

Management of leafmining flies in vegetable and nursery crops in Australia



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Key points

- There are numerous species of leafmining flies established within Australia, most posing little to no economic risk. However, some exotic species are significant pests of horticulture globally, and are a threat to Australian horticulture.
- Identification and in-field monitoring for leafminers is challenging, but support and resources are available.
- Biological control via parasitoid wasps has become a cornerstone of successful leafminer management programs overseas.
- Australia is home to numerous parasitoid wasp species that provide natural control of leafminers.
- There are several insecticides effective in controlling leafminer flies overseas, of which a number of these are now available in Australia.

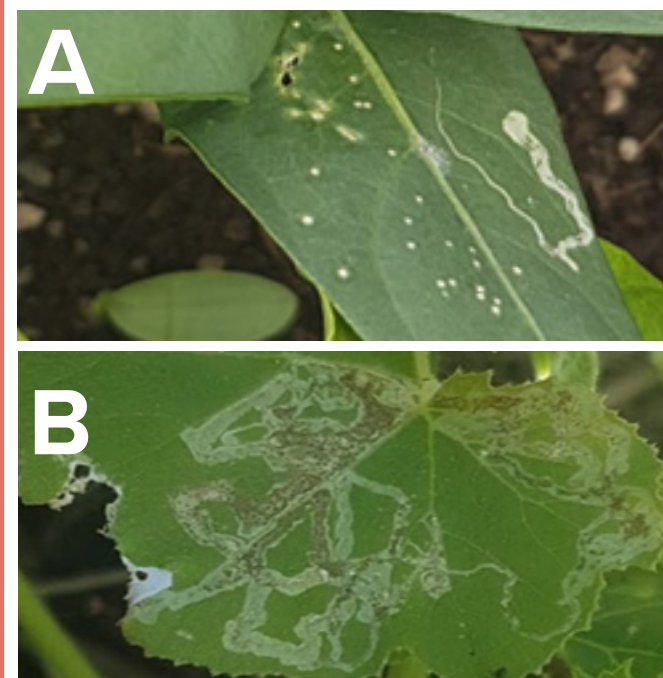
About leafmining flies

Australia has many species of leafminer flies, some of which are occasional pests of cultivated crops. Overseas, several species of polyphagous leafminers are well known pests, posing threats to Australian horticulture (Table 1). These polyphagous species can cause considerable damage, particularly when heavy infestations affect young crops. Yield losses are variable, depending on leafminer species, plant age, environment, pest density and management practices. The exotic leafminers of most concern to horticulture in Australia are vegetable leafminer (*Liriomyza sativae*), potato leafminer (*L. huidobrensis*) and American serpentine leafminer (*L. trifolii*) (Table 1).

Lifecycle and damage







Leafminer flies have four lifestages. Adults create holes to feed on leaves and to lay eggs inside leaves, creating 'stippling' damage (Figure 1A). Upon hatching, larvae tunnel through leaves, feeding and creating thick white trails, called 'leaf mines'. Most damage occurs at the larval stage. Leaf mines can vary in shape from serpentine (Figure 1B) to linear to blotched shapes. Some leafminers are stem feeders (e.g. *Ophiomyia phaseoli*). Depending on species, larvae either pupate inside the leaves or stems, or emerge to pupate in the soil. Adult flies emerge from pupae.

Figure 1. Symptoms in leaves



(A) Stippling damage caused by adult vegetable leafminer on snake bean leaves; (B) leafmining damage caused by vegetable leafminer in cucumber leaves. Images: Elia Pirtle, cesar Pty Ltd.

Table 1. Some naturalised and exotic leafminer flies*

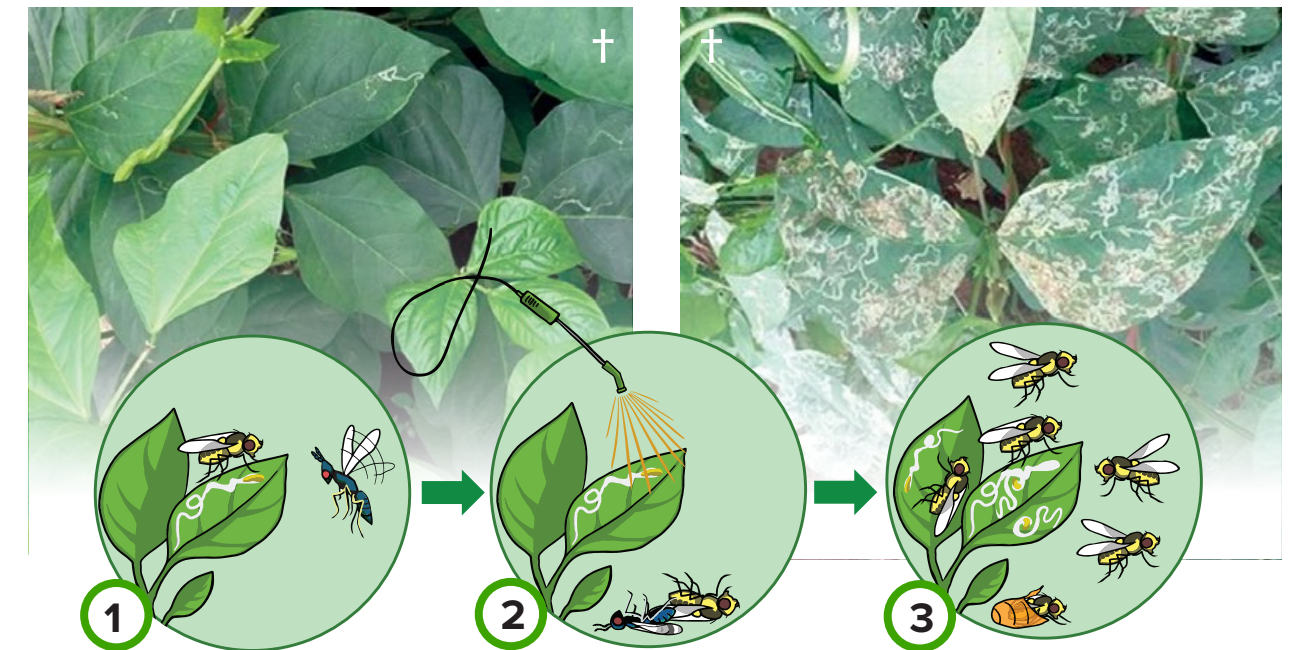
Economic concern	Low	Low	Low	Low	High	High	High
	Cabbage leafminer <i>(Liriomyza brassicae)</i>	Chrysanthemum leafminer <i>(Phytomyza syngenesiae)</i>	Beet leafminer <i>(Liriomyza chenopodii)**</i>	Bean fly <i>(Ophiomyia phaseoli)</i>	Vegetable leafminer <i>(Liriomyza sativae)</i>	American serpentine leafminer <i>(Liriomyza trifolii)</i>	Potato leafminer <i>(Liriomyza huidobrensis)</i>
				no photo available			
Mine type	leaf	leaf	leaf	stem	leaf	leaf	leaf
Common hosts	brassicas	sowthistle	beets, chickweed	beans	beans, melons, tomatoes and others	capsicum, melons, potatoes, beans and others	potatoes, tomatoes, beans, brassicas, and others
Present in Australia? (as of June 2020)	Yes	Yes	Yes	Yes	Yes (Seisia, QLD)***	No	No

* Image source: Central Science Laboratory, Harpenden, British Crown, Bugwood.org

** Image source: National Plant Protection Organization, the Netherlands, Bugwood.org

When chemical control backfires

Only one of these bean plants has been treated with insecticide, but which one it is may surprise you...



Leafminer fly outbreaks overseas

The plant in the right-hand image was treated weekly with insecticide sprays, but only accumulated heavy damage after treatment. These images come from a study conducted in Ecuador[†] exploring the nature of leafminer flies as 'secondary pests', or those that do not become problematic until their natural enemies are disrupted:

- 1 Leafminer flies are naturally controlled by parasitoid wasps.
- 2 Non-selective insecticides destroys parasitoid wasps but not leafminer flies (due to insecticide not reaching larvae within leaves, or because of insecticide resistance).
- 3 Without parasitoids, leafminers are no longer controlled naturally and populations can grow substantially.

Overseas, problems with leafminers are universally associated with destruction of their natural enemies, parasitoid wasps, by excessive use of non-selective insecticides. It has been demonstrated repeatedly that conservation of parasitoids is one of the foundations of successful integrated pest management (IPM) programs overseas, and that an integrated plan must take into account all chemical use in a system.

Previous page:

* Lepidopteran leafminers are also common on beans and other crops.
** *L. chenopodii* is a native species but native hosts are as yet unknown.
*** As of June 2020, *L. sativae* is established within Seisia, QLD, but is under quarantine.

Foundations of an IPM approach

- **Monitor pest activity:** apply economic thresholds to delay and reduce sprays to allow parasitoid populations to build.
- **Avoid broad-spectrum insecticides:** do not target leafminer flies with inappropriate chemicals (carbamates, organophosphates and synthetic pyrethroids); consider softer chemicals when targeting other pests when leafminer activity is high.
- **Understand role of parasitoids:** understand the signs of parasitism to determine if visible leaf mining damage is associated with an active leafminer population or a population already controlled by wasps; understand the role of non-crop hosts (non-pest leafminer flies) as reservoirs of parasitoids.

Avoid leafminer outbreaks by monitoring during high risk periods and by choosing softer chemicals

This page:

[†] Image source: Chirinos, DT., Castro, R., and Garces, A. (2017) Effects of insecticides on *Liriomyza sativae* (Diptera: Agromyzidae) and its parasitoids in bean, *Phaseolus vulgaris*. Revista Colombiana de Entomologia, 43 (1), 21-26.

An integrated approach to control

Selecting insecticides

Contact insecticides control leafminers poorly as they only kill adults. To control leafminer larvae developing inside the leaf, effective insecticides must be systemic or translaminar (e.g. abamectin, cyromazine) (Figure 2 & Table 2). Translaminar insecticides may have short lived surface residues, making them less disruptive to beneficial wasps.

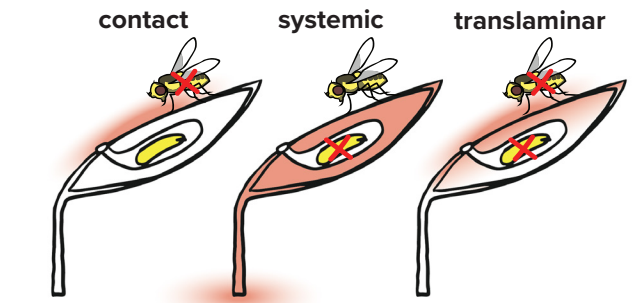
Toxicity to beneficials

Secondary pest outbreaks following the destruction of parasitoids by insecticides have been documented frequently with leafminer pests. To avoid these outbreaks, insecticides with minimal disruption to parasitoid populations should be selected. Consideration must also be given to the impact of insecticides targeting other pests. For example, the use of organophosphates/synthetic pyrethroids against *Helicoverpa* or imidacloprid against whitefly will interfere with parasitoids and could cause outbreaks of leafminer. Overseas, successful management plans rely on insecticide rotations that are compatible with all pests and natural enemies in a system. Figure 3 shows insecticides used for leafminer control overseas, four of which are also available for use in Australia, grouped by toxicity to parasitoids (Table 2).

Insecticide resistance

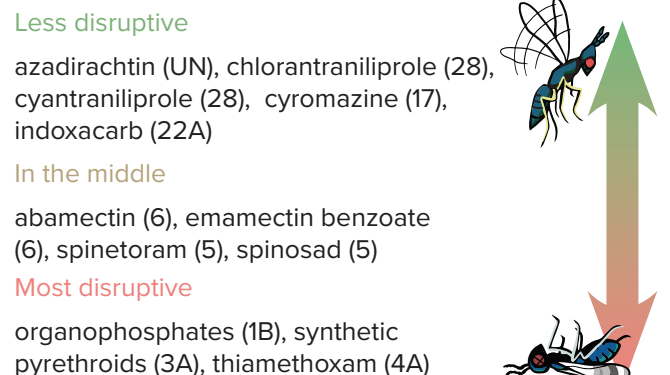
In many countries, reliance upon insecticides as the main control method for leafminer pests has led to some leafminer species evolving resistance to synthetic pyrethroids (3A), organophosphates (1B), toxaphene (2A), DDT (3B), spinosad (5), abamectin (6), cyromazine (17), and diamides (28). Reducing

Figure 2. Insecticide modes



X's indicate mortality of leafminer adult or larva
 ■ indicates dispersal of chemical on/in plant tissue

Figure 3. Insecticide toxicity to parasitoids



Some of these insecticides do not yet have permits and/or labels for use in Australia. Check APVMA for all current permits and labels. MoA groups shown in parentheses†.

the applications and rotating insecticides across MoA groups is the best way to minimise resistance evolution.

Table 2. Chemicals available for use against leafminer flies under minor-use permits (P) or labels (L) in Australia *

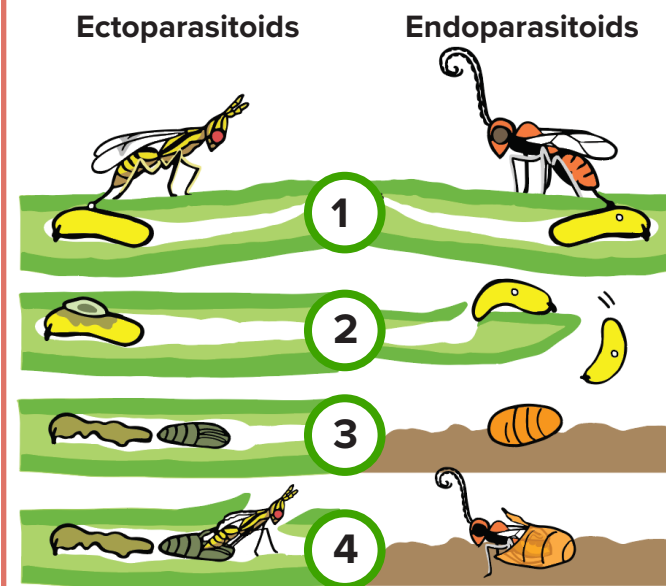
Chemical	MoA group**	Activity**	Labels/permits in AUS														
			lettuce	cely	curcubits	peas and beans	fruiting vegetables	nursery stock/ fruit trees (non-food)	brassicas	leafy vegetables (excl. lettuce)	root and tuber vegetables	onion	bulb vegetables	rhubarb			
Cyromazine	17	T						P									
Abamectin	6	C/T	P	P	P	P			P	P	P	P	P	P	P		
Emamectin benzoate	6	T							P								
Dimethoate	1B	C/S						L									

* As of February 2020

** T = translaminar ; C = contact ; S = systemic ; MoA = Mode of Action

† Fig 3 Sources: DeLittle, S (2018). Review of chemical management options for the vegetable leafminer, *Liriomyza sativae*, in Australian horticultural crops ; CottonInfo (2019). Cotton Pest Management Guide ; GRDC (2019). Insecticide resistance in the southern region: current status, future risk and best management practices.

Figure 4. Lifecycles of parasitoid wasps



- | | |
|---|---|
| <ol style="list-style-type: none"> Female wasp lays egg on or in fly larva. Wasp egg hatches and feeds on fly larva. After consuming the fly, the wasp pupates inside the leaf mine. Adult wasp emerges from the leaf mine. | <ol style="list-style-type: none"> Female wasp lays egg on or in fly larva. Wasp egg stays dormant until fly larva emerges and pupates. Wasp egg activates, consuming pupating fly. Wasp emerges from otherwise healthy looking fly pupa. |
|---|---|



A parasitoid wasp hunting a leafminer larva inside a leaf mine. Image: Elia Pirtle, cesar Pty Ltd.

Natural control by beneficials

The most effective natural control of leafminer comes from parasitoid wasps. Mortality results from parasitism, or by stinging and feeding by adult wasps. Unassisted field mortality rates can reach as high as 80%.

Australia has at least 50 species of parasitoid wasps that attack native leafminer flies. Of these, many are known to also attack exotic leafminer pests, including *Hemiptarsenus varicornis*, *Diglyphus isaea* and *Opius spp.*, three species particularly important for leafminer management overseas. In addition, some Indo-Australian species such as *Zagrammosoma latilineatum* may play important roles should exotic leafminers establish in Australia (Table 3).

Parasitoids have a variety of lifecycles which influence observable signs of parasitism. Parasitoids can generally be classified as "endoparasitoids", which emerge from fly pupae, and "ectoparasitoids", which emerge from leaf mines (Figure 4).

Table 3. Key parasitoid wasps that attack leafminer flies in Australia

<i>Opius spp.</i>	<i>Diglyphus isaea</i>	<i>Hemiptarsenus varicornis</i>	<i>Zagrammosoma latilineatum</i>
<ul style="list-style-type: none"> Endoparasitoid Recorded in all states At least three different species of this group attack native leafminers in Australia Unknown whether Australian species will attack exotic leafminer 	<ul style="list-style-type: none"> Ectoparasitoid Present in southeastern Australia (but likely only recently established) Mass reared overseas for biological control 	<ul style="list-style-type: none"> Ectoparasitoid Recorded in all states Important source of control overseas Early exploiter of new exotic leafminer 	<ul style="list-style-type: none"> Ectoparasitoid Sampling limited, recorded in QLD, NSW and VIC to date Major source of leafminer control in Far North QLD Ecology and biology is poorly understood

Monitoring for pest and beneficials

A cornerstone of successful IPM programs overseas is the use of economic thresholds to delay and reduce pesticide sprays to allow parasitoid populations to build up. For economic thresholds to be implemented successfully, effective monitoring techniques are needed.

How do I monitor on my farm?

1. Choose a block of crops (at least 30 rows of plants) that may be at high risk of leafminer outbreaks, due to being:
 - A preferred host crop (see Table 1).
 - Near to transport routes and unloading areas.
 - The 'incoming wind side' of paddock edges.
2. Within the block, survey by following a snaking transect line (red dotted line in Figure 5), which begins with any broadleaf weeds present along the highest risk edge of the block (grasses do not need to be inspected) and travel down every other row of plants (Figure 5).
 - Scan plants at a slow walking pace of 10 seconds per 1 metre*.
3. Record your survey results.

*The recommendation of 10 sec/metre aims to maximise detection likelihood, based on experimental data that explored the trade-off between slower search pace and larger area coverage.

How do I tell old damage from fresh damage?

The presence of leaf mines is not enough to determine if a population of leafminer requires management. Leaf mines may be old, or may contain more parasitoids than fly larva. In both cases, insecticide application would be inappropriate. More reliable assessments of leafminer activity can be made by looking for healthy larvae or signs of parasitism within leaf mines, using a hand lens (Figure 6), or monitoring for pupae and adults via traps (Figures 7 and 8).

Monitoring with traps

Sticky traps

Commercially available yellow sticky traps attract adult leafminers and may be used to monitor leafminer populations, especially in closed cropping. Trapping may also reduce leafminer damage rates within closed cropping. Traps should

Figure 5. Surveillance guidelines

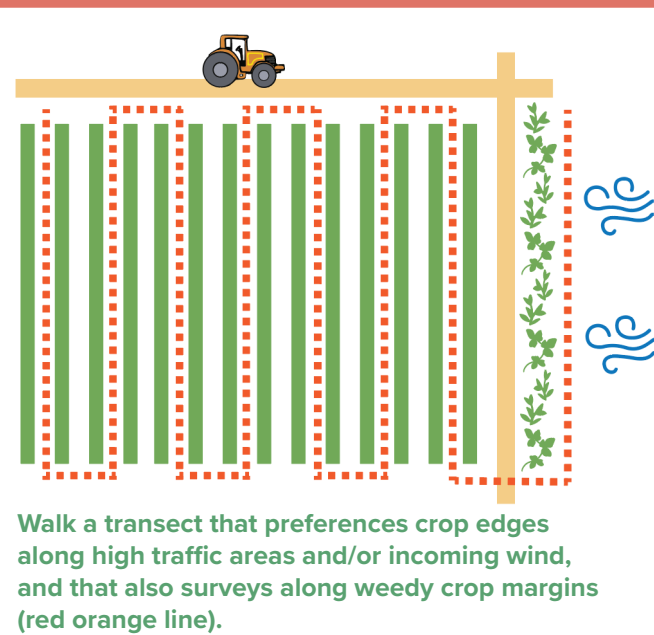


Figure 6. Signs of parasitism



Signs of parasitism visible under a microscope or hand lens. Top: A wasp larva (solid arrow) inside a leafmine, near a leafminer larva carcass (dotted arrow). Bottom: A wasp pupa inside a leafmine (solid arrow). Images: Elia Pirtle, cesar Pty Ltd.

Figure 7. Sticky traps



A yellow sticky trap (left) hung at plant canopy height above a tomato plant, and a vegetable leafminer adult captured on a trap (right). Images: Elia Pirtle, cesar Pty Ltd.

be hung at about plant canopy height.

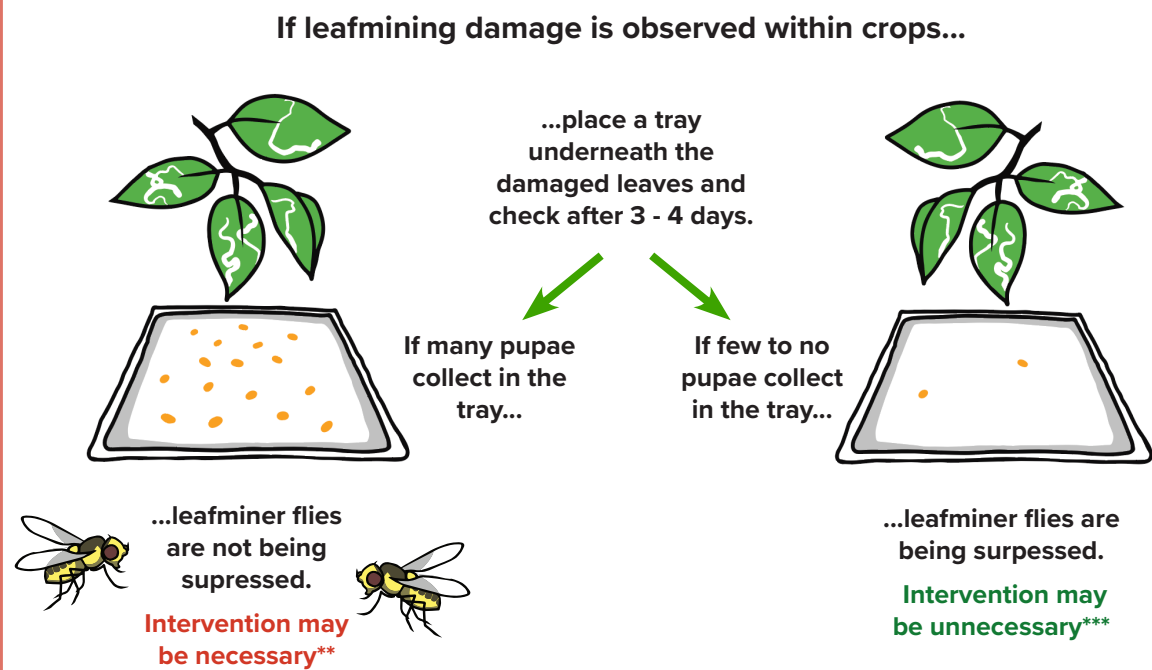
Erecting sticky traps in a young crop may give you an indication that flies may be moving into the crop (potentially from a neighbouring paddock).

Pupal trays

In California, in fresh market tomatoes, scientists and consultants measure leafminer activity by collecting mature larvae fallen into polystyrene trays over a period of 3-4 days (Figure 8). Visit the UC IPM management page for *Liriomyza* (see 'Useful Resources' section, pg 8) to learn more about this sampling technique.

If exotic leafminers establish in Australia, pupal trays could be an effective monitoring tool, although they would require some validation under local conditions.

Figure 8. Using pupal trays to monitor activity of *Liriomyza* leafminers*



* This technique does not work for leafminer flies which pupate inside the leaf. However, exotic leafminers of high economic concern to Australia all emerge from leaves to pupate.

** If endoparasitoid wasps (see Figure 4) are present, the number of pupae collected in the tray may still overestimate the fly population. Pupae can be collected and stored in sealed plastic bags with a damp paper towel until emergences of flies and/or wasps occur, to determine the level of endoparasitism.

*** Thresholds for pupa counts within trays have not yet been developed within Australia for the exotic leafminers of high economic concern. If these leafminers establish, this technique would need to be validated, and thresholds developed.

FAQs

How do leafminers spread?

Adults can disperse by wind, however, most spread overseas has been a result of human-assisted movement. Leafminers can hitchhike on goods, aircraft, vehicles, or the movement of plant material. Eggs and larvae may be spread via live plant material or cut flowers. Plants showing no outward signs of infestation may already be harbouring eggs. Pupae may be spread with crop debris or soil coming from infested areas.

What are some known reservoirs of parasitoid wasps?

There are many other species of leafminer flies in Australia that may act as reservoirs of beneficial wasps, including leafminers that attack a range of weeds such as sowthistle, plantain, brassicaceous weeds and volunteer grasses. More research is needed to identify other reservoirs and determine how they could be manipulated to improve biological control of leafminers in crops.

How can biocontrol be applied in glasshouses?

Some parasitoid wasp species are mass reared for augmentative control in glasshouses overseas, including *Diglyphus isaea*, already found naturally in Australia. There are currently no parasitoids being mass reared for leafminer control in Australia, and more research is needed to determine the potential for rearing wasp species already present here.

Contact Dr Elia Pirtle with any questions or feedback:

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Useful resources

- UC IPM Pest Management Guidelines: Tomato (2016). <https://www2.ipm.ucanr.edu/agriculture/tomato/leafminers/>
- CottonInfo (2019). Cotton Pest Management Guide. <https://www.cottoninfo.com.au/publications/cotton-pest-management-guide>

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