against all thrips species. PER 10265 on ornamentals (non-bearing) against WFT only.	For quarantine treatments only.	C, I		**H** – 6-8 weeks residual	Sporadic low to high level resistance[7]. Some trials have shown limited efficacy in Australian pepper field trials[9].
2B	Fipronil	Regent	PER 9929 only allows for use as a quarantine treatment of ornamental nursery stock. All thrips species allowed.	For quarantine treatments only.	C, S, I	Do not handle plants for 48 hours following application.	**H** – at least 1 week residual	Low level resistance[6].
3A	Pyrethrins and piperonyl butoxide	S-Py, Py-Bo	For all ornamentals against all thrips species.	No limits on label	C		**H** – at least 4 weeks residual	Widespread high-level resistance to pyrethroids; not recommended against WFT[6], [15].
4A	Acetamiprid	Crown 58558	Registered against plague thrips and greenhouse thrips on ornamental plants.	No limits on label	C, I, S, T	Do not use against WFT. Identify thrips species before use.	**H** – 6-7 weeks residual	No resistance detected[6].
4A	Imidacloprid	Confidor, Spectrum	Only registered against greenhouse thrips on ornamental plants as a foliar spray only. Not all products are registered for greenhouse	No limits on label	C, I, S		**H** – 2-4 weeks residual as a foliar spray; L toxicity as a soil drench.	Not reported but has been shown to be ineffective in

Mode of action	Active ingredient	Example	Registration information	Limits on applications per season	Action	Other information	Toxicity to beneficials	Notes on WFT resistance/efficacy against WFT
			thrips on ornamental crops.					Australian pepper field trials[9].
5	Spinetoram	Success neo	For all ornamentals against WFT only.	Make 3 consecutive sprays 3-5 days apart (6-12 days apart less than 20°C) then switch to a different product from another chemical group.	C, I		Unknown – probably moderate toxicity with low residual.	Not reported in Australia but strong spinosad cross resistance highly likely[13].
5	Spinosad	Success2	Ornamental registration against WFT.	No more than 3 consecutive applications.	C, I	Make 3 consecutive applications at various intervals dependent on temperature. See label for details.	**M** – 1-week residual.	High level resistance[6]
6	Abamectin	Vantal 18 EW	For ornamental use, including roses, chrysanthemums, carnations and indoor foliage plants against WFT, also many vegetables registered. Can only be used against melon thrips for interstate quarantine requirements	No more than 2 times per season.	T, I	Test for phytotoxicity on plants that have not been sprayed with this product previously. Do not use on ferns or Shasta.	**M** – 1-2-week residual	Low level resistance[6]. Not effective in Australian pepper field trials[9].
NA	Fatty acids – K salts	Natrasoap, bugguard	For all thrips species in ornamental plants, indoor and outdoor.	No limits on permit.	C	Do not apply during hot part of the day. May not be suitable for delicate ferns, mosses, flowers and plants under stress.	**M-H** – no residual.	Not reported but, not effective in Australian pepper field trials[9]

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., 'Managing western flower thrips in production nurseries' Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

The following table lists chemicals registered for specific crops. The chemicals listed here have no general 'ornamental' permit or registration.

Mode of action	Active ingredient	Example	Registration information	Limits on applications per season	Action	Other information	Toxicity to beneficials	Notes on WFT resistance/efficacy against WFT
1B	Omethoate	Folimat	For use on carnations, chrysanthemums, pelargoniums, roses, callistemons, *Eucalyptus* spp., *Grevillea* spp., paperbarks, wattles and onions against all thrips species.	No limits on label	C, S, I		**H** – 8-12 weeks residual.	Not reported
1B	Phorate	Thimet, Umet, Zeemet	For all thrips species on carnations, chrysanthemums, dahlias, lily bulbs, azaleas, roses and other woody ornamentals, cabbage, broccoli, cauliflower, Brussel sprouts, carrots, onions and potatoes in all states. Tomatoes in NSW, Qld, WA, SA, Vic and Tas only.	No limits on label. Soil drench only.	S		Unknown, probably high toxicity with long residual.	Not reported
1B	Chlorpyrifos	David Grays Chlorpyrifos	Registered against certain thrips species on bananas and citrus.	No limit on label	C, I, V		**H** – 6-8 week residual	Low level resistance[6]. Not effective in Australian pepper field trials[9].
1B	Disulfoton	Disulfoton	For all thrips species but only on bulbs and gladioli		S		Unknown, probably high toxicity with long residual, perhaps 6-8 weeks.	Not reported
3A	Beta-cyfluthrin	Prolong,	Registered for all thrips species on azaleas, hibiscus, pelargoniums and roses.	No limits on label	C, I	Unknown – probably high toxicity with at least 4 weeks residual	Unknown – probably high toxicity with at least 4 weeks residual	Widespread high level resistance to pyrethroids; not recommended against 3A Bifenthrin Bifenthrin, WFT[6], [15].
3A	Bifenthrin	Bifenthrin, WFT 24, 28. Fivestar	Most products registered against *Thrips imagines*, *T. simplex* and *T. hawaiiensis* on roses, carnations and other ornamental plants. Some products registered against other thrips species, e.g. *T. florum*.	No limits on label	C, I	Not registered for WFT	**H** – 8-12 week residual	
3A	Tau-Fluvalinate	Mavrik	Against plague thrips only, on apples, cherries, nectarines, peaches, plums and grapes in Qld, NSW, Vic, SA and WA only.	Apply a maximum of two consecutive sprays	C, I		**H** – probably at least 4 weeks residual.	
4A/28	Thiamethoxam and Chlorantraniliprole	Durivo	No ornamental registration, but may be applied against WFT on the seedlings of a variety of brassica, fruiting vegetables and leafy vegetables	1 per crop	C, I, S	Final volume must be sufficient to wash product into the seedling root ball but not cause runoff or leaching from seedling cells.	Unknown, probably moderate toxicity and residual.	No resistance detected for thiamethoxam[6].
23	Spirotetramat	Movento	Registered against WFT and tomato thrips (*F. schultzei*) on green beans; WFT only on eggplant, eggplant, Peppers and tomatoes; onion thrips on onions; Kelly's citrus thrips on citrus.	2-3 applications per crop, dependent on plant species.	I, T, S	Refer to label for each plant species. Not effective against adults in Australian pepper field trials 26.	Unknown – probably moderate toxicity with low residual activity.	Not found, despite test[9].

Mode of action	Active ingredient	Example	Registration information	Limits on applications per season	Action	Other information	Toxicity to beneficials	Notes on WFT resistance/efficacy against WFT
NA	Paraffinic oil	Bioclear, Trump	Registered for asparagus, beet, cucurbits, radish, squash, azalea, begonia, camellia, chrysanthemum, crown of thorns, diffenbachia, easter lilly, fern, gardenia, hibiscus foliage, jade plant, palm, philodendron, poinsettia reiger begonia and zinnias in all states. Beans, tomatoes, corn, and peppers are also registered in all states except Qld. All registrations are against all thrips species.	No limits but only once per week.	C	Do not apply to plants in direct sunlight behind glass. Do not use on coconut palms and maidenhair ferns or chrysanthemum blooms. Test on a small number of plants for phytotoxicity prior to using in a widespread manner.	Unknown – probably moderate toxicity with no residual effect.	Not reported.
NA	Petroleum oils	Biocover	Registered for asparagus, beet, cucurbits, radish, squash, azalea, begonia, camellia, chrysanthemum, crown of thorns, diffenbachia, easter lilly, fern, gardenia, hibiscus foliage, jade plant, palm, philodendron, poinsettia reiger begonia and zinnias in all states. Beans, tomatoes, corn, and peppers are also registered in all states except Qld. All registrations are against all thrips species.	No limits but only once per week.	C	Do not apply to plants in direct sunlight behind glass. Do not use on coconut palms and maidenhair ferns or chrysanthemum blooms. Test on a small number of plants for phytotoxicity prior to using in a widespread manner.	**M** – no residual.	Not reported.

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., 'Managing western flower thrips in production nurseries' Your Levy at Work: Nursery Production Plant Health and Biosecurity Project.

Information resources

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

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

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

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

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

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

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

Record sheet templates

Videos on how to perform the procedures for the following record sheet templates:

https://nurseryproductionfms.com.au/videos/

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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