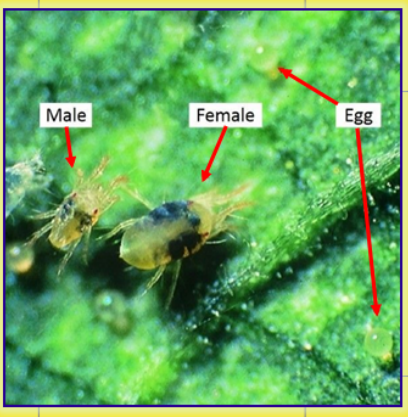
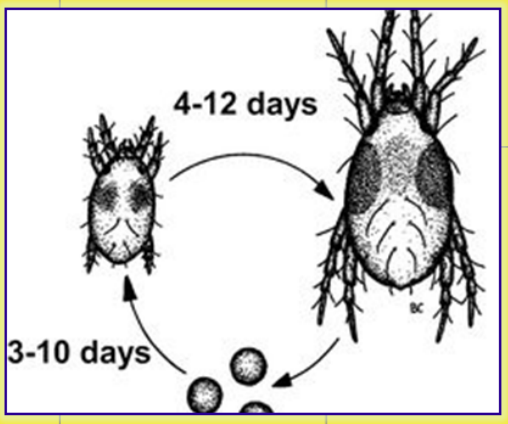
Integrated Pest Management Strategy

Two spotted mite Family Tetranychidae



Adults two spotted mite, male, female & egg



Female two spotted mite adult lays 10 eggs per day

Stippling on leaf surface caused by spider mite and cast of skins ([1]Manners, A., n.d.)

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/

Common mites of production nurseries

- Two spotted mite & other spider mites (most common)
- Broad mites and cyclamen mites
- Flat mites
- Eriophyid mites
- Astigmatid mites

Crop monitoring

- Crop monitor regularly looking for signs of damage / presence
- Plant beating method most effective for spider mite ID requires a x10 or x15 hand lens
- Microscopic examination of growing tips / bulbs for all other mites
- Keep records for future reference
- For further information consult BioSecure HACCP guidelines

Cultural management

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

Introduce biological controls at first sign of mites

Predator	Mite controlled
Californicus	Spider, Broad & cyclamen mites
Cucumeris	Broad, cyclamen mites
Killer mite	Bulb mites
Montdorensis	Broad & Cyclamen mites
Occidentalis	Spider mites
Persimilis	Spider mites

Continue crop monitoring to gauge effectiveness of treatments applied

Chemical controls

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

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Images courtesy of QDAF

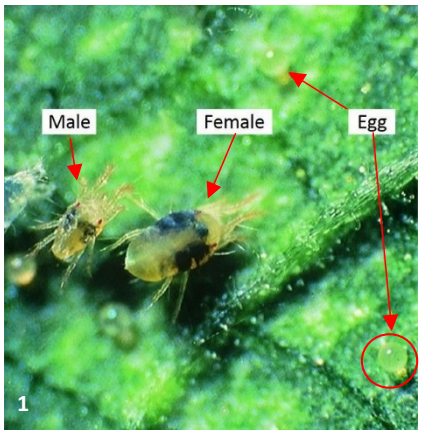
Developed by the GIA National Nursery Industry Biosecurity Program Team 2020

Herbivorous Mites: Spider mites (Family *Tetranychidae*)**, Tarsonemid mites, Flat** mites (Family *Tenuipalpidae*)**, Eriophyid mites** (Family *Eriophydae*)**, Astigmatid mites including bulb mites.**

Spider mites (Family *Tetranychidae*)

The following information is summarised from [1]Manners, A, n.d., *'Herbivorous mites A 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/



1. Male and female adult two spotted spider mite with egg. Image courtesy of QDAF

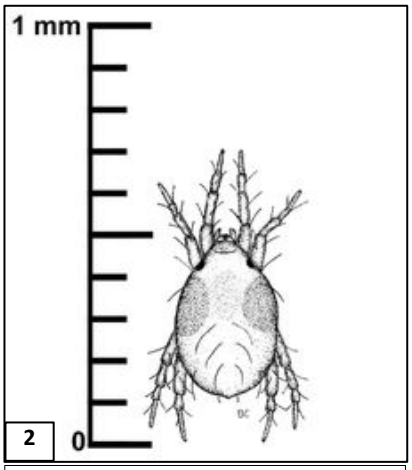
Morphological features

Spider mites are the most common pest mite of plants. They are called spider mites because they can produce silk. All species of spider mite feed on plants. Two-spotted mite (TSM) *(Tetranychus urticae)* is the most well known of the spider mites. Microscopic examination is needed to tell spider mite species apart.

Eggs are 0.14mm (not visible to the naked eye) in diameter, globular transparent when laid turning to opaque pale yellowish white.

Larva has **6 legs**, is pale yellowish white and oval shaped, two dark spots appear on the abdomen of TSM as they feed. Larvae then develop into an **8-legged** nymph (Agriculture Victoria, 2020).

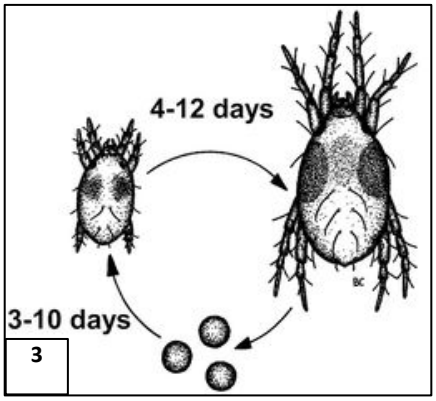
Adult female TSM are about **0.6mm long** oval shaped with a rounded rear and eight legs. Colour varies from light yellow, orange to dark yellow or brown. **Male TSM** are smaller about **0.3mm long** with a more pointed rear. Both male and female have two dark spots on either side of their body, long needle like mouthparts and two red eyes (Agriculture Victoria, 2020) ([1]Biological, Services 2015). Adults can be seen with a x10 hand lens (QDAF, 2017).



2. Two spotted mite size scale. Image courtesy of QDAF

Life Cycle of TSM

Development from egg to adult in optimal conditions takes1-2 weeks with female spider mites laying about 10 eggs per day. These hatch within 3 – 10 days dependant on temperature. Six-legged nymphs hatch from the eggs and moult twice eventually becoming and 8-legged nymph. The 8-legged nymph then moults to become the adult mite. Adults may live for 3 weeks or more ([2]Manners, A., n.d.). **Populations increase rapidly in hot dry weather** (QDAF, 2017).



3. Two-spotted mite lifecycle. Image courtesy of QDAF

Damage to plants

TSM has a wide host range. Look for tiny yellow/white dots on the upper leaf commonly referred to as **stippling**. Stippling may increase in severity and large irregular greyish regions may appear on the upper leaf surface between leaf veins. **Yellowing** or **bronzing** of the leaf may also occur as well as leaf and stem death. In large infestations **silk** can be seen covering the plant.

4. Spider mite webbing. Images courtesy of QDAF

5. Stippling from spider mite damage. Images courtesy of QDAF

Spread of TSM

TSM are easily spread via wind, by staff as they brush against plants, on tools and by crawling from plant to plant.

Tarsonemid mites: Broad mites *(Polyphagotarsonemus latus)* **and Cyclamen mites** (*Phytonemus pallidus)*

Morphological features

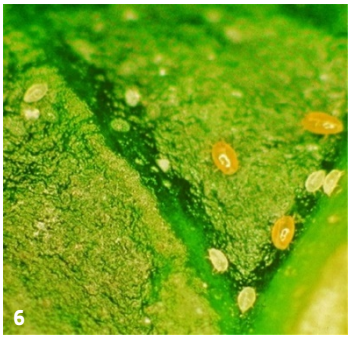
Tarsonemid mites are microscopic in size being about **0.1-0.3mm long**, requiring a microscope to be identified accurately.

Broad mite eggs are a dome like shape with flat base and a distinct **polka-dot** structure pattern on top. **Cyclamen mite eggs** are smooth opaque and oval shaped. Both are found on the underside of leaves.

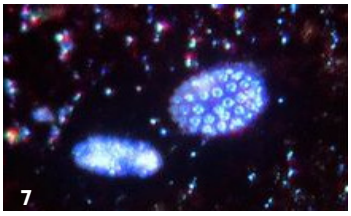
Larvae of both have 6 legs, are whiteish in colour and appear pointed at the back of the body.

Broad mite adult females are oval shaped, light brown to deep amber or dark green in colour. Males are smaller than females, with longer hind legs ([1]Biological Services, 2015), opaque developing to a light brown or amber colour.

Cyclamen mite adults are oval shaped, yellow to brown (Cloyd, R. A., 2010) about 0.2mm in size (Bessin, R., n.d.).



6. Broad mite nymphs and adults Images courtesy of QDAF



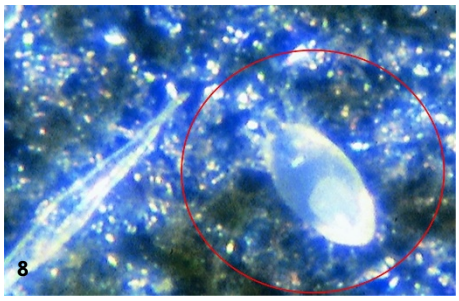
7. Broad mite egg. Image courtesy of QDAF

Life cycle of Tarsonemid Mites

Generally made up of three life stages, although the nymph stage tends not to occur. This contributes to a very quick lifecycle which can be completed in a week or less at moderate temperatures.

For **broad mites** females lay between 1-5 eggs per day over a period of about 1 – 2 weeks. At 15 °C completion of the life cycle will take about 2 weeks, at **30 °C** the **complete cycle** can be reduced **to 4 days**.

For **cyclamen mites** the lifecycle can take a little longer. At 15 °C completion of the life cycle will take about 20 days, taking while at **30°C** it takes **6 days**.



8. Cyclamen mite adult

Damage to plants

Broad mites typically **damage younger leaves** and **growing tips**. Leaves will not expand properly and will appear **wrinkly and small**. Flowers become distorted with discoloured rays. Broad mite damage is commonly mistaken for virus infection. Broad mites have a wide host range.

9. Broad mite damage

Cyclamen mites cause damage to **young leaves and flowers**, however, tend to feed on the upper leaf surface rather than the lower. Leaves can become **curled, deformed**, and **twisted,** failing to expand normally. Some plants will have bronzed patches along the midrib with deformed flowers.

Spread of Tarsonemid mites

Tarsonemid mites are easily spread via **wind**, by **staff** as they brush against plants, on **tools** and by crawling from plant to plant. They have also been known to hitchhike on whitefly species such as silverleaf whitefly and glasshouse whitefly.

10. Cyclamen mite damage. Images 8-10 courtesy of QDAF

Flat Mites (Family *Tenuipalpidae*)

Known vectors of Citrus leprosis virus and Orchid fleck virus, flat mites tend to be flat and orange to red in colour. Some species are large enough to see with a x10 hand lens with others requiring a microscope to see.

Flat mite eggs are **oval shaped** and often **orange to red** in colour.

Larvae and nymphs are light orange in colour with colouration becoming darker at each moulting.

Adult flat mites range in size from **0.02 – 0.4mm** in length.

11. Flat mite Brevipalpus spp on dandelion: Berger, J., n.d., Image number 5435382, viewed 1st December 2020, *https://www.insectimages.org/browse/detail.cfm?imgnum=5435382#*

Life cycle of flat mites

Similar to the TSM, flat mites go through four stages of development. Development from egg to adult is complete within 3 – 4 weeks, with adult females laying about 1 egg per day. Adults may live for up to 2 months.

Damage to plants

Flat mites have a **wide host range**.

Symptoms of damage from flat mite includes **stippling** of leaves similar to TSM with the addition of a **brown discolouration** along the sides of the leaf midrib, leaf cupping, leaf drop, **distorted new growth**, small deformed leaves, corky stems and necrotic lesions on stems.

Spread of Flat mites

Being slow moving flat mites that spread via crawling spread over short distances, they are also likely spread via the wind and movement of infested material.

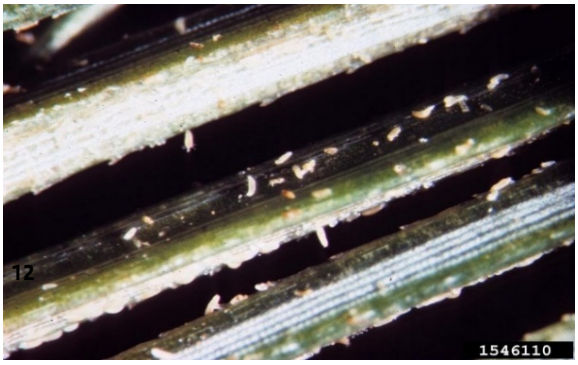
Eriophyid mites (Family *Eriophydae*)

Morphological features

Very small in size **eriophyid mites** are generally **0.1mm – 0.2mm long**. A microscope is required to observe them properly.

Eggs are white or opaque in colour and oval.

Nymphs and adults are different in appearance to other mites, eriophyid mites are long and tubular, white to grey in colour, with four legs throughout all stages of their lifecycle.



12. Eriophyid mites on cedar. Boone, A. J., n.d., Image number 1546110, viewed 1st December 2020 https://www.insectimages.org/browse/detail.cfm?imgnum=1546110

Life cycle

Development from egg, to larvae to nymph to adult is complete within about **a week at 25°C**. Adult females lay up to 3 eggs per day and can live for up to one month.

Damage to plants

Damage to plants varies dependant on the species of eriophyid mite. Eriophyid mites feed on expanded leaves, young leaves, growing tips, flower buds or fruit.

Symptoms of damage can include: **Galls**, masses of **unusual plant growth**, small and deformed leaves, short petioles and internode length, bud distortion, stunting or russeting.

Spread of Eriophyid mites

Spread via the **wind** and **other organisms** such as insects and birds, movement of infested material is commonly the cause of dispersal of Eriophyid mites.

15. Eriophyid mite damage on Bougainvillia- pest (mManners. A., n.d.)

Eriophyid mite damage: galls on black cherry . Taken from: Lacy L. Hyche, Auburn University, Bugwood.org, https://www.insectimages.org/browse/detail.cfm?imgnum=1540903

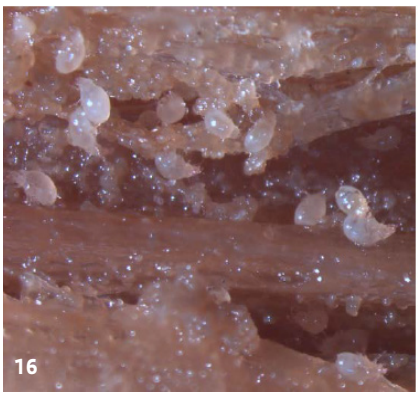
13. Russeting due to eriophyid mite. Csoka, G., n.d., Image 5444390, Viewed 1st December 2020, https://www.insectimages.org/browse/detail.cfm?imgnum=5444390

Astigmatid mites including bulb mites

Morphological features

This group of mites damage bulbs, roots and foliage of plants. Medium sized they range from **0.3 – 0.9 mm** long so can be seen with a hand lens.

Astigmatid mites have four life stages, egg, larvae, nymphal, and adult stages. Adults are slow moving, generally pale whitish to brown, soft bodied, elongated oval shaped.



16. Mites in internal plant tissue (Manners, A., n.d.)

Life Cycle

Life cycle of Astigmatid mites is usually complete from **1 – 3 weeks** with optimal temperature for development being **30°C**. Temperatures below 10°C will halt development.

Damage to Plants

Look for **dark brown streaks on bulbs**, growing tips and roots along with distorted leaves. Whole bulbs can become rotten quickly. Astigmatid mites may also be a vector for *Fusarium*, *Verticillium* and *Pythium* spp.

Spread of Astigmatid mites

Astigmatid mites attach themselves to other insects during unfavourable conditions.

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

What is IPM?

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

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

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

Why IPM works

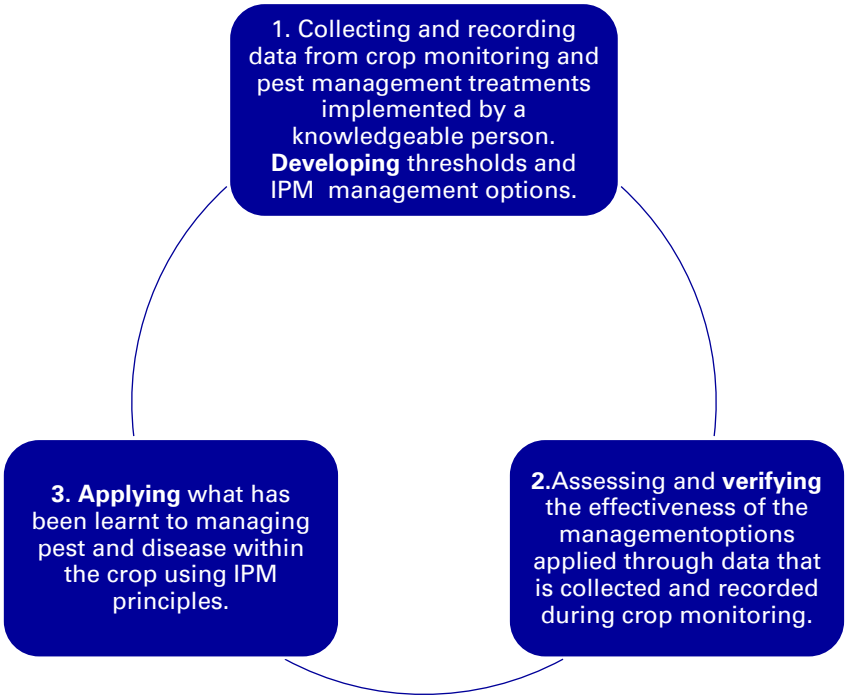
At the centre of any successful IPM program is **structured**, **consistent crop monitoring** (Newman, et. Al. 1999, LeBude, A.V., et. al, 2012)). Consistent monitoring means that the crop monitoring is performed on a schedule that suits the crop age and type. If you are producing seedlings then this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

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

Elements of a good IPM system

A systematic approach

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



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

Communication and information

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

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

Biological control options

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

Physical control

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

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

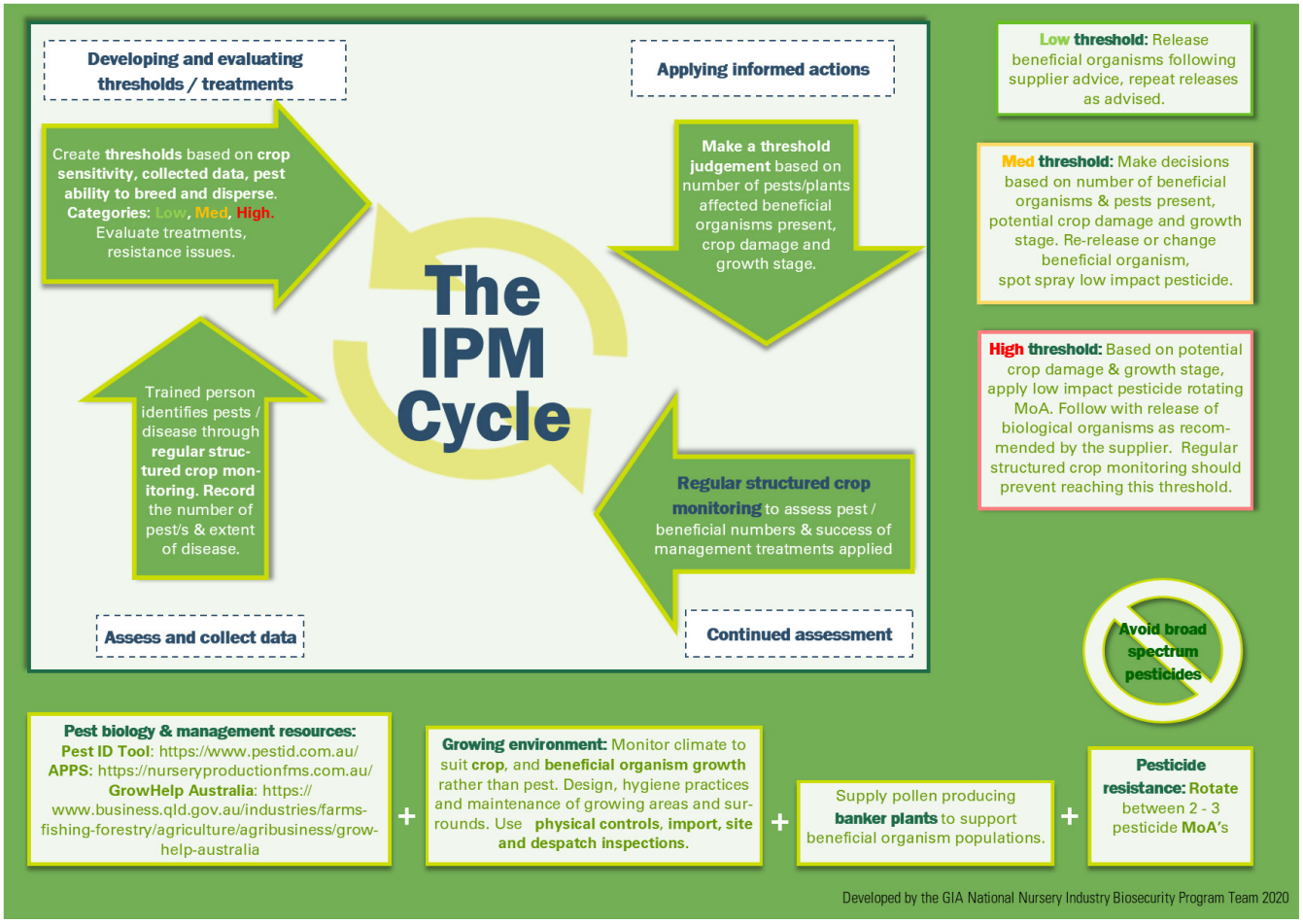
Many studies worldwide on broadacre cropping have found that intercropping to include flower strips or planting nectar-producing plants supports biological control parasites and predators by providing plant-based food, shelter, and alternative prey, increasing their abundance, while pest populations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

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 with 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:	September to May

Trees and shrubs. Palms. Indoor / houseplants. Ornamental grasses. Succulents.	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 TSM

Plant beating is the best method for detection of TSM. Plant beating involves gently hitting foliage over a uniformly coloured (black or white) tray or bucket and checking the tray for insects and mites that are dislodged. Then identifying and counting the number of pests' present using a x10-15 hand lens where required.

Monitoring for Tarsonemid mites

Difficult to detect before damage has occurred. Where practical and when damage indicates their possible presence, remove a growing tip and observe under a microscope or use a x 20 hand lens.

Monitoring for Flat mites

Larger of the species may be observed without magnification. For smaller species plant beating as described for TSM is effectively used along with examination under a microscope.

Monitoring for Eriophyid mites

Difficult to detect before damage has occurred. Where practical remove a growing tip or flower buds and observe under a microscope. Pull apart buds for examination using forceps.

Monitoring for Astigmatid mites

If signs of damage are found, investigate further by examining the bulb or root material free of growing media under a microscope.

Cultural management of mites

"Monitoring is a critical component of a successful IPM program" (Liburd, O & Rhodes, E., 2019). This is particularly true for mites, 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:

- Training staff to identify mites, especially the most common TSM and broad mites. To ensure correct identification, make use of professional diagnostic services such as Grow Help Australia https://www.business.qld.gov.au/industries/farms-fishing-forestry/agriculture/agribusiness/grow-help-australia.

- Identify infestations through regular structured monitoring. Early identification and treatment are the key to success for controlling any pest or disease.
- Excluding populations from greenhouses with insect proof glasshouses/tunnels particularly for susceptible crops.
- Quarantining incoming stock and inspecting for signs of infestation prior to moving the stock into production areas.
- Throw out or quarantine highly 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 of mites. This is enabled by frequent crop monitoring to inform pesticide usage.
- Overhead watering can assist in creating a more humid environment which is less favoured by mites.
- Control weeds around the nursery as they will harbour mite populations.
- Propagate from uninfested material. In some cases, this means that propagation material should be examined under a microscope before use for the presence of smaller mite species.
- For crops that have been found infested with Tarsonemid or Eriophyid mites, remove growing tips before spraying. This will remove some of the population as well as the emerging damaged growth.

Biological management of mites

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

Californicus (*Neoseiulus californicus*)

17. Californicus top, TSM bottom. Image courtesy of QDAF

Habitat: Lives in plant foliage. Tolerates warm conditions up to 35 °C, surviving short periods of up to 40°C and freezing temperatures. Prefers humid conditions (40-80% humidity) ([1]Bugs for Bugs, 2015) but is still effective at lower humidity. Feeds on pollen when other sources of food are unavailable, remaining in the crop when pest mite density is low.

Feeds on: Spider mites (all stages) and tarsonemid mites.

Lifecycle: Faster than spider mite species. Full lifecycle including 6-legged larval and 8-legged nymphal stage is complete in 4 – 10 days ([2]Biological Services, 2015).

Appearance: Adults are less than 1mm long, pear shaped, light brown or tan, with males slightly smaller and darker. Eggs are larger than those of spider mites, hatching after 1-2 days. Larvae are 6-legged with nymphs and adults 8-legged ([2]Biological Services, 2015).

Application rate:

The below table can be used for application rates or refer to your supplier.

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

Table from: [1]Bugs for Bugs, 2015., Californicus, viewed 3rd December 2020, https://bugsforbugs.com.au/product/californicus/

Tips for release: Can tolerate pesticide residue better than other predatory mites. Best used at first sign of pest mites. "Californicus establishes quickly and can outperform Persimilis in hot dry conditions" (Bugs for Bugs, 2015). Follow supplier directions for release, can be released as a preventative. Banker plants can assist to keep adult populations within the crop by providing pollen as an alternative food source.

Cucumeris *(Neoseiulus cucumeris)*

18. 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.). Survives but does not develop outside 13°C - 32°C.

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

Lifecycle: Complete in about 8-11 days at 20-25°C, adults live for about 3 weeks. Like Californicus, Cucumeris feeds on pollen when other sources of food are unavailable, remaining in the crop when pest mites 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, larger than those TSM (Llewellyn, R (ed.) 2002).

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

Tips for release: Not successful on tomatoes or geraniums due to leaf structure and toxic plant exudates. 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 (Llewellyn, R (ed.) 2002). Banker plants can assist to keep adult populations within the crop by providing pollen as an alternative food source.

Killer mite (*Geolaelaps* (*Hypoaspis*) *aculeifer*)

19. Killer mite Taken from: (Manners, A., n.d.)

Habitat: Soil dwelling predatory mite. Temperatures outside of 10-30°C are detrimental to the survival and activity of the Killer mite.

Feeds on: Nymphs and adults feed on bulb mites, thrips pupae and other soil dwelling organisms. Adults will dig up to 100mm into the soil making them good predators of bulb mites ([4]Biological Services, 2015).

Lifecycle: Lifecycle is complete in about 12 days at 27°C but can be up to 40 days at 16°C.

Appearance: About 1mm in length, brown to orange in colour.

Application rate: '1 litre of mix (30,000mites) will cover 40-100m^2 of seedlings or cuttings at propagation, 200-300m^2 of bedding plants or 400-600 x 150mm pots preventatively. Higher rates are required if bulb mites are already present. Repeat application in two weeks ([4]Biological Services, 2015)'. Or refer to your supplier.

Tips for release: Best used at first sign of pest mites. Can be applied to bulbs before planting with a follow up treatment two weeks later ([4]Biological Services, 2015.)

Montdorensis *(Typhlodromips montdorensis)*

20. 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, 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).

Occidentalis *(Typhlodromus occidentalis)*

21. Adult Occidentalis and TSM. Image courtesy of QDAF

Habitat: Above ground plant parts. Optimal temperatures are between 20 - 32°C, tolerating temperatures above 40°C and also very low temperatures where mites will become less active or hibernate.

Feeds on: Spider mites including TSM (Llewellyn, R (ed.) 2002).

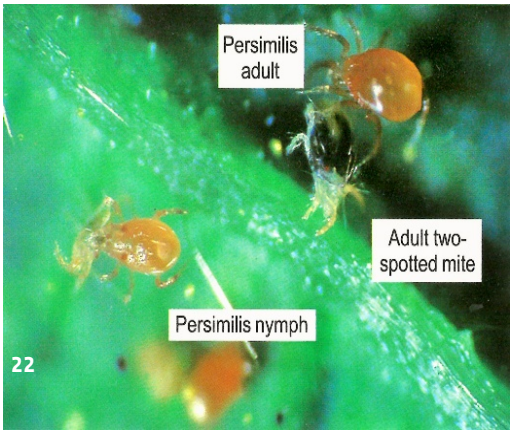
Lifecycle: Lifecycle can be complete in as little as 7-8 days at temperatures of 27-32°C. Eggs are larger than TSM eggs and oval shaped rather than round (Llewellyn, R (ed.) 2002).

Appearance: Adults off-white, pear shaped and about 0.6mm in length (Similar to TSM). Eggs are larger TSM eggs and oval shaped rather than round (Llewellyn, R (ed.) 2002).

Application rate: 25,000mites per ha, re-release in two to four weeks ([5]Biological Services, 2015).

Tips for release: "Tolerates many organophosphate chemicals and is resistant to azinphos-methyl. Miticides such as Apollo, Acramite, Calibre, Omite, Unimite, Torque and Pyranica are relatively safe to use at IPM rates" ([5]Biological Services, 2015).

Persimilis *(Phytoseiulus persimilis)*



22. Persimilis adult and nymph. Image courtesy of QDAF

Habitat: Warm semi-shaded conditions on above ground parts of plants. Temperatures of 20-30°C and humidity greater than 60% are optimal for development.

Feeds on: Two-spotted mite / spider mites. Will disperse or die when TSM populations have declined.

Lifecycle: Lifecycle at 20°C takes about 7 days compared with 15 days for spider mites.

Appearance: Adults are deep orange to red, pear shaped, about 0.5mm long. Younger stages are clear. Eggs are orange-tinged, oval, and twice as large as TSM eggs (Llewellyn, R (ed.) 2002).

Application rate:

Situation	Release rate	No. of releases	Interval between releases
Protected crops	3 – 10 mites / m2	1 - 2	1 - 2 weeks
Hotspot treatments	20 - 50 mites/ m2	As required	1 week

[3]Bugs for Bugs, 2015, Persimilis, viewed 3rd December 2020, https://bugsforbugs.com.au/product/persimilis/

or one pack of 10000 per 200-500m^2 (Llewellyn, R (ed.) 2002).

Tips for release:

Plants should be touching to aid spread via crawling. Release at first sign of pest. If synthetic pyrethroids or organophosphates have been used, they will take about 8 weeks to break down enough for introduction of Persimilis. Fungicides are generally low in toxicity to Persimilis except for mancozeb or chlorothalonil. Most compatible miticides for use with Persimilis are bifenazate (Acramite), clofentezine (Apollo), fenbutatin oxide (Torque) and hexythiazox (Calibre) ([3]Bugs for Bugs, 2015) (Llewellyn, R (ed.) 2002).

Summary table of biological management options for the control of mites		
Predator name	**Commercial supplier**	**Mite groups managed**
Calfornicus	Biological Services Bugs for Bugs	Spider mites and tarsonemid mites. Flat mites and eriophyid mites consumed incidentally.
Cucumerris	Biological Services	Mainly tarsonemid mites. Bulb mites on leaves, flat mites, spider mites and eriophyid mites consumed incidentally.
Killer mite (Geolaelaps aculeifer)	Biological Services	Bulb mites in growing media only. Bulb mites, flat mites, spider mites and eriophyid mites consumed incidentally.
Montdorensis	Bugs for bugs	Mainly tarsonemid mites. Eriophyid mites, flat mites, spider mites consumed incidentally.
Occidentalis	Biological Services	Spider mites
Persimilis	Biological Services BioWorks Bugs for Bugs	Spider mites

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

Chemical and biological management of mites

Chemical control of mites in production nurseries should be minimised to prevent instances of insect resistance and promote the survival of both natural and introduced beneficial organisms. There are circumstances when this is not possible.

Chemical control of mites would be considered practical in the following situations:

- To control small infestations of about a $50m^2$ in size.
- When pest numbers are very high.
- When climate and environment are not conducive to beneficial insect survival and breeding.
- When infestations are apparent and spray residues already present will counteract the success of beneficial organism release.
- When product is sold and ready for despatch.
- Where other pests can only be controlled with broad spectrum long residual products.

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 mite: **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 (see table below, guide only).

Residual toxicity guide of chemicals to beneficial organisms for the control of mites			
Toxicity	**Very Short residual i.e., product is still wet**	**Short residual (1-2 weeks)**	**Long residual 3+ weeks**
Low	Bifenazate Clofentezine Fenbutatin oxide Hexythiazox	Azadirachtin Oil products	
Moderate	Potassium salts	Propargite Sulphur	
High		Abamectin, Diafenthiuron Emamectin benzoate Milbemectin, Pyridaben Tebufenpyrad	Bifenthrin, Dicofol Etoxazole, Imidacloprid (spray) Lambda-cyhalothrin, Maldison Omethoate, Tau-fluvalinate

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

Two-spotted mite (TSM) and chemical resistance

Worldwide TSM is known as one of the 'most resistant species' of plant pests (IRAC, 2020). **The following MoA pesticide groups have been documented in TSM instances of resistance**:

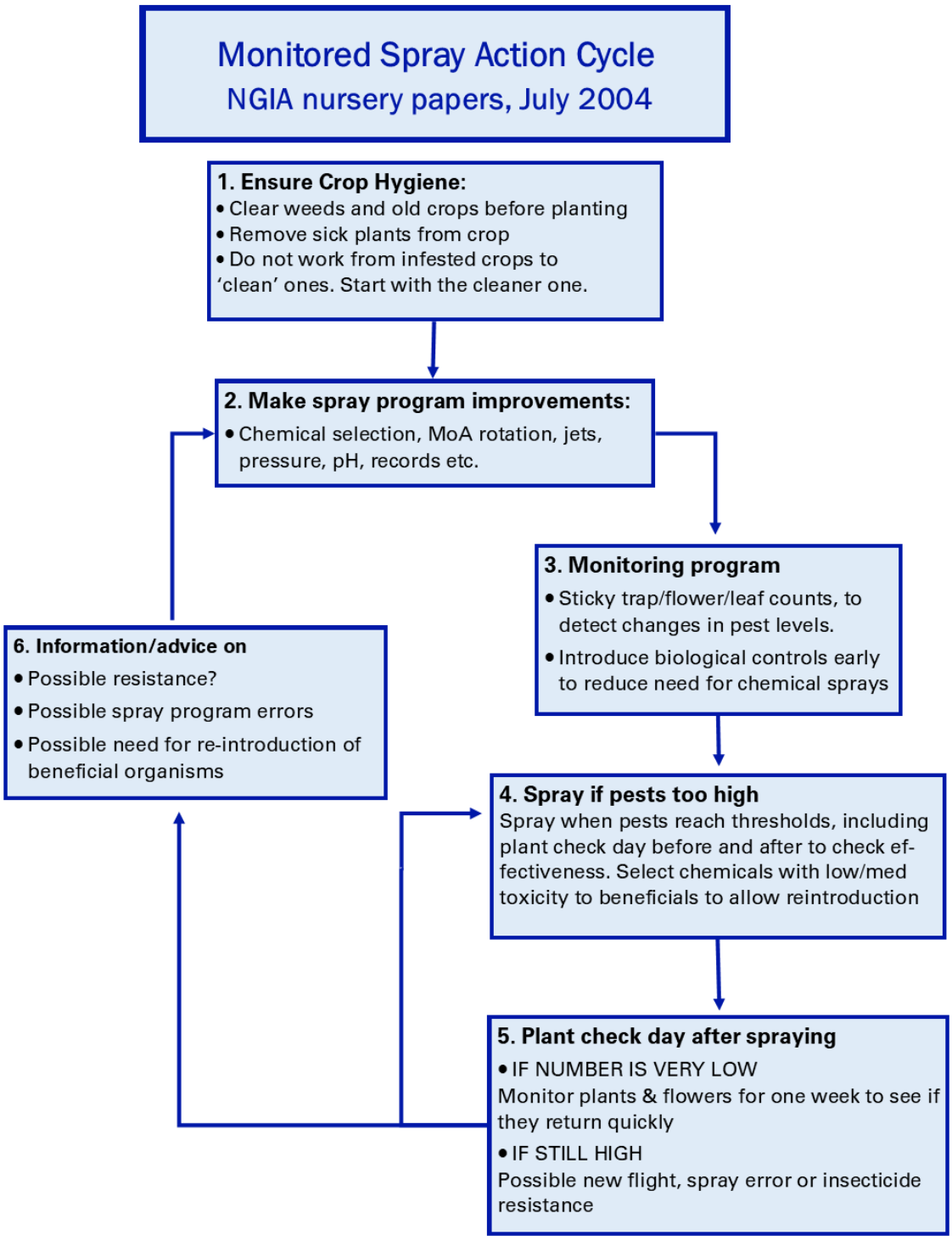
- Carbamates – Group 1A
- Avermectins, Milbemycins – Group 6
- Clofentezine, Hexythiazox, Diflovidazin – Group 10A
- Oganotin miticides – Group 12B
- Acequinocyl – Group 20B
- METI acaricides & insecticides – Group 21A
- Unknown or uncertain MoAs – Group UN (IRAC, 2020)

The following table provides guidance on biological management of TSM, combination chemical and biological management of TSM and chemical only control of TSM.

Management options for TSM			
	Low infestation	**Moderate infestation**	**High infestation**
Biological management	Release persimilis, californicus or occidentalis.	If plants are highly susceptible to damage, refer to combination approach below. Otherwise, release persimilis, californicus or occidentalis but at higher rates.	Refer to combination approach.
Combination	Release persimilis, californicus or occidentalis.	If plants are susceptible to spider mite damage, release persimilis, californicus or occidentalis 3-5 days another application of a low residual pesticide (if possible, apply in combination with an oil product): Bifenazate, Azadirachtin, Group 10A product	As per moderate infestation, however, apply a suitable pesticide, monitor pest populations, apply a pesticide from a different mode of ac on group if populations are still high, then release predators 3-5 days later.
Pesticide management only	If predators are not to be conserved, rotate between: Oil products Group 6 product Group 10 product Group 12 product Sulphur product (not to be applied within two weeks of oil products) Tebufenpyrad Azadirachtin	Bifenazate Products from the below groups can be added if required, but have very broad-spectrum effects for relatively long residual periods Group 1B product Group 2B product Group 3A product Group 4A product	

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

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



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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