Managing green peach aphid in production nurseries

Background and general biology

Green peach aphid (GPA – *Myzus persicae*) is a worldwide pest that can damage a wide range of host plant species. Although *Prunus* spp. are primary hosts, other host plants include beans, cabbage, capsicums, cucurbits, tomatoes, spinach, beets, lettuce, potatoes, peaches, and various ornamental plants including chrysanthemums, roses, carnations and many other plants can be affected. Weeds may also be significant reservoirs for populations of GPA that may infest your crop, e.g. dandelions. They are generally found on flowers, young foliage and the undersides of leaves. Relatively large numbers of aphids can cause leaf chlorosis, wilting and stunting of new growth. However, the main cause of damage is associated with viruses vectored by GPA. Aphids and other sap-sucking insects generally produce honeydew (excretion which is mostly sugary plant sap). Honeydew will often result in the growth of black sooty mould which reduces photosynthetic area and can cause plants to look unsightly. Furthermore, ants may tend aphids, harvest honeydew and provide a level of protection from certain predators.

Fig. 1. Green peach aphid. Note relatively long siphunculi and presence of tubercules.

GPA are oval/almond shaped, generally light to dark green, orange or pink, 2-3 mm in length and may have wings. Populations of GPA are favoured most in late winter and early spring, when maximum temperatures are about 20-25°C. However, they can be present at damaging levels at any time of the year, particularly in warmer climates. Populations of GPA are almost always 100% female in Australia. Eggs are only laid rarely and only in cool, temperate climates where there is a need to overwinter; eggs are only laid on *Prunus* spp [27]. Instead, females give birth to live nymphs at a rate of about 1-2 nymphs per day, depending on temperature. Each female can give birth to about 25-75 nymphs over her 20-40 day lifespan. Nymphs can take as little as 8 days to develop to adulthood and new nymphs may be birthed within a few days. In warm climates there can be as many as 20 generations per year.

GPA can give rise to winged (alate) and non-winged (apterous) females. Winged females are produced when relatively high densities of aphids occur or when plant conditions deteriorate. Winged aphids reproduce at about half the rate of their wingless counterparts but are able to disperse, increasing the area of the infestation.

GPA as a virus vector

There are reports of GPA vectoring over 100 plant viruses and is considered by many to be the most efficient vector of plant viruses across all insect species. Some of the more common viruses transmitted by GPA include *Cucumber* and *Celery mosaic virus*, *Potato leaf roll virus*, *Potato virus Y*, *Beet western yellows virus* (and other beet yellow viruses), *Papaya ringspot virus* and *Lettuce mosaic virus*. In general, many Potyviruses and Luteoviruses are transmitted by GPA [4, 10] (Fig. 2). Viruses vectored by GPA may have persistent or non-persistent transmission, depending on the particular virus. It takes a few hours of feeding for the aphid to acquire a persistent virus and the virus must circulate and reproduce in the aphid's body for at least 12 hours before it can transmit the virus to a new host [i]. Once it can transmit the virus it is able to do so for many weeks, or the rest of its life, without needing to obtain more virus from an infected plant. Non-persistent viruses are acquired by aphids very quickly, e.g. less than one minute, and transmitted in a similar period. However, the virus remains in the mouthparts and is only viable for a few hours. Therefore the aphid would have to feed on an infected plant to obtain a new 'charge' of virus before it can infect additional plants. The host range of each virus varies but often includes ornamental species and weeds. If you are experiencing virus infection it is well worth having it identified to gain further information on virus and vector biology and host range. This will aid in management of both pest and disease.

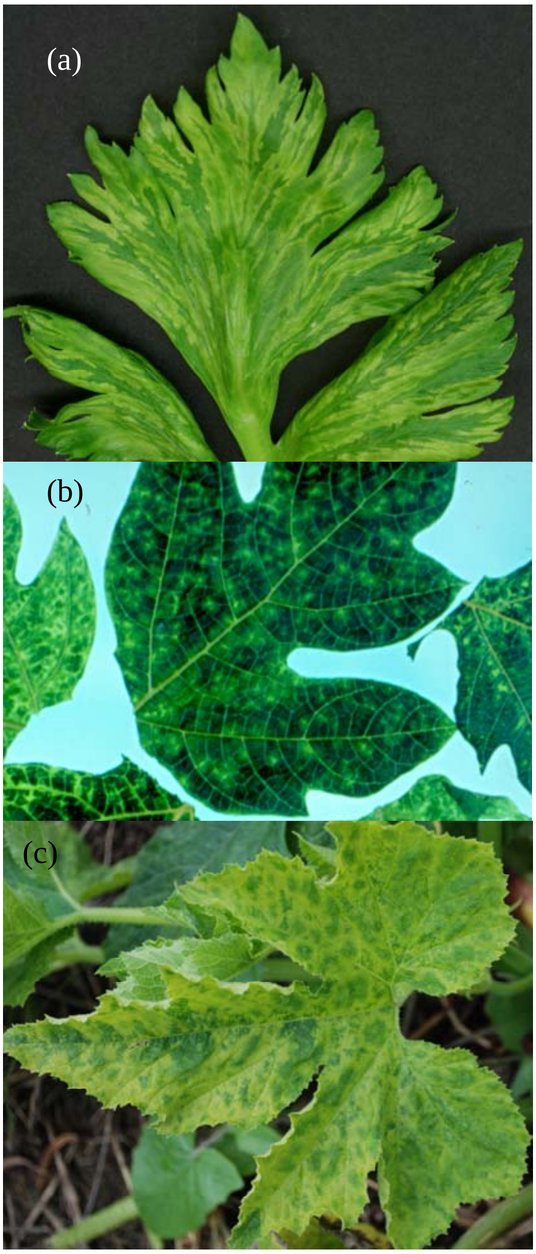

Fig. 2. A selection of symptoms of viruses that are transmitted by GPA; *Celery mosaic virus* on celery (a) and *Papaya ringspot virus* on papaya (b) and a cucurbit (c). Photos by Denis Persley and Cherie Gambley.

While it is not possible to list details on all of the viruses that are vectored by GPA, some brief information is provided (see references for more details). *Potato leaf roll virus* infects tomato and some other members of the family Solanaceae [21]. Generally it causes some

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[i] http://www.daff.qld.gov.au/documents/PlantIndustries_FruitAndVegetables/Managment-of-aphid.pdf

combination of chlorosis, interveinal necrosis, leaf rolling and stunting, depending on the host plant species. *Potato virus Y* can infect a wide range of hosts, particularly solanaceous species, including tomato, capsicums and many weeds, e.g. nightshades (*Solanum* spp.) and *Physalis* spp. (gooseberries and groundcherries) [21]. Symptoms range from leaf crinkling to severe mosaic, necrosis and leaf drop. *Beet western yellows virus* infects lettuce, various brassicas, tomatoes, peppers and various weed species. Symptoms in lettuce tend to resemble nutrient deficiency[ii]. *Lettuce mosaic virus* can cause stunting, deformity and mosaic or mottling patterns and may infect many weed species, lettuce, chickpea, pea, *Aster* spp., marigolds, lisianthus and various flowering plants and vegetables [iii]. Ornamental host plants species that are commonly infected by viruses transmitted by GPA in Australia include carnation, chrysanthemum, gladiolus, tulip, lilium, hyacinth, iris, narcissus, daphne, lilac, philodendron and many of the Araceae [iv]. Symptoms will depend upon the virus species, host plant infected and the viral load in the plant. As viral load increases, so too does the severity of symptoms expressed.

Host range and varietal resistance

While GPA can reproduce asexually on perhaps some 400 plant species, the rate of reproduction varies with host plant species. For example, GPA can produce 30-40 nymphs per month per female on cauliflower, cabbage and turnip, but only 6-10 nymphs on lettuce [9]. In addition, certain varieties/species of plants may be more or less resistant to aphid feeding. The mechanism of the resistance may also vary with plant species, for example, resistant tobacco is related to toxic material in leaf hairs, whereas in Brussels sprouts its related to waxy leaves [28]. The resistance status of plant species grown across the nursery sector has not been investigated. Therefore, records of pest infestations on your property are very important for assisting you to determine which species and varieties of plants are more likely to be infested. These patterns can then be used to inform management decisions on what to grow and what level of monitoring effort is needed for a particular crop.

Fig. 3. GPA can build up to large populations quickly. Photo by © Denis Crawford/Graphic Science.

Managing aphids

The appropriate management technique will depend on a number of factors, such as the extent of the infestation, the presence of other pests and predators in the crop, presence of viruses, other host plants present at the property and environmental conditions. The exact management strategy therefore has to be tailored to each property. However, the following actions should assist in the management of GPA and aphids in general.

Chemical control and insecticide resistance

GPA is one of the most notorious insects for developing pesticide resistance, having done so against at least 70

[ii] http://www.ipm.ucdavis.edu/PMG/r441101411.html
[iii] http://www.ipm.ucdavis.edu/PMG/r441101011.html
[iv] http://www.dpi.vic.gov.au/agriculture/pests-diseases-and-weeds/pest-insects/ag0182-aphids-as-pests-of-ornamentals

different synthetic compounds. Research indicates that GPA has multiple mechanisms for resistance against neonicotinoid (Group 4A) [3], pyrethroid (Group 3A) [2] and anti-cholinesterase (Group 1A) [23] insecticides overseas. Historical levels of resistance in Australian indicates widespread resistance to organophosphates (Group 1B) and almost all aphids tested had some resistance to pyrethroid insecticides [6]. Carbamate resistance was relatively low [6, 12] and no resistance has been reported for neonicotinoid insecticides in Australia [6, v].

Current and on-going research indicates growing resistance to the active ingredient pirimicarb (particularly in WA but also suspected in the rest of the country). Resistance to organophosphates has remained reasonably constant over the last decade. Pyrethroid resistance is high in the eastern states and highly variable in WA. One concern is the observation that increased levels of resistance to all pesticides monitored was associated with concentrated vegetable production in WA [v]. For a summary of resistance to all pesticides for use against GPA, see Tables 1 and 2.

Chemical control of GPA should not be relied upon solely as frequent and regular insecticide applications will contribute to the development of insecticide resistance in your region. Cultural and biological controls should be employed to prevent or at least minimise aphid infestations, with insecticides used in a targeted, strategic manner to clean up any high level infestations. To assist growers in management decisions, all insecticides which are registered or that have permits for use on ornamental plants are summarised in Table 1. Registrations and permits on horticultural crops that are part of the nursery sector, but without a general ornamental label, are summarised in Table 2. Included in these tables are notes on their effect on beneficials and prevalence of insecticide resistance. Tables are current as of December 2012. Check the APVMA website registrations[vi] and permits[vii] or Infopest [viii] for changes to labels. It is recommended to rotate between as many different mode of action groups as possible, e.g. pirimicarb ➔ oil ➔ pymetrozine ➔ diafenthiuron ➔ imidacloprid. However, ensure that your particular crop is covered by each label. Do not underestimate the usefulness of petroleum and botanical oils as greater than 95% efficacy is reported for some products [19]. If using oil as a stand alone option, ensure aphid densities are relatively low [17] and that spray volume is sufficient to thoroughly wet foliage [11].

Cultural control

The prevention of aphid infestations and their spread is very important for successful management, as large populations can build up quickly and are more difficult to control. It is extremely important to prevent and manage aphids successfully to reduce economic impacts caused by aphid-vectored viruses.

Print pictures of pests and beneficial species (either from a factsheet or from a web search on a particular species) and place them in a visible area, e.g. tea room or common area, to make staff more familiar with insects and mites on your property.

1. Manage sources of infestation: control broad-leaf weeds and reduce other alternative hosts in the production area and surrounds. The use of weed matting, plastic or gravel on the floor can help in nursery situations. Good weed management will also help reduce a variety of other pest problems including whiteflies, thrips and mealybugs.
2. Prune and thin plants with light to moderate infestations to reduce the pest load, increase airflow and access by insecticides.
3. Remove and destroy heavily infested stock. Retaining unsaleable stock provides a source of further infestation. Infested material should be bagged and deep buried or

[v] Paul Umina (University of Melbourne) and Owain Edwards (CSIRO), personal communication, Jan 2013
[vi] http://services.apvma.gov.au/PubcrisWebClient/welcome.do
[vii] http://www.apvma.gov.au/permits/search.php
[viii] Infopest is now free online at: www.infopest.com.au

placed in a black bag in the sun for several hours to kill pests. Leaving unbagged, infested plants or cuttings in the bin encourages pests to reinfest the property, particularly when winged aphids are present.

4. Be aware of winged and non-winged aphids; as the number of winged aphids increases so too does the risk of spread to other areas of the property (Fig. 4).
5. Identify the species of aphid/s commonly found on your property and educate staff to distinguish between them. While GPA and a number of other aphid pests have a large number of hosts, many aphids are often very host-specific. Some photos of common pest aphid species have been included here (Fig. 5) and may help in making a preliminary identification. Seek an expert through Grow Help Australia[ix] or your local department of agriculture for diagnostic expertise.
6. Check incoming stock, new seedlings and other new planting material to ensure it is clean and to break the lifecycle of GPA and other aphids. The guidelines for managing biosecurity in nursery production (BioSecure HACCP) has more information on inspecting incoming stock. A self-imposed quarantine area, where plants are kept apart from the rest of your stock, is a valuable strategy to reduce pest and disease infestations. The length of time the plants are kept separate will depend on a variety of factors including temperature, plant species, the biology of pests and diseases encountered on the plants and the amount of space available. However, 4-6 weeks is a good rule of thumb which should allow visible symptoms of many pests and diseases to be observed. Returning stock that has arrived from a supplier infested with a pest or disease may be a valid action.
7. Screens placed over greenhouse vents and doors can be used to help prevent entry by aphids. However, placement of such 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.
8. If infestations persist for long periods in a particular area or glasshouse, grow plants that are not hosts of GPA for a season to break the life cycle.
9. Practice good crop hygiene to avoid contamination between greenhouses or production sites. Mark areas that are known to have infestations with visible signs so that workers can avoid moving through that area. Many species of aphids drop from plants when disturbed which can increase the rate of spread to other areas of the property.

Fig. 4. Educate workers to distinguish winged and non-winged aphids. Winged aphids reproduce more slowly but are more likely to spread to other areas of the property.

10. Most importantly, identify infestations early through regular monitoring.
11. Avoid broad spectrum, highly residual chemicals that will cause high mortality of naturalised parasitoids and predators (see section on biological control below).

Additional and important steps to manage aphid transmitted viruses

12. Do not transport plants from areas with aphids and viruses to areas without the virus.
13. Dispose of throw-outs promptly, ensuring that aphids will not migrate from the plants to other parts of your property. If necessary, apply an insecticide or oil spray to kill aphids

[ix] http://www.daff.qld.gov.au/4790_12360.htm

before destroying the crops.

14. Reduce weeds around your property, as they can harbour viruses and may remain non-symptomatic.
15. If possible, plant virus-resistant plants in areas where the virus is likely to be a problem.
16. Only use plants that have been tested and shown to be free of virus (for those viruses that are seed transmitted).
17. Plant non-host plants for a period of time to reduce the reservoir of virus on your property. This is particularly important if the virus has been continuously present for a relatively long period of time.
18. Aphid vectored viruses that are persistent and non-persistent cannot be treated the same way. Insecticides are unlikely to be an effective strategy to manage aphids vectoring non-persistent viruses because the virus can be transmitted in seconds. Furthermore, insecticides may agitate insects and encourage movement and feeding on greater numbers of plants.
19. Prevent aphids from infesting your crop, either in an insect-proof glasshouse or using oils to deter insects.
20. If aphid-vectored viruses are consistently encountered, natural enemies alone may not be sufficient in preventing economic loss.
21. Do not use secateurs on infected plants followed by uninfected plants as this can transmit certain viruses.

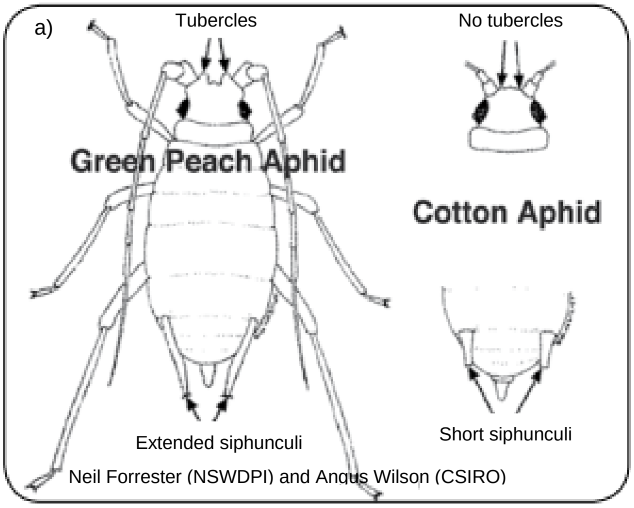

Fig. 5. Species level identification of aphids can be very important. For example, the melon aphid, *Aphis gossypii*, has extremely high and widespread resistance to imidacloprid but GPA does not [16]. Knowing the species of an aphid can make the difference between a successful application and wasting time and money applying an inappropriate product. GPA and cotton aphid (a) are very similar and can be distinguished by their short tubercles and long siphunculi. Other aphid species include:
(b) black citrus aphid (*Toxoptera citricidus*),
(c) woolly apple aphid (*Eriosoma lanigerum*),
(d) cow pea aphid (*A. craccivora*), and
(e) rose aphid (*Macrosiphum rosae*).

Monitoring for aphids

Plants should be inspected on a weekly basis for the presence of aphids and data recorded. Increase the frequency of monitoring during warmer weather and on host plants which are known to be more susceptible to GPA. Frequent monitoring will enable infestations to be spotted while they are still light, and thus easier and cheaper to manage. Methods of monitoring include:

Fig. 6. Parasitised aphids which have been turned into mummies. Wasps have emerged from some mummies as evidenced by exit holes.

1. Visual inspection and plant beating can be completed simultaneously. Inspect a small percentage of each plant type by hand (generally 1 to 10%, depending upon the number of plants and their susceptibility). Examine leaves of plants that look stunted, chlorotic or have other unusual symptoms on both leaf surfaces using a hand lens. They are generally found on flowers, young foliage and the undersides of leaves. Move through the crop and gently but firmly hit foliage against a beating tray (which can be a folder, bucket or plastic plate). The beating tray should be a single colour; white or black is preferable as this will make moving organisms more visible. Beating plants is a relatively efficient way of monitoring for insects and mites that can be knocked from plants, including herbivorous and predatory mites, aphids, whitefly adults, thrips, lady beetles, small caterpillars and a variety of other insects. Sometimes the cast-off skins (exuvae) may be beat from plants and may provide evidence of the presence of aphids without finding living individuals. Once something is found, a 10-15x hand lens can be used to inspect the catch. Record the number of plants inspected and the number of plants with any given pest in each area of your property. More detailed information (e.g. the number of insects on particular plants or leaves) may also be useful, particularly for determining how effective management actions have been. Accurate records can help determine long-term patterns of host use on the property and thus help in allocating search effort. It is also important to note that aphids may be more difficult to detect on pale yellow or green leaves, particularly at low densities.
2. The presence of ants often provides an indication that aphids or another sap-sucking insect (such as scales or mealybugs) are present on a plant. Always investigate why ants are present on plants as they may lead you to a pest infestation.
3. Yellow sticky traps are useful tools for monitoring a variety of insects and can trap winged aphids. 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 GPA. Inspect sticky traps at least weekly and change traps every 2 to 4 weeks. Presence of winged aphids, particularly if in large numbers, should trigger more detailed surveys to determine the extent of the infestation.
4. Parasitised aphids turn into 'mummies' (preserved corpse – Fig. 6). An aphid that has

been parasitised swells into a hard, brown or black ball which is distinctly different from normal living aphids. Mummified aphids will not reproduce and will give rise to wasps which parasitise or feed on subsequent aphids.

Keeping long-term records can help identify areas and varieties that are more susceptible to infestations. It is also important to continue monitoring following application of insecticides or release of biological controls to determine the effectiveness of treatments. These records can assist with making management decisions in the future. For example, wind patterns at your property may lead one to monitor certain areas more than others or greater monitoring effort during periods when key pests are present. In addition, monitoring can inform you of the level of natural enemies present in the crop, which may modify management actions. 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 property.

Biological control

There are four commercially available biological control agents that consume or parasitise GPA; a green lacewing, a pirate bug and two parasitoid wasps. In addition, a wide array of natural enemies will also consume aphids, e.g. lady beetles, if applications of broad spectrum pesticides are limited. It is recommended to seek the advice of the biocontrol agent provider before releasing predators for the first time.

Fig. 7. *Aphidius colemani* parasitising aphid nymphs.

Aphidius colemani

Aphidius is a small parasitoid wasp which can successfully control GPA and the cotton aphid, *Aphis gossypii*. It may also attack up to 40 other aphid species at varying rates, but probably not at levels that will successfully suppress pest populations. The small wasp is about 2-3 mm in length and has a black abdomen (Fig. 7). Females mostly lay eggs inside young aphids, although any stage can be parasitised. Resultant wasps emerge after about 10 days at 25°C, and 14 days at 20 or 30°C. Aphids swell and turn brown (i.e. turn into mummies) 5-7 days after being parasitised [29]. *Aphidius* requires quite mild temperatures performing best between 20-25°C [29]. At temperatures below 15°C and above 30°C this parasitoid is not effective [8]. Females may lay 100-200 eggs over her 4-8 day lifespan [15] and some reports indicate that up to 400 eggs can be laid per female, conditions permitting [25]. The sex ratio ranges from about 1:1 to 2:1 (F:M) depending upon the size of aphids parasitised [14]. This can facilitate rapid control of GPA under the good conditions. Aphids that sense searching *Aphidius* (males or females) will often produce an alarm pheromone which causes aphids to drop from plants. While this behaviour reduces parasitism rates, aphids that drop from plants may die or have decreased reproduction.

Broad spectrum, persistent pesticides have a major impact on this parasitoid. *Aphidius* is made available through Biological Services in Australia.

Aphelinus abdominalis

Aphelinus is a small, stocky parasitoid wasp (about 3 mm) with a black thorax and head and a pale yellow abdomen (Fig. 8). *Aphelinus* will parasitise GPA but is better suited to control of foxglove aphid, *Aulacorthum solani,* and potato aphid, *Macrosiphum euphorbiae* [x]. However, in some instances release of *Aphelinus* may assist management of GPA. Adult *Aphelinus* are much longer lived and are more robust than *Aphidius*. After an aphid is parasitised, an adult wasp may take 2-3 weeks to emerge, depending on temperature, and adults may live up to 60 days under good conditions. They can lay about 10-15 eggs per day although some reports suggest that females lay 100-200 eggs over their 2-3 week adult lifetime [5]. While they can survive temperatures up to 36°C, optimal temperatures range between 15 and 32°C [xi]. *Aphelinus* can feed on up to about 200 species of aphids, sometimes causing significant mortality and parasitism does not disturb aphid colonies the same way as *A. colmani*. Overall, *Aphidius* (not *Aphelinus*) is the parasitoid that should be used to control GPA first, however, if there are multiple aphid species infesting your crop, including relatively large numbers of foxglove or potato aphid, *Aphelinus* may prove useful in controlling minor infestations of GPA.

Fig. 8. *Aphelinus abdominalis* parasitising an aphid.

Broad spectrum, persistent pesticides have a major impact on this parasitoid. *Aphelinus* is made available through Biological Services in Australia.

Mallada signata, green lacewing

The green lacewing has a relatively wide host range, feeding on aphids, spider mites, various scales, mealy bugs, moth eggs and small caterpillars as well as whitefly species. Pollen and nectar can also be ingested. Larvae (Fig. 9a), but not adults, are predacious. Adults have a green body and hold their transparent wings tentlike over their body and feed on pollen and nectar. Females live for 3-4 weeks and lay up to 600 eggs. Almost all lacewing species are predators and often lay their eggs on thin white stalks with a bulbous white egg at the end; most species lay multiple eggs in the same area, most often in a straight or roughly straight line or in a horseshoe arrangement (Fig. 9b). Green lacewing larvae grow to nearly 1 cm in length before pupating and typically place the remains of their prey on top of spines protruding from their back. In fact, research suggests that green lacewing larvae with trash-packages are more active and forage more efficiently, while those without trash-packages are more likely to become inactive [1]. After about 12 days, larvae pupate and emerge as adults about 9 days later.

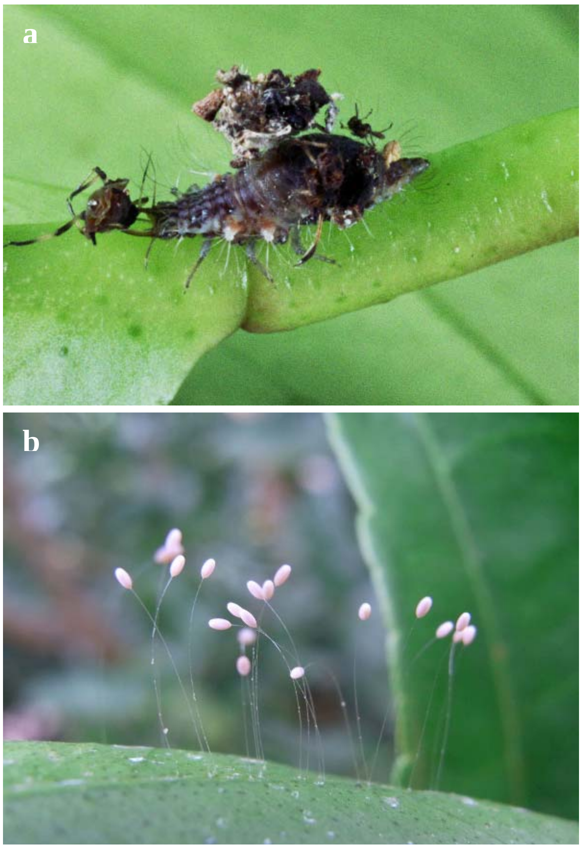

Fig. 9. Larvae of the green lacewing (a) grow to about 8 mm. Eggs are laid in clusters (b), each on a thin stalk. Photos by Dan Papacek.

[x] http://www.syngenta.com/global/bioline/SiteCollectionDocuments/Products/B8%20-%20Aphelinus%20abdominalis.pdf
[xi] http://www.biologicalservices.com.au/aphelinus-a.html;

Females must be about 7 days old before laying their first egg.

It is well adapted to relatively warm conditions and very sensitive to persistent and or broad spectrum chemical applications, although reduced risk pesticides have a relatively minor negative effect on this insect. Green lacewing is made commercially available by Bugs for Bugs.

Orius armatus (*Orius*)

Orius armatus (Fig. 10) is an Australian native pirate bug which is similar to other *Orius* spp. overseas, however, little research into its biology has been completed. *Orius* is mainly a thrips predator but will consume aphids, spider mites, moth eggs and pollen, particularly if thrips prey is not available. *Orius* develops from egg to adult in about 12-18 days at 30-25°C. Adults live for 3-4 weeks. Adults are able to fly and readily disperse to new areas to find prey. *Orius* is light sensitive and less likely to be active during cool, dark periods of the day.

All but the most low toxic insecticides and fungicides will cause significant mortality to *Orius*, e.g. bifenazate and BT sprays are relatively safe but many other products are not. *Orius* is made commercially available by Manchil IPM Services.

Fig. 10. *Orius armatus* nymph on the bud of a chrysanthemum.

Other naturalised beneficials

Lady beetle adults and larvae are major aphid predators which can be promoted and will significantly assist in aphid control. In addition, hover fly larvae, various predatory bugs, native parasitoids and lacewing species which are not commercially available may cause significant mortalities to aphid populations. Such populations can be preserved if broad spectrum and highly residual pesticides are not applied to a crop, particularly early in the season. Monitoring of pest and beneficial populations is extremely important to ensure pest numbers do not build up to damaging levels and to avoid unnecessary chemical applications.

This document was prepared by Andrew Manners (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 Cherie Gambley, Lindy Coates and John Duff for constructive comments which improved this factsheet. Also thanks to Denis Crawford (Graphic Science), Biological Services, Dan Papacek (Bugs for Bugs), Neil Forrester (NSWDPI) and Angus Wilson (CSIRO) for providing images used in the factsheet.

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Table 1. Pesticides currently registered or with minor use permit in Australia for ornamental use against aphids, including GPA and other species. Results presented were from queries of Infopest, 2012 and the APVMA pubcris [xi] and permit [xii] searches. Notes on their use, toxicity to beneficial organisms and the level of resistance (which has been combined according to mode of action group). Check full product labels and/or permits to determine suitability of use. The following table is current as of December 2012.

Mode of action group	**Active ingredient**	**Example product name**	**Registration information**	**Limits on applications per season**	**Action** [xiii]	**Other information**	**Toxicity to beneficials** [xiv]	**Notes on insecticide resistance**
1A	Pirimicarb	Pirimor, Atlas	Registered against aphids on ornamental plants in NSW, WA and Qld only; also registered against a variety of aphid species in specific states on apples, citrus, stone fruit, blueberries, pepino, strawberries, artichokes, asparagus, beetroot, beans, various brassicas, cucurbits, capsicums, kiwano, leeks, okra, peas, radishes, shallots, spinach, Swedes, turnips, tomatoes, watercress, roses and chrysanthemums. Permit 13032 allows application on sweet potato (GPA only), brassica leafy vegetables, chicory and coriander against aphids. Permit 11292 allows application on pyrethrum plants against aphids.	Maximum of 2 non-consecutive aphid sprays per season. If used as the last aphid spray for the season, do not use as the first spray for the next season.	C, S, I T, V	See label – not all crops are registered in all states.	L – 1 week residual.	Low to moderate level, but increasing, resistance reported in south-eastern Australia [12]. Recently, high level resistance reported in WA pulse and oilseed crops [xV]. Low to moderate resistance in Australian cotton [16].
1B	Acephate	Eraser, Lancer	Registered against aphids for ornamental crops in all states.	Spray when infestation occurs and at 14 day intervals.	C, S	Do not apply to carnations later than 6 days before picking. Test on a small number of plants before spraying for the first time to avoid phytotoxicities. Some labels suggest not spraying carnations or chrysanthemums more than once every 28 days.	H – persistence unknown, probably at least 4 weeks.	Widespread mod-high level resistance reported in Australian grains to OPs generally [6].
1B	Dichlorvos	Dichlorvos	Registered against all aphids on ornamental plants inside glasshouses (NOT outdoors).	None specified.	C, I, V	Fog or mist. Do not spray directly onto plants. Phytoxocity may occur to young tomatoes, cucumbers and chrysanthemums.	H – 1-2 week residual.	
1B	Fenamiphos	Redback, Assassinator	Registered against aphids on annual and perennial ornamentals and nursery root stock. Various crops also registered against all aphids, e.g. tomatoes, strawberries, cucurbits, carrots, beetroot, onions, celery, sweet potatoes, lettuce, endive, parsnips and crucifers. Registration of certain crops limited to particular states. Some product labels vary.	None specified	C, S, I	Various withholding periods apply to certain crops, check label for details.	Not known – probably high with moderate residual.	
1B	Maldison	Malathion	Registered against aphids on ornamental flowers and shrubs, in all states except Qld. Specific crops registered against all aphids in various states: cabbage, cauliflowers, tomatoes, cucurbits, lettuce, celery, carrots, beans; woolly aphid on apples and pears, black peach aphid and GPA on stone fruit; citrus aphid on citrus.	None. Repeat every 7-10 days as needed.	C, S, I	Not specified. Labels vary, not all crops are on all labels.	H – 4-12 week residual.	
1B	Methidathion	Supracide, Suprathion	Registered against aphids on ornamentals, trees and shrubs in nurseries.	Apply as needed every 10-14 days	C, S, I	Not specified	H – 4+ week residual.	

Mode of action group	Active ingredient	Example product name	Registration information	Limits on applications per season	Action [xiii]	Other information	Toxicity to beneficials [xiv]	Notes on insecticide resistance
3A	Bifenthrin	Bifenthrin, Talstar	Registered against aphids on ornamental crops.	Repeat as necessary at 10-14 day intervals.	C, I	None on label	H – 8-12 week residual.	Widespread medium to high level pyrethroid resistance in grain and pasture crops, particularly when sprayed frequently [6].
3A	Pyrethrins and piperonyl butoxide	Py-zap, S-py, Py-bo	Registered against aphids on ornamentals.	Not specified	C	Not specified	H – 1-2 week residual.	
3A	Tau-fluvalinate	Mavrik	Registered against aphids on roses, shrubs and other ornamentals.	Not specified	C, I	Do not apply when soil is dry and plants are suffering from moisture stress. Add a wetting agent for hard to wet foliage.	H – probably 4+ week residual.	
4A	Imidacloprid	Confidor, Spectrum	Registered against aphids on ornamental plants. Not all labels have ornamental registration. Permit 11221 allows application on exotic pine, hoop pine and eucalypt nursery plants.	No more than once per annual crop. No more than three sprays for perennials in any 12 month period.	C, I, S	None specified.	H – 2-6 week residual.	None found despite test in Australian grain and pasture [6].
9B	Pymetrozine	Chess	Permit 11973 allows application against aphids on nursery stock seedling and plugs, potted colour, trees and shrubs, foliage plants, palms, grasses and fruit trees (non-bearing and non food). Also registered against GPA and cabbage aphid on brassica vegetables, potatoes (GPA only) and GPA and black peach aphid on stone fruit. Permit 12822 allows application against aphids on snow peas and sugar snap peas.	Do not apply more than 2 applications per cropping season, do not apply consecutively and allow a minimum of 7-14 days between applications.	C, S	See label.	L-M – 1-2 weeks residual.	None reported.
22A	Azadirachtin A and B	Eco-neem, Azamax	Registered against aphids on ornamental crops. Permit 11221 allows application on exotic pine, hoop pine and eucalypt nursery plants.	Apply at 7-10 day intervals while pests are present	C, I	Label recommends addition of a botanical oil at recommended rates. Test on a small number of plants before spraying the entire crop for the first to avoid phytotoxicities.	L-H depending on formulation [24]	None reported, but selection in laboratory setting possible [7].
NA	Botanical oil	Eco-oil	Registered against aphids on ornamental plants.	Apply two sprays 3-5 days apart. Do not apply to plants more than 3 times in a 4-8.	C	Do not apply above 35°C, to plants suffering from heat or moisture stress and do not apply to sensitive flower heads. Test on a small number of plants before spraying the entire crop for the first to avoid phytotoxicities.	L-M – No residual.	None reported.
NA	Fatty acids of K salts	Natrasoap, Hitman	Registered against all aphids on ornamental plants.	Apply 5-7 days apart as needed.	C	Phytotoxicities may occur on delicate ferns, mosses, flowers and plants under stress. Test on a small number of plants before spraying the entire crop for the first to avoid phytotoxicities.	L-M – 0-1 week residual. May reduce parasitism of sprayed aphids [26]. Impact increases with increasing concentration [26].	
NA	Petroleum oils	White oil, biocover	Registered against aphids on deciduous fruit trees and roses. Permit 11815 registered for	Not specified.	C	Colour, appearance and quality of herb crops could change. Test on a small	L-M – 0 residual.	

Mode of action group	Active ingredient	Example product name	Registration information	Limits on applications per season	Action [xiii]	Other information	Toxicity to beneficials [xiv]	Notes on insecticide resistance
			aphids on all culinary herbs, galangal, rocket and chervil, lemon verbena, turmeric, dianthus and roses. Some labels registered for aphids on a wide range of flowering plants, shrubs, woody ornamental and ornamental trees, ornamentals and bedding plants.			number of plants before spraying the entire crop for the first to avoid phytotoxicities. Refer to label for more detail.		
NA	Potassium oleate and citronella oil	Clensel insect and mite killer	Registered against aphids on ornamental and indoor plants.	No limit	C	Spray for two or four days in succession for light and heavy infestations. Do not use on sweet peas, nasturtiums, delicate ferns, horse chestnut, American mountain ash and crown of thorns. Test on a small number of plants before spraying the entire crop for the first to avoid phytotoxicities.	Unknown – probably L-M with 0-1 week residual.	

xi http://services.apvma.gov.au/PubcrisWebClient/welcome.do

xii http://www.apvma.gov.au/permits/search.php

xiii Action: C = contact; S = systemic; I = ingestion; T = translaminar; V = vapour.

xiv In the context of the table, beneficials refers to *Aphelinus abdominalis*, *Aphidius colemani*, *Orius armatus* and *Mallada signata*. Summarised primarily from *The Good Bug Book* [18], http://side-effects.koHppert.nl/ , http://www.biologicalservices.com.au/, http://www.bugsforbugs.com.au/, http://www.biobest.be/neveneffecten/3/3/ and http://www.ipm.ucdavis.edu/PMG/r280390111.html

xv http://www.cesaraustralia.com/sustainable-agriculture/pestfacts-south-eastern/past-issues/2010/pestfacts-issue-no-12-3rd-november-2010/carbamate-resistance-detected-in-green-peach-aphids/

Table 2. Pesticides that have limited use for the nursery industry because they do not have an "ornamental" permit or registration in Australia for use against aphids, including GPA and other species. Results presented were from queries of Infopest, 2012 and the APVMA pubcris [xi] and permit [xii] 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. The following table is current as of December 2012.

Mode of action group	Active ingredient	Example product name	Registration information	Limits on applications per season	Action[xiii]	Other information	Toxicity to beneficials [xiv]	Notes on insecticide resistance
1A	Methomyl	Lannate	Registered against GPA on Peaches and nectarines	Not specified.	C, S, I	1 day withholding period. Do not apply to early peach varieties or to stressed trees.	H – 4-12 week residual	Low level resistance detected in NSW cotton [13].
1B	Azinphos-Methyl	Benthion	Registered against woolly aphid on apples, pears and quinces in NSW, Vic, Tas, SA and WA only.	Not specified.	C, I, V	Not specified.	H – 4-8 weeks	Moderate to high level widespread resistance detected in Australian cotton, grains and pasture industries [16, 17]. Certain products have greater levels of resistance than others; high level resistance detected against omethoate and chlorpyrifos [16]. Application against other insects, when GPA is below economic threshold, will increase the likelihood of resistance in GPA.
1B	Chlorpyrifos	Chlorpyrifos, Lorsban	Some labels registered against GPA on tomatoes only; selected other species on field and pasture crops; against cabbage aphid on cole (brassica); woolly aphid on apples and pears;	Not specified.	C, I, V	None on label. Some labels suggest spray 10-14 days apart.	H – 2-5 week residual.	
1B	Methamidophos	Nitofol, Monitor	Permit 10331 allows application against GPA on Duboisia in Qld only. Also registered against all aphids in brassicas (Qld, WA and NT only), GPA in field grown capsicums, GPA on peaches, potatoes and field grown tomatoes.	Not specified.	C, S, I	See label for withholding periods.	H – 4+ weeks residual.	
1B	Diazinon	Diazinon	Varies by label, registered against all aphids on nursery plants in ACT, NSW, Vic and WA; some labels are not registered in all these states. Otherwise specific aphid species are registered on certain crops, Woolly aphid on apples, cabbage aphid and GPA in various brassicas (not in all states) and GPA and black cherry aphid in stone fruit (not in all states),	Not specified.	C, I, V	Apply as drench or foliar spray. Different crops have different registrations.	H – 2-4 weeks residual.	
1B	Disulfoton	Disulfoton	Registered against GPA on potato, pea aphid, GPA and cowpea aphid on peas and beans and all aphids on bulbs and gladioli. Registration on beans in Vic, SA, WA and Tas only, other registrations in all states.	Not specified	S	Apply to soil, refer to label for details.	Not known, probably high impact with long residual.	
1B	Omethoate	Folimat	Registered against aphids on citrus, potatoes, carnations, chrysanthemums, pelargoniums, roses, callistemons, *Eucalyptus* spp., *Grevillea* spp., paperbarks and wattles; woolly aphid on pears and apples (WA only).	Not specified.	C, S, I	Not specified.	H – probably 4+ weeks.	
1B	Phorate	Thimet, Zeemet	Registered against aphids on carnations, chrysanthemums, dahlias, lily bulbs, azaleas, roses and other woody ornamentals, cabbage, broccoli, cauliflower, Brussel's sprouts, tomatoes (not NT), carrots and potatoes. Per 10460 against aphids on sweet potato.	Refer to each crop, however, often indicates repeat after 4-5 weeks if necessary.	S	Refer to label. Not all products are registered for all crops.	Not known, perhaps low impact [22].	
3A	Beta-cyfluthrin	Tempo, Prolong ultra	Registered against aphids on azaleas, hibiscus, pelargoniums and roses.	None listed.	C, I	None mentioned.	H – 8-12 week residual.	Moderate to high level resistance occurs sporadically, particularly where
3A	Permethrin	Ambush	Registered against GPA and cabbage aphid on cabbage, cauliflower, Brussel's sprouts and	Not specified.	C, I	Not specified.	H – 8-12 week residual.	

Mode of action group	Active ingredient	Example product name	Registration information	Limits on applications per season	Action[xiii]	Other information	Toxicity to beneficials [xiv]	Notes on insecticide resistance
			broccoli (Qld and WA only).					applications have been made prophylactically [6].
4A	Clothianidin	Samarai	Registered against GPA on peaches and nectarines and woolly apple aphid on apples. Permit 12301 for all aphids on Indian/tropical sandalwood and associated trees in mixed species plantation forest (in Qld, NT and WA only).	One or two applications per season depending upon the rate applied.	C, S, T	Can be applied as foliar spray or soil drench. Spray after petal drop on apples. Addition of a surfactant may increase efficacy. Refer to permit for critical use comments in sandalwood and plantations.	Not known, probably similar to imidacloprid.	Resistance not reported in Australia [6], although occurs overseas [3].
4A	Imidacloprid	Initiator	Registered against aphids on roses.	One tablet beneath root ball at time of planting	C, I, S	Can be used on established plants – see label for details.	Foliar: H – 2-4 week residual; Drench: L-H 0-6 weeks residual.	
4A	Thiacloprid	Calypso	Registered against aphids on camellias, maybush and roses.	Use a maximum of three applications per year (including other 4A products).	C, I, S	Do not use on tea camellia.	M-H – 2 weeks residual.	
4A	Thiamethoxam	Actara	Registered against GPA on tomatoes.	Not specified	C, S	Apply to seedlings – see label for specific instructions.	M-H – 2+ weeks residual.	
4A, 28	Thiamethoxam and chlorantraniliprole	Durivo	Registered against GPA and cabbage aphid on brassicas, GPA on fruiting vegetables (excluding cucurbits), GPA and lettuce aphid on leafy vegetables.	Do not use more than one application per crop.	C, I, S	Refer to label for withholding period and specific methods of application.	M-H – 2+ weeks residual.	None reported in Australia.
12A	Diafenthiuron	Pegasus	Permit 11971 allows application against all aphids on non-food nursery stock and non-bearing fruit trees	Two applications within an annual production cycle, which must not be sequentially applied.	C, I	Spray before damage occurs. Requires a closed canopy to obtain best results from fumigant action [17].	M-H – 1-2 weeks residual.	None reported in Australia.
23	Spirotetramat	Movento	Registered against GPA on beans, peas, brassica leafy and non-leafy vegetables, cucurbits (also registered against cotton aphid), eggplant, peppers and leafy vegetables. Also registered against currant lettuce aphid on lettuce and corn aphid on sweet corn. Permit 11839 allows use against GPA on corn.	Do not apply more than 2 applications per crop. Do not re-apply within 14 days.	I, T, S	Refer to label for specific information relevant to each crop.	L – probably 0-1 week residual [20].	None reported in Australia.
M2	S as polysulphide	Lime sulphur	Registered against GPA on fruit trees.	Apply midwinter only.	C	Do not apply with any other insecticide. Do not apply in the heat of the day or when temperatures are above 32°C. Do not spray when trees are wet, just before rain or within 10 days (before or after) of an oil spray.	L-H – 1 week residual.	None reported in Australia.
NA	Paraffin oil	Ecopest oil, Bioclear, Biopest paraffin oil	Registered against aphids on roses and indoor and outdoor ornamentals. Not all labels are registered in all states.	None.	C	Do not spray for at least one month after spraying with sulphur or lime sulphur. Do not spray if shade temperatures exceed 32°C (35°C for citrus), or when soil is dry or plants are suffering moisture stress.	L-M – 0-1 week residual.	None reported in Australia.