Preparedness for the vegetable leafminer in vegetable and nursery crops in Sydney, NSW

Resource prepared for project MT14006 workshop
October 2019

Key points

- **Vegetable leafminer (VLM) is a significant pest of horticulture globally, and a recent threat to Australian horticulture.**
- **Identification and in-field monitoring for VLM is challenging, but support and resources are available.**
- **Biological control via parasitoid wasps has become a cornerstone of successful VLM management programs overseas.**
- **Australia is home to at least 95 parasitoid wasp species that might provide natural control of VLM.**
- **There are several insecticides effective in controlling VLM, and a selected number of these are now available in Australia.**

Hort Innovation

EXOTIC PEST - CALL THE HOTLINE IF SUSPICIOUS ON 1800 084 881

About the pest

Pest and Impact

The exotic leafminer fly, *Liriomyza sativae* (vegetable leafminer - VLM), was detected on mainland Australia at the coastal town of Seisia on Cape York Peninsula in 2015. It is now under quarantine but represents a major risk to Australian horticulture, particularly **the vegetable industry, melons industry, and the nursery and gardens industry.** Overseas, VLM is a well known pest and can cause considerable damage, particularly when heavy infestations affect young crops. Yield losses are variable, depending on plant age, environment, pest density and management practices. The impact of VLM (left unmanaged) is predicted to be high across the eastern coast of Australia (Figure 1).

Lifecycle and seasonality

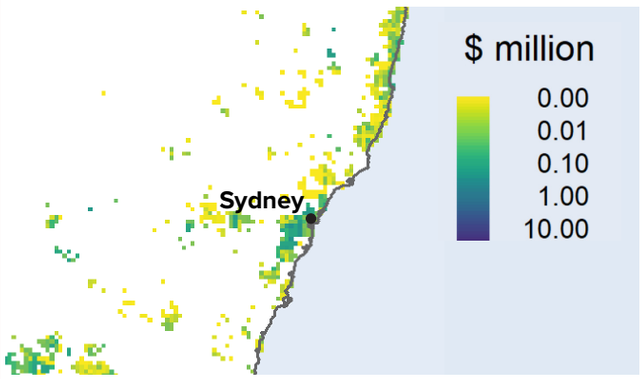
VLM has four lifestages. Adults create holes to feed on leaves and to lay eggs inside leaves, creating 'stippling' damage. Upon hatching, larvae tunnel through leaves, feeding and creating thick white trails, called 'leaf mines' (see 'Monitoring' section on pg 3). Larvae then emerge from the leaves to pupate in the soil and finally emerge as a fly. At 25°C, the lifecycle takes about 3 weeks. Most damage occurs at the larval stage. Heavy leaf mining can reduce plant growth or even kill young plants. Oviposition and feeding holes created by adults exposes plants to secondary infection.

In coastal NSW, VLM risk is expected to be highest during the spring and autumn, when the climate is most suitable for their growth (Figure 2). Early detection surveillance should focus on this period. Risk is expected to be low during the summer and winter. See the 'Useful resources' section (pg 7) for a link to an online, interactive map to explore regional risk across season and crop at your location.

Seasonality in glasshouses

Active periods for VLM will be increased inside glasshouses, and if plants are growing, they should be considered at risk, regardless of season. For example, in northern Chinese provinces where winter temperatures fall below survivable temperatures for VLM, they are able to successfully overwinter as pupae within greenhouses, and repopulate the field in the spring.

Fig 1. Predicted impact in Sydney



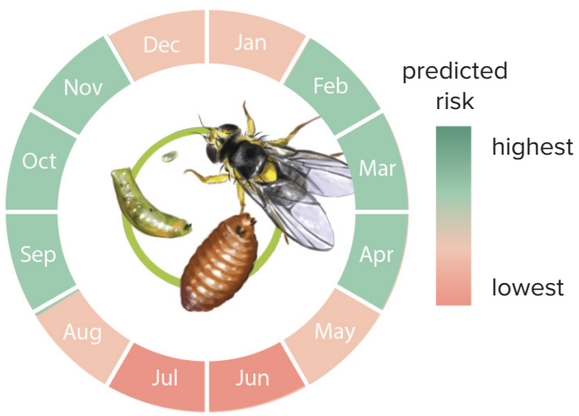
Predicted impact (in dollars) of VLM in the Sydney region, based on climate and crop value.

Fig 2. Crops at risk of VLM in Sydney

- Cabbage
- Cucumber
- Eggplant
- Head brassica
- Head lettuce
- Leafy Asian vegetables
- Sweet corn
- Nursery (ornamentals and vegetable seedlings)
- Cut flowers

Major commodities grown in the Sydney Region.

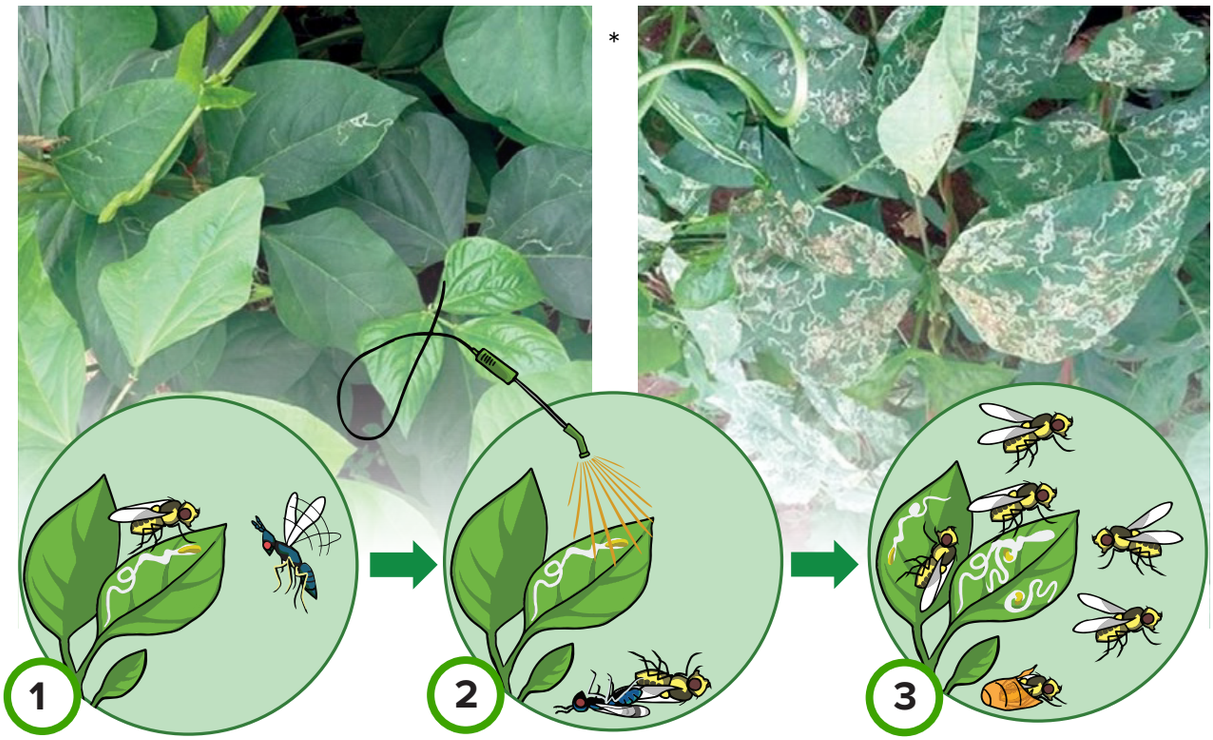
Fig 3. Predicted seasonality in Sydney



Average predicted seasonality of VLM within 100km of Sydney, NSW. Risk is predicted to be highest during the spring and autumn, and lowest during peak summer and winter.

When chemical control backfires

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



VLM outbreaks overseas

The plant in the right-hand image was treated weekly with insecticide, but only accumulated heavy damage after treatment. These images come from a study conducted in Ecuador* exploring the nature of VLM as a 'secondary pest', or one that does not become problematic until its natural enemies are disrupted. In the case of VLM:

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

Overseas, problems with VLM are universally associated with destruction of their natural enemies, parasitoid wasps, by excessive use of non-selective insecticides that target VLM or any number of other pests. 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.

Foundations of an IPM approach

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

Avoid VLM outbreaks via monitoring and 'wasp-safe' chemical choices during high risk periods

** Image source (photographs): Chirinos et al. 2017*

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Monitoring

Why should I monitor?

VLM is most likely to cause problems early upon arrival, before chemical management plans have been adjusted to conserve parasitoids. Early detection monitoring for VLM will ensure that correct chemical choices can be made as soon as VLM arrive, to avoid sudden outbreaks and crop losses, and to increase the chance of local containment or eradication. Monitoring also forms a cornerstone of a successful IPM approach to managing VLM.

What should I look for?

Adult VLM are very small, black and yellow flies that are difficult to see by eye. Surveillance should focus on the damage they create on plants:

Symptoms visible on leaves

- White serpentine mines (A, B)
- Stippling appearance (C)

Symptoms visible on fruit

- Fruits are unaffected, with the exception of bean pods which may show leaf mines (D)

It is important to note that some native flies create very similar looking damage (see back page). Always photograph suspicious damage and contact **the Exotic Plant Pest Hotline**.

Where and when do I look?

Crops at risk include tomato, capsicum, chilli, eggplant (Solanaceae), melon, pumpkin, squash, zucchini (Cucurbitaceae), and beans (Fabaceae). VLM also attacks weeds in other plant families such as Asteraceae and Brassicaceae. Ornamentals (e.g. snap dragon and petunia), and most Allium species, including onions and garlic are also at risk. Surveillance will be most important when a high predicted population potential overlaps with young crops (see 'Seasonality' section on pg 1).

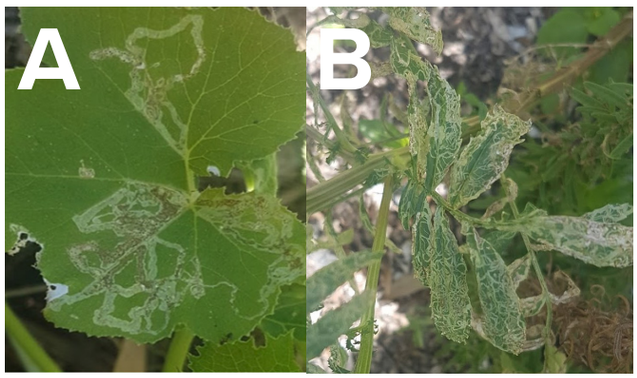
Can traps be used?

Commercially available yellow sticky traps attract adult VLM. If you report suspicious damage, you may be advised to hang traps nearby. Traps should be hung at about plant canopy height, and be collected within 2 weeks, by gently folding sticky side inwards, placing in a sealed plastic bag and storing in a refrigerator (not freezer) until analysis can be arranged.

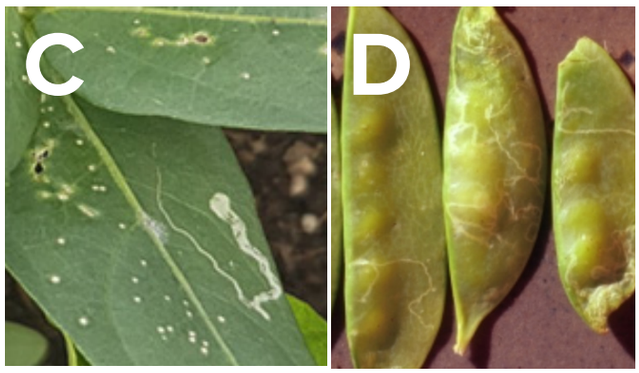
Actual size:

1-2 mm

Fig 4. Symptoms in leaves



Moderate damage on melons (left) and heavy damage on ornamental flowers (right)



Stippling and mining damage on beans (left) and mining in bean pods (right)

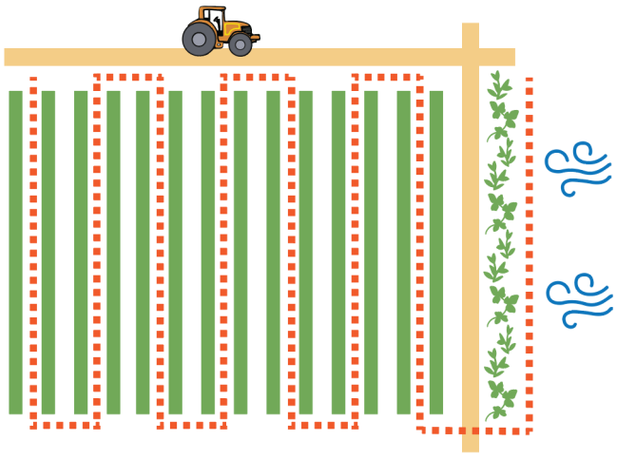
Can I confidently identify VLM under a hand lens or by the shape of the leaf mine?

Unfortunately, no. VLM are only identifiable in their adult stage, and even then only can be distinguished from native fly species by an expert. Moreover, leafminer fly species already found in Australia can create indistinguishable leaf mines on the same crops that could be affected by VLM, including brassicas, asters, beets and beans.

Molecular methods will be key for identifying incursions of VLM. This means sample collection is invaluable.

If you see something suspicious, always take a sample and contact **the Exotic Plant Pest Hotline on 1800 084 881.**

Fig 5. To survey, walk a transect...



Walk a transect that preferences crop edges along high traffic areas and/or incoming wind, and that also surveys along weedy crop margins (dotted orange line).

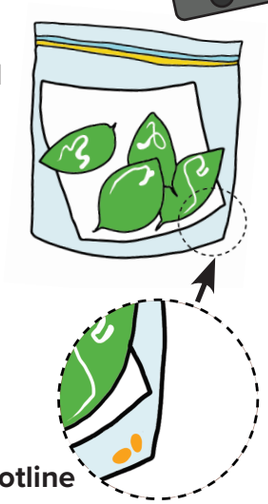
and for each plant...

Scan
leaves for leaf mines

Snap
a photo of damaged leaves

Collect
and label leaf mines and store in a refrigerator

You may observe small orange pupae collecting at the bottom of the bag within a day. These are very valuable for genetic identification.



Call
The Exotic Plant Pest Hotline

IF YOU SEE ANYTHING UNUSUAL, CALL THE EXOTIC PLANT PEST HOTLINE

1800 084 881

How do I survey my farm?

1. Choose a block of crops (at least 30 rows of plants) that may be at high risk, due to being:
   - An at risk crop (Figure 2)
   - 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 (orange 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.

How do I assess each plant?

1. **Scan**: Scan upper surfaces of leaves as you walk, looking for signs of stippling or mining.
2. **Snap:** Take a photo of any suspicious damage and record a GPS point.
3. **Collect:** Take a sample of the damage
   - Place a sheet of paper towel into a large plastic freezer bag, followed by the affected leaves. Seal the bag, partially inflated, and place bag in a dark cool place (ideally a refrigerator).
     - Collect as many mined leaves as possible.
     - You may notice small orange pupae collecting at the bottom of the bag. These are very valuable for genetic identification, and greatly increase chances of identification.
   - Label the bag using a permanent marking pen with the following information:
     - Your name; contact number; date; address, town, postcode; crop type.
   - Immediately report the suspicious damage to **the Exotic Plant Pest Hotline on 1800 084 881**. This will put you in touch with the Department of Primary Industries or Agriculture in your state or territory.

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

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An integrated approach to control

Selecting insecticides

Contact insecticides control VLM 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 6/Table 1). Translaminar insecticides may have short lived surface residues, making them less disruptive to beneficial wasps.

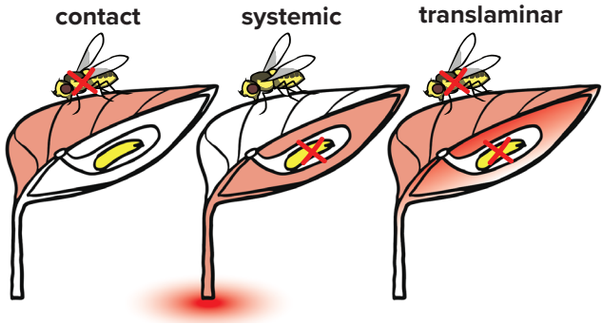
Toxicity to beneficials

Secondary pest outbreaks following the destruction of parasitoids by insecticides have been documented frequently with VLM. 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 VLM. Overseas, successful management plans rely on insecticide rotations that are compatible with all pests and natural enemies in a system. Figure 7 shows insecticides used for leafminer control overseas, four of which are also available for use in Australia, grouped by toxicity to parasitoids (Table 1).

Insecticide resistance

In many countries, reliance upon insecticides as the main control method for VLM has led to resistance evolving to synthetic pyrethroids. Similarly, it is likely Australian populations of VLM will develop resistance to synthetic pyrethroids or have the potential to evolve this resistance readily.

Fig 6. Insecticide modes



X's indicate mortality of VLM adult or larva
indicates presence of chemical on/in plant tissue

Fig 7. Insecticide toxicity to parasitoids*

Less disruptive

azadirachtin (UN), chlorantraniliprole (28), cyantraniliprole (28), **cyromazine (17)**, indoxacarb (22A)

In the middle

abamectin (6), **emamectin benzoate (6)**, spinetoram (5), spinosad (5)

Most disruptive

organophosphates (1B), synthetic pyrethroids (3A), thiamethoxam (4A)

Insecticides in bold are to date available for use against leafminer (as a permit or label) in Australia. Others are as yet only available overseas for use against leafminer. MOA groups shown in parantheses.

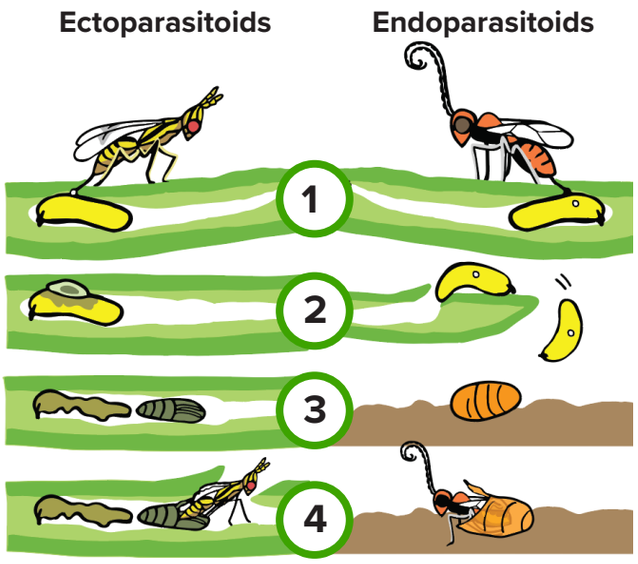
Table 1. Chemicals available for use against leafminer under minor-use permits (P) or labels (L) in Australia

Chemical	MoA group*	Activity*	Labels/permits in AUS											
			lettuce	celery	cucurbits	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	T		P	P	P	P		P	P	P	P	P	P
Emamectin benzoate	6	T							P					
Dimethoate	1B	C/S						L						

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

Fig 7 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.

Fig 8. Lifecycles of parasitoid wasps



Ectoparasitoids	Endoparasitoids
1 Female wasp lays egg on or in fly larva.	1 Female wasp lays egg on or in fly larva.
2 Wasp egg hatches and feeds on fly larva.	2 Wasp egg stays dormant until fly larva emerges and pupates.
3 After consuming the fly, the wasp pupates inside the leaf mine.	3 Wasp egg activates, consuming pupating fly.
4 Adult wasp emerges from the leaf mine.	4 Wasp emerges from otherwise healthy looking fly pupa.

A parasitoid wasp hunting a VLM larva inside a leaf mine

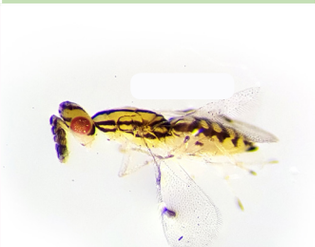
Natural control by beneficials

The most effective natural control of VLM comes from parasitoid wasps. Unassisted field rates of parasitism can reach as high as 80%. In protected cropping, mass rearing and release of wasps is used extensively overseas.

Australia has at least 95 species of parasitoid wasps that attack native leafminer flies. 70 of those parasitoids are species known to attack VLM, including *Hemiptarsenus varicornis*, *Diglyphus isaea* and *Opius* sp., three species particularly important for VLM management overseas. In addition, some Indo-Australian species already show signs of very effective VLM control on the incursion front in Far North QLD, including *Zagrammosoma latilineatum* (Table 2).

Parasitoids have a variety of lifecycles which influence observable signs of parasitism. Parasitoids can generally be classified as “endoparasites”, which emerge from fly pupae, and “ectoparasites”, which emerge from leaf mines (Figure 8).

Table 2. Key parasitoid wasps that attack leafminer flies in Australia

Opius sp.	*Diglyphus isaea*	*Hemiptarsenus varicornis*	*Zagrammosoma latilineatum*
			
• Endoparasite • Recorded in all states • At least three different species of this group attack native leafminer in Australian	• Ectoparasite • Present in southeastern Australia (but likely only recently established) • Mass reared overseas for biological control	• Ectoparasite • Recorded in all states • Controls VLM in Far North QLD • Important source of control overseas • Early exploiter of new exotic leafminer	• Ectoparasite • Poorly sampled, recorded in QLD and VIC to date • Major source of VLM control in Far North QLD • Ecology and biology is poorly understood

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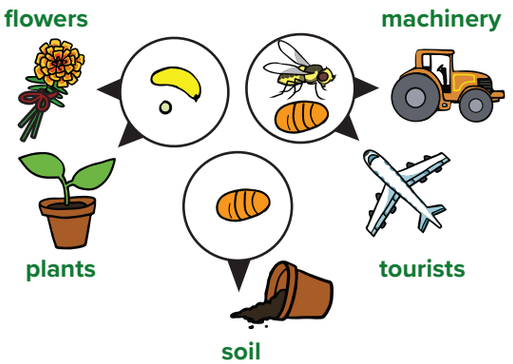
Frequently asked questions

How can VLM spread?

Adults can disperse by wind, however, most spread overseas has been a result of human assisted movement (Figure 9). VLM 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 associated with infested areas.

Fig 9. Human assisted spread



What are some known reservoirs of the parasitoid wasps?

There are many other species of leafminer flies in Australia that may act as reservoirs of beneficial wasps, including leafminer that are specific to saltbush, or that are specific to grasses and cereals. More research is needed to identify other reservoirs and determine how they could be manipulated to improve biological control of VLM.

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. Mass emergence devices, that can be filled with infested plant material and use mesh filters to allow only parasitoids to escape, can be used to build parasitoid populations within glasshouses. However these have not been commercialised.

How can I tell if VLM are being naturally controlled by parasitoids?

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 innapropriate. More reliable assessments of VLM activity can be made by looking for healthy larvae within leaf mines, using a hand lens, or placing trays below plants to determine if pupae are emerging (Read more at the UC IPM Pest Management Guidelines).

Useful resources

- ***https://bowengumlugrowers.com.au/***
- An interactive tool to explore VLM risk across region and season. ***https://ausveg.com.au/biosecurity-agrichemical/biosecurity/mt16004/***
- IPCC (2016). ISPM 27 Diagnostic protocols for regulated pests; DP 16: Genus Liriomyza. ***https://www.ippc.int/static/media/files/publication/en/2017/01/DP_16_2016_En_2017-01-30.pdf***
- UC IPM Pest Management Guidelines: Tomato (2016). ***http://ipm.ucanr.edu/PMG/r783300911.html***
- CottonInfo (2019). Cotton Pest Management Guide. ***https://www.cottoninfo.com.au/publications/cotton-pest-management-guide***
- GRDC (2019). Insecticide resistance in the southern region: current status, future risk and best management practices. ***(https://grdc.com.au/resources-and-publications/all-publications/publications/2019/insecticide-resistance-in-the-southern-region-current-status,-future-risk-and-best-management-practices)***

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