Fungus gnat pest management plan for production nurseries

This pest management plan, compliments the NGIA Nursery Paper on fungus gnat management, released in 2013. This pest management plan is more detailed. The nursery paper has case studies from two Australian nursery propagators.

General biology and damage

Fungus gnats (*Bradysia* spp., Sciaridae) are small, mosquito-like flies which are a common problem in nurseries and greenhouses where propagation and seedlings are being grown. Adult fungus gnats are about 3-5 mm, have relatively long, delicate legs and antennae and are weak fliers, but are very active runners. Females lay about 100-150 eggs over their very short 3 day lifetime [9]. Eggs are laid in the soil or potting media and hatch after about 4 days (depending on temperature). Larval fungus gnats are white maggots with a shiny black head and are 1-8 mm in length (Fig. 1) that tend to inhabit the top 3 cm of growing media. Larvae are primarily fungus feeders but will feed on root hairs, callus, organic matter present in the growing media, including leaves touching the soil in the absence of fungus food [6, 14]. Large larvae may feed on the insides of roots and large infestations may see larvae boring into larger roots or stems in the soil. It takes about 15-30 days

Fig. 1. Fungus gnat larvae infesting a plant cutting.

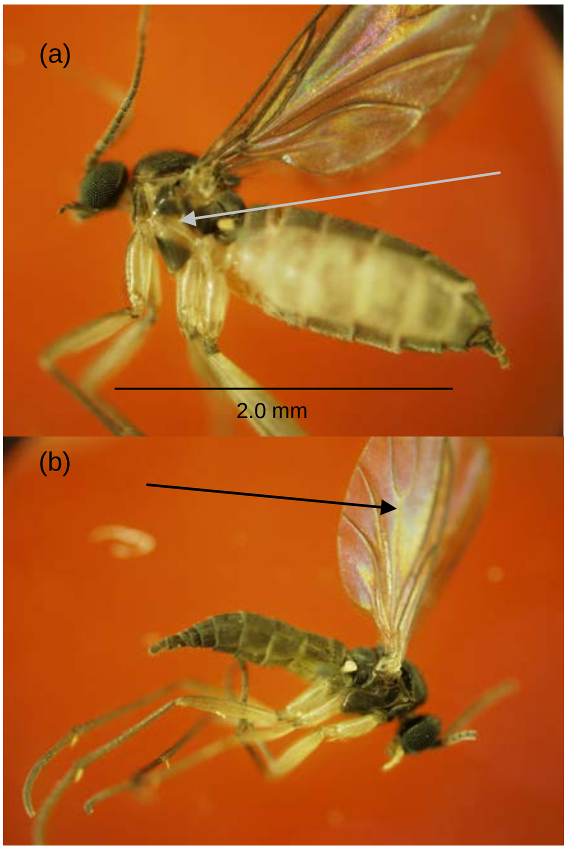

Fig. 2. Adult fungus gnats from the genus *Bradysia* have a yellow band running below their wing (see arrow in photo (a)) and are relatively large, species in the genus *Lycoriella* are smaller and do not have the yellow band (b). All fungus gnats have a prominent ‘Y-shaped’ wing vein (see arrow in photo (b)). Photos by Afsheen Shamshad.

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at 25-18°C temperatures to develop from egg to adult, depending upon the species of fungus gnat [9]. Larvae pupate in the soil and emerge as adults. Optimal temperatures for fungus gnats is between 15-30°C, with temperatures above 32-35°C and below about 10°C being unsuitable [9]. However, the exact temperature range will vary with the species of fungus gnat. Fungus gnats from the genus *Lycoriella* have a similar biology and appearance (Fig. 2) to that described above and may also infest greenhouse crops but are not reported as horticultural pests [20]. Here, all mention of fungus gnats refers to *Bradysia* spp. which is the focus of this pest management plan, except when explicitly mentioned otherwise.

Fig. 3. Adult fungus gnat on a tomato seeding.

Adults tend to rest on plants and on soil media (Fig. 3), flying in a zig-zag pattern when disturbed. Adults are favoured by moist conditions, do not directly damage plants, but have been associated with spread of fungal diseases including C*halara* and *Botrytis* [5, 9]. Large populations can irritate staff and have caused consumer complaints. Direct damage from larval feeding on plants is far more serious and may cause poor callus formation, slow down or completely inhibit root establishment and development, wilting and even death. Furthermore, larvae can spread diseases including, *Pythium*, *Phytophthora*, *Chalara*, *Fusarium*, *Rhizoctonia* and *Verticillium* [5, 7, 9] which can cause significant crop loss. Establishment of disease may be enhanced from wounds created by larval feeding, particularly at high densities.

Fig. 4. Cover media such that it is protected from rain and other moisture.

Larvae are voracious, prefer feeding on organic matter found in the growing media, but will feed on plant material and are cannibalistic at times. A considerable amount of research has shown that certain growing media are more attractive to fungus gnats and can have a significant effect on their abundance. In general, growing media with high levels of organic matter, such as composted wood bark mixes, coco coir, peat and sawdust favour fungus gnats over media such as perlite and rock wool [8]. There is some evidence that coco coir may reduce fungus gnat problems over sphagnum peat [18], but not always [4]. Regardless, the exact composition of the mix and level of moisture can have an effect [18]. With careful testing, one can optimise pant growth parameters and inhibit fungus gnats. For example, tests with impatiens and poinsettias showed that a mix with nearly equal parts of coir and vermiculite and about 15% perlite minimised fungus gnat population growth and provided beneficial properties for plant growth [23]. By contrast, tests on geranium showed that a mix of nearly equal parts of vermiculite and perlite, with little or no coir, was most beneficial for plant growth and reduced fungus gnat populations [23]. The main conclusion is that no one growing media mix will work best to optimise plant growth for all plant species and reduce fungus gnat populations. While the growing media is important, an available food source (e.g. plant material or fungi) is extremely important for fungus gnat populations [18]. In fact, without a fungal food source, larval survival (and root damage) can be much reduced [14]. Nevertheless, a wide range of host plant species can be damaged by fungus gnats. However, plants with succulent stems, such as geraniums, sedum, coleus and poinsettias, are particularly susceptible and can suffer serious loss if proactive steps are not taken. In addition, fungus gnats have been reported on begonias, carnations, chrysanthemums, cyclamen, gerberas, asparagus, corn, cucumber and clover [9], however many more are affected across the nursery sector.

Management of fungus gnats

Historically, fungus gnats have been managed using insecticides, but current trends indicate that sole reliance on chemicals to control fungus gnats is unreliable. Preventative measures, predators and biopesticides can be used very effectively to the exclusion of all insecticide applications. Taking an integrated approach, using a wide array of options to minimise and manage fungus gnat populations, is very effective for keeping fungus gnats under damaging levels.

Fig. 5. Shorefly adults are bulkier and are less likely to fly when disturbed. Shorefly larvae primarily eat algae and rarely cause damage to roots of growing plants.

Cultural control – taking preventative measures

There are many ways to modify the growing environment to reduce fungus gnat infestations, most of which are basic hygiene practices.

Growing media and storage

1. Use growing media low in organic content. High organic content can promote fungus gnats. However, this must be balanced by using a mix that provides beneficial growth properties for the plant species in question [23].
2. Store growing media in a clean, dry area. Storage of media in an unprotected area subject to rain or other sources of moisture may promote fungal growth, which in turn will promote fungus gnat populations. Ideally, cover unused media in a sealable container to prevent further infestations.
3. Growing media may be delivered contaminated with fungus gnats, even when sold in bags [3]. Pasteurise media prior to use whenever possible, particularly if using media which is high in organic matter or if you are reusing media.

Protect your growing area

4. Prevent entry to the growing area by using an insect proof glasshouse or tunnel. Placement of insect-proof screens can increase the humidity in the structure, causing ventilation problems. It is recommended to use a protected cropping consultant/designer before retrofitting or building an insect-proof tunnel or glasshouse. This method will only be successful if growing media and incoming plants are free of fungus gnats.
5. Check incoming stock and growing media, either before purchase or on arrival for signs of infestation. If present, assess the level of infestation and the effort that will required for management. Returning stock or changing suppliers can be valid options.
6. Quarantine incoming stock as per NIASA Best Practice Guidelines and monitor plants for fungus gnats and other pests prior to incorporation in production areas.
7. Grow cultivars that are more resistant to fungus gnats. Since research is not available on exact varieties that are more or less susceptible to fungus gnats, your records and

experience can provide important information on the level of susceptibility of each plant. For example, research on twenty varieties of Chinese chives showed that certain varieties had relatively high levels of resistance to fungus gnats compared to others [19]. It is likely that similar trends occur for many nursery plants.

8. Most importantly, identify infestations early through regular monitoring; actions against relatively low populations of pests are always more effective.

Irrigation and fertilising

9. Avoid excess watering. Fungus gnat numbers are lower when moisture levels are relatively low. Therefore, using the smallest volume necessary to maintain required growth rates is best. Ideally allow the top surface of the growing media to dry before watering again. If possible, increase media porosity to reduce water holding capacity.
10. Fertilise using the minimum amount required to maintained required growth. Excess fertiliser will favour the growth of algae in the growing area which will promote fungus gnat populations.

Sanitation and general hygiene

11. Reduce fungus growth in the media and growing area. This will minimise spread of diseases by adults and larvae and reduce larval survival significantly. See Appendix 2 in the NIASA best management practice guidelines for more information on this topic.
12. Sanitation and basic hygiene are both very important. Disinfest growing surfaces and paths to remove algae, ensure that growing surfaces, below benches, walkways and areas around the growing area are free-draining and free of algal growth. Remove weeds and plant waste regularly. Modify the growing area such that algal growth is minimised and that water does not pool in or near the growing area; regrade floors if necessary. Poor drainage and plant waste will promote fungus gnat populations building up in the growing area. Ensure that plant waste is removed hygienically into tightly sealing bins or in sealed bags as pests can reinfest the growing area from open or loosely sealing bins [11]. Leave bins in the sun if possible.
13. Remove unsold or unsaleable infested crops from the growing area quickly to reduce populations spilling into uninfested crops.

Treat wisely

14. Avoid broad spectrum, highly residual chemicals that will cause high mortality of naturalised parasitoids and predators (see sections on pesticides and biological control below).

Monitoring for fungus gnats

Plants should be inspected daily with results of monitoring recorded weekly. Frequent monitoring will enable infestations to be spotted while they are still light, and thus easier and cheaper to manage. Different methods can be used for monitoring adults and larvae.

Monitoring adults:

1. Yellow sticky traps are essential for monitoring fungus gnat adults in cuttings and seedlings (Fig. 6). Position traps about 10 cm above the crop canopy, particularly near susceptible crops. Traps should also be placed near doors, vents and any susceptible crops or areas. At least one trap per 100 m^2 is recommended for greenhouse crops, more in varieties that are known to be susceptible to

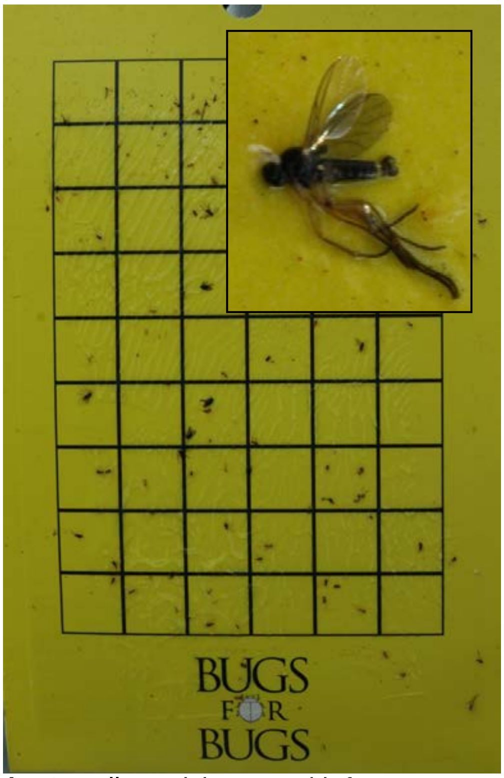

Fig. 6. Yellow sticky trap with fungus gnats and close-up of adult on sticky trap in top-right corner.

fungus gnats. Inspect sticky traps at least weekly and change traps every 2 to 4 weeks. Numbers less than 20 flies per trap/week may be under the economic threshold but will vary with each crop variety [5]. Sticky traps also physically kill adults, precluding their ability to reproduce and further infest the crop. Learn to distinguish fungus gnats on sticky traps from other insects, e.g. particularly shorefly (Fig. 5).

Fig. 7. Poor establishment caused by fungus gnats.

2. Visual inspection of the crop can also provide valuable qualitative information about the abundance of adult populations. Adult fungus gnats fly in random patterns around the crop and skitter quickly across the growing area when disturbed. If relatively large numbers are observed in this fashion further investigation should be undertaken.
3. Pots, trays, media or root masses that are suspected, or are known, to be infested with fungus gnats can be placed in a clear plastic bag or other container (with ventilation) to determine how many adults emerge. A yellow sticky trap can be placed in the container to trap adults and help prevent them from escaping. This can give an explicit measure of the size of populations in a certain area. The method can easily be modified for on-farm testing to answer questions, e.g. does the growing media have fungus gnat larvae present prior to potting up? Which growing media is better than another, in terms of fungus gnat numbers? Are my pasteurisation/sterilising techniques eliminating fungus gnats from the media (be sure to include treated and untreated media in your tests otherwise results may be ambiguous)? Which varieties or plant species support greater numbers of fungus gnat larvae? When conducting such on-farm tests it is important to standardise your trials, using the same amount of media or particular sized plants/plugs. It is also important to conduct at least three to five identical samples of each media or plant type so that you can gain a better indication of variability across your farm. Run tests for at least one week, monitoring every few days, counting the number of adults that emerge from the test sample. IPM consultants or your local department of agriculture may be able to provide advice when conducting such tests. Regular monitoring of potting media (i.e. when potting up) can provide base line knowledge of the numbers of fungus gnats going into the growing area, from which management actions can be taken.

Monitoring larvae

4. Visual inspection of cuttings and surrounding media can reveal the presence of fungus gnat larvae. Remember that larvae tend to inhabit the surface of the growing media and tend not to go deeper than about 3 cm. However, this method can be time consuming and may damage cuttings/roots so only conduct such monitoring when you are sure that it is safe to do so. Small larvae can also be difficult to detect.
5. Potato plugs can be used to lure larvae to the surface. Place a slice of uncooked potato about 3-5 cm in diameter (and about a cm thick) without skin face down on the growing media. Smaller chunks or slices can be used in small plugs/containers. Ensure that most of the surface is in contact with the media so that the potato does not dry out. After 24-48 hours, lift the potato plug and first examine the growing media under the potato, as larvae will rapidly vanish from view on the surface. Then check the potato itself for larvae. It is recommended to mark pots or plugs where potatoes are placed so you can find them more easily. If not removed, potato chunks can rot, sprout, promote fungus gnats and other pests e.g. mice.

Keep long-term records to assist identification of areas and varieties that are more susceptible to fungus gnat infestations. It is also important to continue monitoring following application of biological control agents and other control measures to determine the effectiveness of each treatment. These records can assist with making management decisions in the future. For example, one might modify the composition of growing media to reduce infestations or select varieties that are found to be more resistant to fungus gnat attack. Insect monitoring data sheets are available in the BioSecure HACCP protocols available on the NGIA website (www.ngia.com.au). Alternatively, simple spreadsheets can be created and modified to suit your farm.

Fungus gnats and pesticides

Pesticides can be used to assist management of fungus gnat larvae (Table 1). It is important to note that different species of fungus gnats and geographic populations may have different levels of pesticide resistance. In Australia, there have not been any confirmed cases of pesticide resistance in horticultural or mushroom crops. However, resistance has been reported for certain organophosphates (e.g. diazinon) and permethrin overseas [21]. Currently, there are no commercially registered products against fungus gnat adults in Australia. Refer to Table 1 for a list of all registered and minor-use permits for fungus gnats on ornamental stock. Included in this table is important information on the effect of products on natural enemies, MOA group and stage which is most affected by the product.
Management of fungus gnats can be achieved using cultural control measures, regular monitoring and preventative treatments in conjunction with biological control and biopesticides. However, if pesticides are to be used then below are some practical tips to increase their success:

1. Ensure that the product is applied correctly. Most drenches must be thoroughly applied to the medium to reach all larvae in the growing container. Larvae may be difficult to contact with the pesticide due to their cryptic habit and over-watering can leach chemicals out of the media or move it below where larvae feed.
2. Do not use products consecutively from the same mode of action (MOA) group unless specifically stated on the label insecticide resistance management strategy. Alternate between as many MOAs as possible prior to repeating an application with a product (Table 1).
3. If you are using biological control in the growing area, be aware of the effect of the product on beneficial insects (Table 1) and the length of time over which beneficials will have reduced capacity or be ineffective after its application.
4. Do not continue to use a product which has not been effective (particularly if it was applied correctly and good control has been achieved in the past). Such continued use will only serve to increase the level of resistance in the population and decrease the likelihood that the product will be effective in the future. Contact your local IDO to inform them of possible insecticide resistance.
5. Be aware of product shelf-life and phytotoxicity. Refer to the Nursery Pesticide Application Best Practice Manual for more details on effective application of pesticides [i].

Biological control of fungus gnats

Biological control requires the same level of dedication as management with pesticides however is more gradual. Therefore it is critically important to monitor fungus gnat populations and release predators early, preferably as part of a regular preventative plan. Early intervention increases the likelihood that economic loss will not occur and will give best results.

[i] <www.ngia.com.au> search for ‘pesticide application manual’

Geolaelaps aculeifer (*Hypoaspis* A or killer mite) = *Hypoaspis aculeifer* *Stratiolaelaps scimitus* (*Hypoaspis* M) = *H. miles*

Geolaelaps aculeifer is a relatively large, brown to orange coloured (Fig. 8), soil-dwelling predatory mite (about 1 mm in length). Nymphs and adults feed on fungus gnat larvae, thrips pupae and other soil organisms, including nematodes, springtails, root aphids and mites, preferring moderately moist habitats high in organic material. The killer mite takes about 12 days to complete development at 27°C, but up to 40 days at 16°C and can survive for long periods scavenging on soil arthropods without specific pest prey. Temperatures above about 30°C are detrimental and activity below 10°C is very low. Soil conditions do not always reflect outside air temperatures and this should be taken into account when deciding to use soil predators. Direct sun on the container of plants may increase the temperature for media within pots compared to air temperature. By contrast, soil in the shade may be substantially cooler than air temperature. Females lay about 3-4 eggs per day under good conditions.

Fig. 8. The appearance of *Stratiolaelaps scimitus* and *Geolaelaps aculeifer* are very similar, the later of which is slower moving, has hairier, darker legs and the back of the carapace is more rounded than *S. scimitus.* Above is an adult *S. scimitus*.

Stratiolaelaps scimitus feeds on a similar range of prey as *G. aculeifer*, fungus gnats, thrips pupae etc. Females lay about 2-3 eggs and consume 1-5 prey items per day. Development from egg to adult ranges from 10-18 days at 25°C and 20°C, and 30 or more days at 15°C. Do not store them below 10°C as this will kill them and populations are likely to crash in unheated structures where the temperature drops below 10°C in winter.

While soil predators may have some protection from foliar sprays of insecticides, run-off from high impact pesticides can still have a severe negative effect on predators, particularly if they have long residual activity. Biological Services produces *G. aculeifer* and *S. scimitus*; Bioworks produces *S. scimitus* only. They are commonly referred to as *Hypoaspis* (A or M) on their web-pages.

Dalotia coriaria = *Atheta coriaria*

Adults and larvae of the rove beetle, *Dalotia coriaria*, feed on a range of small insects and mites, feeding heavily on fungus gnat and shorefly eggs and larvae and thrips pupae [1]. Eggs and small larvae of a wide range of insects are consumed [17]. Adults are slender, fast moving glossy blackish-brown beetles that are 3-4 mm long (Fig. 9). Optimum temperature for *D. coriaria* is 27°C, at which development is completed in 13 days, but it is also active between 15°C and 32°C [17]. Adults have wings and may fly to find food. Adults live about 21 days and lay up to about 8 eggs per day, and may eat up to about 150 fungus gnat larvae [1]. Adults prefer to eat fungus gnat larvae more than shorefly or western flower thrips pupae, when given a choice [13]. Biological Services is the only provider of *D. coriaria* in Australia.

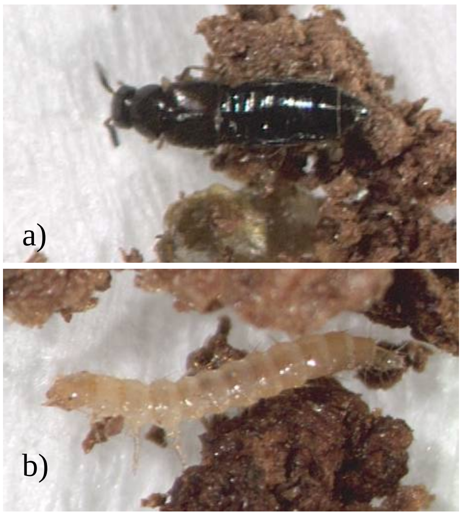

Fig. 9. Dalotia coriaria adult (a) and larva (b). They are about 3-4 mm in length.

Fig. 11. Fungus gnat larvae have a distinctive, relatively hard, shiny black head capsule.

Insect-killing nematodes (e.g. *Steinernema feltiae*)

Insect-killing (entomopathogenic) nematodes (ENs) are tiny, very slender, worm-like, soil-dwelling organisms that are a little less than 1 mm in length. The ENs have limited dispersal capacity and thus must be drenched into the growing media. Once they come in contact with a host, they enter it and release bacteria, which break down the tissue into food. This process causes septicaemia and kills the host, usually within 48 hours after infection. Thousands of ENs can breed within a certain hosts, largely dependent on its size, e.g. up to 100 000 nematodes can develop from a single scarab beetle larva. Once the food is completely consumed the prey basically disintegrates, releasing the ENs into the soil to infect new hosts.

There are a number of factors that can influence successful control of fungus gnats using *S. feltiae*. Media temperatures greater than 30°C and less than 10°C will cause ENs to become inactive and prolonged soil temperatures greater than 25°C may reduce efficacy of *S. feltiae* against fungus gnats [12]. As mentioned above, air temperatures may not reflect temperatures in the media. Plant species and growing media also can affect the efficacy of ENs; the percentage reduction of fungus gnats was greater on impatiens than poinsettia and different growing medias also was associated with greater or lesser control [12]. Certain stages of fungus gnats are more susceptible to ENs than others, generally larger larvae are more susceptible [12, 15]. However, ENs will be effective in controlling larvae of any size. Application of ENs can be completed using a high volume low pressure spray to drench nematodes into the media a short distance or through existing irrigation. In either case, ensure that all filters are removed and speak to your distributor for more specific instructions before applying for the first time. ENs are UV sensitive, so application when the area is in high levels of direct sun is not recommended, particularly if the area in which they are to be applied is not in a protected structure. ENs are compatible with most insecticides and miticides and may even be tank mix compatible (refer to your supplier), but application of nematicides will harm them. There are two suppliers of insect-eating nematodes in Australia, Ecogrow and Becker Underwood. Ecogrow produces nematodes in Australia, Becker Underwood imports their nematodes from the UK.

Bacillus thuringiensis subsp. *israelensis* (Bti)

Bacillus thuringiensis (Bt) is an entomopathogenic bacteria which causes diseases in insects. After ingestion by an insect host, the bacteria produce a number of substances which cause cell disruption and other physiological problems which cause the cuticle to disintegrate and the insect to die. There are a large number of Bt subspecies which are specific to certain pest groups, e.g. flies or caterpillars. Bti (e.g. Vectobac, Bactivate and other products) is specific to various fly larvae, including fungus gnats. Research has shown that Bti is mainly effective against first instar fungus gnat larvae, not larger second or third instars [21, 22]. This is because larger larvae must consume more bacteria to cause mortality than smaller larvae. If using Bti one must apply the product when fungus gnats first appear and may require multiple applications. Bti is UV sensitive, as per ENs, so one must take this into account before application. Bti is available from most agricultural supply outlets.

Naturalised predators

Fig. 10. A small parasitoid wasp, *Synacra* sp., parasitises fungus gnats in Australia. It can easily be confused with adult fungus gnats.

At least one naturally occurring parasitoid wasp may cause substantial mortality to fungus gnats. *Synacra* sp. are similar in size and habit to fungus gnat and thus are easily confused. They are often found running across growing media similar to fungus gnats. However, *Synacra* have four wings, not two, and a more pointed, strictured abdomen than fungus gnats and can easily be distinguished on yellow sticky traps (Fig. 10). Female *Synacra* lay eggs into larval fungus gnats, the wasp larvae feeds inside the host larva until it pupates. As a result fungus gnat larvae may still cause damage to plants even though they are parasitised and will die shortly after pupating [10]. They have been known to be quite effective against fungus gnats in glasshouses where broad spectrum, long residual pesticides are not in use (Marilyn Steiner, Biocontrol Solutions, personal communication). The biology of this species is not well known. Overseas, closely related species can parasitise 2-300 fungus gnat larvae, survive best between about 15 and 25°C and multiply more quickly than their fungus gnat hosts [10].

Releasing multiple predators

Research has shown that both *G. aculeifer* and *S. scimitus* feed on *D. coriaria* larvae, particularly relatively small larvae [13]. Furthermore, *D. coriaria* also feed on eggs and nymphs of *G. aculeifer* and *S. scimitus*, sometimes feeding on equal numbers of fungus gnats as predators [13]. These interactions may reduce the efficacy of multiple predators released to control fungus gnats. While these interactions were only tested in small laboratory arenas, the results suggest that releasing both *D. coriaria* and a predatory mite may not be beneficial for the control of fungus gnats.

Recommendations: putting it all together

The following recommendations can be used as a guide but may require changes to suit your exact situation. Thresholds indicated here (based on sensitive crops) may differ at your farm, depending upon plant species grown and a variety of other factors. Modify the guide as necessary to gain successful management of fungus gnats. Talk to your IDO to inform them of your progress regarding fungus gnat management. Always monitor adults and larvae as this will aid determining the efficacy of each treatment and put into practice cultural control measures described in this document, regardless of other management practices. Use of biological control agents to completely manage high populations of fungus gnats may take several applications of multiple predators, but is very effective.

Focus on biological control

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

[i] Spread 1L of *G. aculeifer*, *S. scimitus* or *D. coriaria* over 100-150 m^2 for preventative rates, 50-75 m^2 for moderate rates and 30 m^2 for high rates.

[ii] Spray nematodes in a drench using low pressure. Use one 55 million pack of nematodes in 100-200 litres of water covering 200, 150 and 100 m^2, respectively, at low, medium and high rates. Refer to your suppliers guidelines before applying nematodes. Please note that Becker Underwood and Ecogrow differ in their recommended rates of release, probably due to the different formulation of the nematodes they supply. Nematodes may also be applied through irrigation lines, but filters must be removed.

Focus on chemical control

1. Incorporate a pesticide into growing media when potting up (Table 1).
2. Rotate chemicals with different modes of action, apply when numbers are greater than 20 fungus gnats per sticky trap per week.
    a. i.e. Bti (but see point b. below) ➔ Pyriproxyfen (7C) ➔ 22A product ➔ 4A product ➔ 1B product ➔ 1A product
    b. Exception: use Bti when there are relatively large numbers of small larvae, generally when fungus gnats first appear. Repeat twice in one week before moving to the next product.
    c. ENs may also be used as an additional application at any time; there are no known cases of resistance to ENs.
    d. Avoid using a product from the same group that has been incorporated into the growing media, i.e. skip this mode of action group.
    e. Periodically check minor use permits to see if additional products become available for use against fungus gnat larvae.

This document was prepared by Andrew Manners (Agri-science Queensland, Department of Agriculture, Fisheries and Forestry, Ecosciences Precinct, GPO Box 267, Brisbane QLD 4001) as part of NY11001 Plant health biosecurity, risk management and capacity building for the nursery industry. Thanks go to Dr Afsheen Shamshad, Steve Hart (NGIQ), Marilyn Steiner and Stephen Goodwin (Biocontrol solutions), Craig Wilson (Ecogrow) and James Altmann (Biological Services) for providing comments that improved previous drafts of this document.

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Table 1. Pesticides currently registered or with minor use permit in Australia for ornamental use against fungus gnats (FG). Results presented were from queries of Infopest (2012)[b] and the APVMA pubcris[c] and permit[d] 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 and/or permits to determine suitability of use. This table was up-to-date in December 2012.

Mode of action group	Active ingredient	Example product name	Registration information	Limits on applications per season	Action[e]	Other information	Toxicity to beneficials[f]
1A	Methiocarb	Mesurol	Registered against fungus gnats on ornamental crops.	None specified.	C, I	Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. Refer to label for application instructions. **Effective against larvae.**	H – probably 4-8 week residual.
1B	Chlorpyrifos	Suscon green	Registered for fungus gnats and shorefly for ornamental nursery plants (rooted cutting or seedlings or direct seed or unstruck cuttings) but only if in a peat based growing media.	Incorporated into growing media just before young bare root plants, seeds or cutting are planted, sown or struck.	C, I, V	Refer to label for application instructions. **Effective against larvae.**	Probably M-H – probably a very long residual period, perhaps even greater than 12 months.
1B	Diazinon	Diazinon, Diazol	Registered against fungus gnats in ornamental potted plants but only in Qld.	None specified.	C, I, V	Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. **Effective against larvae.**	M – 1-2 week residual.
4A	Acetamiprid	Crown	Registered against fungus gnats and shore fly on ornamental plant potting mixes, applied as a drench after potting and plant up.	Repeat in 6-8 weeks if pest activity reappears.	C, I, S, T	Refer to label for application instructions. **Only effective against larvae.**	M – probably 1-2 weeks residual.
4A	Imidacloprid	Suscon maxi	Permit 11560 allows use against fungus gnats on non-food nursery stock – seedlings, and plugs, potted trees and shrubs, foliage plants, palms, grasses and fruit trees (non-bearing).	Incorporate into growing media prior to potting up.	C, I, S	Do not allow significant leaching and run-off for at least 3 irrigations or 10 days, whichever is longer. **Only effective against larvae.**	M-H – 3 weeks residual.
7C	Pyriproxyfen	Admiral	Permit 12659 allows use against fungus gnats on nursery stock (non-food): including seedlings and plugs, potted colour trees and shrubs, foliage plants, palms, grasses and fruit trees (non-bearing).	Once per crop cycle.	C, T	Use as drench to saturate top 2-4 cm of soil. **Only effective against larvae.**	L-M – 1 week residual.
11	*Bacillus thuringiensis* subsp. *israelensis*	VectoBac	Permit 11472 allows use against fungus gnats in protected capsicums, cucumber, eggplants, herbs, lettuce, ornamentals (including potted plants) and tomatoes.	None specified.	I	Refer to label for application instructions. See section on biological control for more details. **Most effective against small larvae [2].**	None – no residual.
22A	Azadirachtin A and B	Eco-neem; Azamax	Registered against fungus gnats for potting soil of floriculture and ornamentals.	None specified.	C, I	Some sensitive plants have had minor phytotoxic effects. Test in a small area to ensure there are no phytotoxic effects prior to use in a large area. **Only effective against larvae.**	L – no residual.

[b] The Infopest database is now a free web-based service at www.infopest.com.au

[c] http://services.apvma.gov.au/PubcrisWebClient/welcome.do

[d] http://www.apvma.gov.au/permits/search.php

[e] Action: C = contact; S = systemic; I = ingestion; T = translaminar; V = vapour.

[f] In the context of the table, beneficials refers to *G. aculeifer*, *S. scimitus*, *D. coriaria* and *S. feltiae*. Summarised primarily from *The Good Bug Book* [16], http://www.koppert.com/, http://www.biologicalservices.com.au/, http://www.bugsforbugs.com.au/ and http://www.ipm.ucdavis.edu/