# Leafminer pest-generic incursion management plan for the Australian vegetable industry

Elio Jovicich
Department of Employment,
Economic Development & Innovation

Project Number: VG06113

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This report is published by Horticulture Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetable industry.

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the vegetable industry.



ISBN 0 7341 2154 7

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399



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# Leafminer pest-generic incursion management plan for the Australian vegetable industry

Common name: Leafminers (Diptera: Agromyzidae)

Group species: *Liriomyza sativae* (Blanchard 1938)
*Liriomyza huidobrensis* (Blanchard 1926)
*Liriomyza trifolii* (Burgess 1880)
*Liriomyza bryoniae* (Kaltenbach 1858)
*Chromatomyia horticola* (Goureau 1851)

August 2009

Prepared by Elio Jovicich, Queensland Primary Industries, DEEDI
Project No. VG06113. Funded by Horticulture Australia Limited

**Purpose of this report:**
The currently exotic leafminers species *Liriomyza trifolii*, *L. sativae*, *L. huidobrensis*, *L. bryoniae*, and *Chromatomyia horticola* are insects known to damage many vegetable species overseas and can cause economic damage to the vegetable industry if they enter and establish in Australia without any pest response plan in place.

The purpose of this pest-generic incursion management plan for the vegetable industry is to provide background information on the biology; potential geographic distribution of the pest; likely damage caused to the industry; diagnostic tools; available control measures; sampling methods for use in survey procedures; and key experts to contact, to assist with the preparedness for an incursion of these leafminers into Australia.

The report follows guidelines for the steps to be undertaken and considered when developing a Response Plan for this pest group. Any Response Plan developed using information in whole or in part from this Contingency Plan must follow procedures as set out in PLANTPLAN and be endorsed by the National Management Group prior to implementation.

**Funding Sources:**
Horticulture Australia Ltd
AUSVEG
Queensland Primary Industries & Fisheries

August 2009



For more information on this report contact:

Elio Jovicich
Horticulture and Forestry Science
Queensland Primary Industries and Fisheries
Department of Employment, Economic Development and Innovation

Telephone: 07 4720 5107
Postal Address: Ayr Research Station, PO Box 15, Ayr, QLD 4807, Australia
Email: elio.jovicich@deedi.qld.gov.au

Photo in cover page: Leaf (*Capsicum annuum*) with mines made by *Liriomyza trifolii* (photo by Consejería de Agricultura y Pesca, Sevilla, Spain). Insert photos are from <http://entnem.ufl.edu/creatures/>; top right: Adult leafminer (*Liriomyza sativae*) credits: Lyle J. Buss, University of Florida, and bottom left: Adult leafminer (*Liriomyza trifolii*) credits: Lyle J. Buss, University of Florida.

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Acronyms

| | |
|---|---|
| AQIS | Australian Quarantine and Inspection Service |
| APVMA | Australian Pesticides and Veterinary Medicines Authority |
| AUSVEG | Australian Vegetables |
| BA | Plant Biosecurity |
| DAFF | Department of Agriculture, Fisheries and Forestry |
| EPP | Emergency Plant Pest |
| EPPO | European and Mediterranean Plant Protection Organization |
| HAL | Horticulture Australia Limited |
| IPPC | International Plant Protection Convention |
| NAQS | Northern Australia Quarantine Strategy |
| PHA | Plant Health Australia |
| PRR | Pest Risk Review |
| PRA | Pest Risk Analysis |
| QPIF | Queensland Primary Industries and Fisheries |

Summary

A key group of closely-related species in the genus *Liriomyza* and *Chromatomyia* cause serious economic damage to many vegetable crop species throughout the world and is exotic to Australia. The adults of these insect species are flies that as larvae live and feed within plant leaves and share a wide range of hosts, especially economically-important vegetables, ornamentals, and weeds. The present broad geographical distribution of this group of leafminers is attributed to the shipment of infested plant parts from one region to another. A preparedness response plan for Australia is outlined as these insects could eventually invade the country affecting production and trade in the vegetable industry. The incursion management plan covers contents outlined by Plant Health Australia and includes: general information of the pests as a group species; the potential geographical distribution of key exotic leafminers in Australia in relation to climate; the likely damage caused to the industry; diagnostic tools; pest management strategies; and suggests sampling methods for use in survey procedures. In the event of a positive identification, steps necessary to quickly respond to a new pest incursion are framed within the PLANTPLAN communications strategy and action plan. The information in this pest-generic management plan provide guidelines for the leafminer pest group and can be reviewed for use in a Response Plan that can be an appendix in the National Vegetable Industry Biosecurity Plan in PLANTPLAN, and which will need to be endorsed by the National Management Group prior to implementation.

Leaf mines in cucumber. Photo: Elio Jovicich

# 1 Pest Information / Status

## 1.1 Pest group details – Key exotic leafminers

### 1.1.1 General information

Insects of the family Agromyzidae (Diptera) consist of small flies that are morphologically similar and whose larvae feed internally on plants, in many cases as leaf miners. Only a few species in the Agromyzidae are highly polyphagous and have become significant pests of vegetables in many parts of the world. A group of closely-related leafminers species from the Agromyzidae, which are not yet (as of 2009) present in Australia, pose a significant quarantine threat. In the genus *Liriomyza*, four polyphagous species have been identified by Plant Health Australia (PHA) as top incursion pests and as a "high risk" threat to the Australian vegetable industry (PHA, 2006; 2007). These four species are included in the emergency plant pest priority list of the Vegetable Industry Biosecurity Plan (PHA, 2007). Another exotic polyphagous leafminer species in the genus *Chromatomyia*, also in the Agromyzidae, is regarded as a threat pest to a number of vegetable crop species (PHA, 2007; Malipatil and Ridland, 2008; Ridland et al., 2008). This group of insect species, identified hereafter as the key exotic leafminers discussed in this pest-generic management plan, includes: ***Liriomyza sativae*** (vegetable leafminer), ***L. huidobrensis*** (serpentine leafminer), ***L. trifolii*** (American serpentine leafminer), ***L. bryoniae*** (tomato leafminer), and ***Chromatomyia horticola*** (pea leafminer). Leafminer species in this group are also listed as potential exotic pests in the National Industry Biosecurity Plans for Onion, Potato, Grains, and Nursery and Garden.

There are other *Liriomyza* species not discussed in this pest management plan which are considered threat pests to other agricultural industries (e.g. *L. cicerina* in chickpeas in the Grain Industry) but are of less significance to crops in the Vegetable Industry group. The response to a leafminer incursion in Australia will require an integrated effort among the groups of crop industries in order to contain polyphagous leafminers and minimise their impact. Peter Ridland, Mallik Malipatil and Plant Health Australia recently prepared a threat specific contingency plan for Agromizid leafminers for the Grains National Biosecurity Plan (*Liriomyza trifolii*, but including also *L. cicerina, L. huidobrensis, L. sativae, L. bryoniae*, and *Chromatomyia horticola*) (PHA, 2009).

In Australia, Malipatil and Ridland (2008) recently reviewed and compiled vast amounts of information on the taxonomy and biology of leafminer species, including the five key exotic leafminers. The published work, *Polyphagous Agromyzid Leafminers*, exists in an open access Lucid key server which can be located at <http://keys.lucidcentral.org/keys/v3/leafminers/index.htm>. The present pest management plan does not cover every detail in the biology and taxonomy of each of the species in the key exotic group. URL links to the Lucid key and other websites which contain information on many aspects of the biology of leafminer species are given in this report so that further specific information can be located. URL links are also given to find images of the insects and of the damage they cause to plants.

Flies (adult stage) and larvae (immature stage) of the key exotic leafminer species cause damage to plants in different ways. Flies make punctures on the leaf surface when they lay eggs or feed on sap. The damage caused by punctures may sometimes be regarded as of inferior importance. However, when the eggs hatch, larvae tunnel inside leaves as they feed, leaving winding trails that are visible through the leaf surface. This damage caused by the larvae stages is of greater importance as it can reduce photosynthesis and also lead to defoliation in highly infested plants. In addition to leaves of many vegetables, larvae may also tunnel in petioles (e.g. in vegetable seedlings, and celery plants), and the surface of pods in some legumes (e.g. in peas). Both types of damage, punctures and leaf mines, reduce the cosmetic quality of high-value vegetable crops (e.g. leafy commodities and pea pods) to such an extent that they can make the produce unmarketable. When outbreaks of leafminer occur on seedlings and young plants, plants can develop abnormally and slowly, have a reduced marketable yield, or even die, therefore causing substantial economic losses.

The key exotic leafminers are distributed worldwide and are native or endemic pests in countries that may export ornamentals or fresh vegetable produce to Australia. Geographical origins of species in the exotic group range from central and south America to Europe. Distribution of the *Liriomyza* species from the American continent to Europe occurred during the 1980s and to Asia during the 1990s. Species like *L. huidobrensis*, *L. sativae*, and *L. trifolii*, are now spread across South Asia and Oceania (CAB International, 2007) with some of these species already present in proximity to Australia, in Indonesia, East Timor, and the nearby islands of Micronesia. In Australia, many of the vegetable production regions have climates that closely match those of regions overseas where these leafminer pests are native or endemic.

The key leafminers are currently (as of 2009) absent from mainland and insular Australia. However, these leafminers species have been intercepted during inspections of imported commodities (CAB International, 2007). In 2008, *L. sativae* was detected on a tomato plant on Warraber (Sue) Island, Torres Strait (IPPC, 2008). Following eradication measures, *L. sativae* is under surveillance and has since not been detected on the island (IPPC, 2008; QPIF, 2009).

Overseas, the key exotic leafminer species are particularly important pests of many vegetables and ornamentals that are grown in the field or as protected crops (e.g. in glasshouses and polyethylene-covered greenhouses and tunnels). Leafminer species in the key exotic group share numerous hosts. These hosts are many of the grown vegetable and ornamental species as well as common weed species present in Australia. The flies and larvae are morphologically similar and molecular tests may be required in order to diagnose them to the level of species. The symptoms on leaves caused by different leafminer species are also alike.

The key exotic leafminer species are considered to have invaded countries via movement of infested plants or plant materials (e.g. cut flowers and propagation material of some ornamental plant species). It is not believed that the adult leafminers are able to fly long distances and that flying is a key transportation means to spread into new distant regions. However, it has been suggested that air currents could carry flies, and that leafminer species that have already invaded East Timor could eventually reach Australia (PHA, 2006; 2007). *L. sativae* and *L. huidobrensis* are listed by the Northern Australia Quarantine Strategy as target exotic pests that can potentially enter Australia from East Timor, Indonesia or Papua New Guinea via the Australian northern border by natural or non-conventional pathways, including wind currents, traditional vessel movements and illegal fishing activity (NAQS, 2009). Leafminers can also arrive in Australia on plant materials illegally moved by humans from overseas countries that are not intercepted by quarantine or customs officials.

As in Australia, many countries inspect imported fresh produce to ensure that it is free of leafminers and their damage. In the event of a leafminer incursion and establishment in Australia, market access may be disrupted with countries where these pests represent a quarantine threat. The domestic markets for many vegetable crops and ornamentals may also be affected even if it is possible to contain the new leafminer pest within a region/s. To move vegetable produce outside of regions where a new leafminer pest is present, it may be required to demonstrate that the pest was absent in the crop for an established period of time before the produce is shipped, or that effective control treatments are implemented prior to shipment. Similar requirements are in place in EPPO regions that import any plant material that is a known host of leafminers. It is expected that containment of the pests within a region will be difficult in the long term due to the regular transport of fresh commodities that occurs in Australia.

The leafminers species initially became important pests in agriculture because of the harmful effect of non-target pesticides on native parasitoids. Under natural conditions, the larvae of leafminer species are parasitized by several natural enemies. With inadequate biological control, leafminers can reach high populations and cause economic losses. Recent research in Australia and Asia found that leafminer parasitoids are present in some regions of Australia and that could have a positive effect in controlling new invasive leafminer species. Pesticides that will cause minimal disruption to parasitoids or predators of leafminers (native or alien species that might be introduced later on) will have to be included in the pest management program following a leafminer incursion and spread within Australia. This will lessen the pest management problems (e.g. resistance development to pesticides, excessive use of pesticides in food produce, and disruption of biological control) that occur where chemical control is the main control method used. In the event of a leafminer incursion, parasistism and predation should be evaluated during leafminer surveys so that the best pest management strategy can be identified.

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Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

### 1.1.2 Exotic leafminers included in the group

Taxonomic position of the two genera in the group of key leafminers:

Phylum: Arthropoda
Class: Insecta
Order: Diptera
Family: Agromyzidae

Genus: *Liriomyza*
Genus: *Chromatomyia*

It is important to note that not all of the morphologically similar flies in the genus *Liriomyza* and *Chromatomyia* are considered important pests of vegetables and that some of the species in these genera are already present in Australia (Malipatil and Ridland, 2008). Sixteen *Liriomyza* species which are considered non key pests occur in Australia mainland, with an additional species in Lord Howe Island (Malipatil and Ridland, 2008). Only one species in the genus *Chromatomyia* (i.e. *C. syngenesiae*) occurs in Australia. Refer to Malipatil and Ridland (2008) for more details on leafminers that are present in Australia.

The following tables list the names for the key exotic species in the leafminer group. Links to selected web information sources are given here in order to locate detailed information on each species.

| Scientific name: | ***Liriomyza trifolii* (Burgess 1880)** |
|---|---|
| **Synonyms:** | *Liriomyza alliovora* Frick 1955 |
| **Common names:** | American serpentine leafminer, serpentine leafminer, broad bean leafminer, Californian leafminer, celery leafminer, chrysanthemum leaf miner |
| **Status in Australia:** | Absent; intercepted only; quarantine pest (CAB International, 2007) |

**Selected sources of information for this species:**

Factsheet: Nomenclature, Hosts, Distribution, Key characters, Notes, References, WWW resources
**Polyphagous Agromyzid Leaf miners** (Malipatil and Ridland, 2008)
<http://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Liriomyza_trifolii.htm>

Datasheet: Identity, Hosts, Geographical distribution, Biology, Detection and Identification, Means of Movement and Dispersal, Pest significance, Phytosanitary measures
**EPPO datasheet on quarantine pests: *L. trifolii*** (EPPO, 1992)
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_trifolii/LIRITR_ds.pdf>

Important characters, Host plants, Distribution, Economic importance
**Agromyzidae (Diptera) of economic importance** (Dempewolf, 2004)
<http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&record=Liriomyza%20trifolii>

| Scientific name: | ***Liriomyza huidobrensis* (Blanchard 1926)** |
|---|---|
| **Synonyms:** | *Agromyza huidobrensis* Blanchard 1926;<br>*Liriomyza cucumifoliae* Blanchard 1938;<br>*Liriomyza langei* Frick 1951;<br>*Liriomyza dianthi* Frick 1958 |
| **Common names:** | serpentine leafminer, pea leafminer, South American leafminer, potato leafminer fly |
| **Status in Australia:** | Absent; intercepted only; quarantine pest (CAB International, 2007) |

**Selected sources of information for this species:**

Factsheet: Nomenclature, Hosts, Distribution, Key characters, Notes, References, WWW resources
**Polyphagous Agromyzid Leaf miners** (Malipatil and Ridland, 2008)
<http://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Liriomyza_huidobrensis.htm>

Datasheet: Identity, Hosts, Geographical distribution, Biology, Detection and Identification, Means of Movement and Dispersal, Pest significance, Phytosanitary measures
**EPPO datasheet on quarantine pests: *L. huidobrensis*** (EPPO, 1992)
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_huidobrensis/LIRIHU_ds.pdf>

Important characters, Host plants, Distribution, Economic importance
**Agromyzidae (Diptera) of economic importance** (Dempewolf, 2004)
<http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&id=76>

| Scientific name: | ***Liriomyza sativae*** **(Blanchard 1938)** |
|---|---|
| **Synonyms:** | *Liriomyza pullata* Frick 1952;<br>*Liriomyza canomarginis* Frick 1952;<br>*Liriomyza minutiseta* Frick 1952;<br>*Liriomyza propepusilla* Frost 1954;<br>*Liriomyza munda* Frick 1957;<br>*Liriomyza guytona* Freeman 1958 |
| **Common names:** | vegetable leafminer, American leafminer, chrysanthemum leafminer, serpentine vegetable leafminer, melon leafminer |
| **Status in Australia:** | Absent; intercepted only; quarantine pest (CAB International, 2007); found on a plant in Warraber Island (Torres Strait) in 2008, eradicated and under surveillance (IPPC, 2009) |

**Selected sources of information for this species:**

Factsheet: Nomenclature, Hosts, Distribution, Key characters, Notes, References, WWW resources
**Polyphagous Agromyzid Leaf miners** (Malipatil and Ridland, 2008)
<http://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Liriomyza_sativae.htm>

Datasheet: Identity, Hosts, Geographical distribution, Biology, Detection and Identification, Means of Movement and Dispersal, Pest significance, Phytosanitary measures
**EPPO datasheet on quarantine pests: *L. sativae*** (EPPO, 1992)
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_sativae/LIRISA_ds.pdf>

Important characters, Host plants, Distribution, Economic importance
**Agromyzidae (Diptera) of economic importance** (Dempewolf, 2004)
<http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&id=84>

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| Scientific name: | ***Liriomyza bryoniae*** **(Kaltenbach 1858)** |
|---|---|
| **Synonyms:** | *Agromyza bryoniae* Kaltenbach 1858;<br>*Liriomyza solani* Hering 1927;<br>*Liriomyza citrulli* Rohdendorf 1950 |
| **Common names:** | tomato leafminer |
| **Status in Australia:** | Absent; intercepted only; quarantine pest (CAB International, 2007) |

**Selected sources of information for this species:**

Factsheet: Nomenclature, Hosts, Distribution, Key characters, Notes, References, WWW resources
**Polyphagous Agromyzid Leaf miners** (Malipatil and Ridland, 2008)
<http://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Liriomyza_bryoniae.htm>

Datasheet: Identity, Hosts, Geographical distribution, Biology, Detection and Identification, Means of Movement and Dispersal, Pest significance, Phytosanitary measures
**EPPO datasheet on quarantine pests:** *L. bryoniae* (EPPO, 1992)
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_bryoniae/LIRIBO_ds.pdf>

Important characters, Host plants, Distribution, Economic importance
**Agromyzidae (Diptera) of economic importance** (Dempewolf, 2004)
<http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&record=Liriomyza%20bryoniae>

| | |
|---|---|
| **Scientific name:** | ***Chromatomyia horticola* (Goureau 1851)** |
| **Synonyms:** | *Agromyza atricornis* Meigen 1830 *nomen dubium*; *Phytomyza geniculata* Macquart 1835 *nomen dubium*; *Phytomyza atricornis* (partim) Meigen 1838 sensu Hendel 1920; *Phytomyza horticola* Goureau 1851; *Phytomyza cucumidis* Macquart 1855; *Phytomyza tropaeoli* Dufour 1857; *Phytomyza fediae* Kaltenbach 1860; *Phytomyza linariae* Kaltenbach 1862; *Phytomyza pisi* Kaltenbach 1864 ; *Phytomyza subaffinis* Malloch 1914; *Napomyza lactucae* Vimmer 1926; *Phytomyza bidensivora* Séguy 1951; *Phytomyza nainiensis* Garg 1971 |
| **Common names:** | pea leafminer |
| **Status in Australia:** | Absent; intercepted only; quarantine pest (CAB International, 2007) |

**Selected sources of information for this species:**

Factsheet: Nomenclature, Hosts, Distribution, Key characters, Notes, References, WWW resources
**Polyphagous Agromyzid Leaf miners** (Malipatil and Ridland, 2008)
<http://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Chromatomyia_horticola.htm>

Important characters, Host plants, Distribution, Economic importance
**Agromyzidae (Diptera) of economic importance** (Dempewolf, 2004)
<http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&id=54>

Brief description
**Leafminers of Europe** (Ellis, 2007)
<http://www.bladmineerders.nl/minersf/dipteramin/chromatomyia/horticola/horticola.htm>

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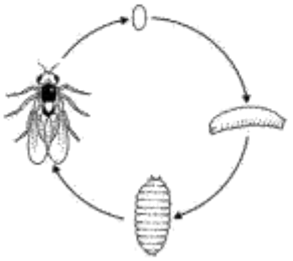
### 1.1.3 General life cycle

The general life cycle of a leafminer consists of six stages: egg, three larval stages (instars), pupa and adult. The following diagram represents a general life cycle of a leafminer (source: KOPPERT Biological Systems <http://www.koppert.com/>).




The differences in morphology are small among the key exotic leafminer species. The following insect dimensions are general for the group. The adult leafminers are small flies (ca. 1.5 to 2 mm long). Adult *Liriomyza* leafminers have black and yellow markings on the head and the thorax. Eggs are oval (ca. 0.25 x 0.10 mm), off-whitish colour to translucent, and are inserted just beneath the leaf surface. The larvae (ca. lengths for $1^{st}$ instar: 0.6 mm, $2^{nd}$ instar: 1.6 mm, and $3^{rd}$ instar: 2.5 to 3 mm long x 1 mm diam.) are of white yellowish colour. The larvae form mines as they feed in the leaves of plants. Some authors include a description of a fourth larval stage occurring between puparium and pupation formation. Pupae are oval (ca. 1.5 to 2 mm long and 0.75 mm diam.) and gold-yellow to dark black colour.

Adults are active at sunrise and during the morning. Mating occurs within one or two days after the adults emerge from the pupa. A single mating may be sufficient to fertilise all eggs. Soon after mating, the females begin to lay eggs. Unfertilised females do not lay eggs. The females puncture leaves to feed on plant sap and to lay eggs. Males feed on punctures made by females. Both sexes lap up the liquid exuding from the leaf punctures. The eggs are inserted singly under the epidermis of the leaf. Many eggs can be laid on one leaf. Approximately 15% of the leaf punctures have eggs. The number of eggs laid depends on temperature and host plant. Under optimal conditions (25 ºC), females can lay an average of 250 eggs during their approximately 30-day lifespan. Eggs hatch after 2 to 6 days and the small larvae begin feeding (mining) below the epidermis, on the upper and/or the lower surface of leaves. The whitish mines become wider (up to ca. 1.5 mm) as the larva increases in size. Larvae of *Liriomyza* ($3^{rd}$ instar larvae) exit the fully developed mines (in 4 to 7 days in the summer) in order to pupariate, usually in the soil nearby or on the floor or ground cover in greenhouses, and sometimes on the surface of the leaf. In the case of *C. horticola*, pupariation occurs within the mine, and the anterior spiracles usually project out from the lower surface of the leaf.

Peak emergence of adults occurs before midday. Adults emerge 7 to 14 days after pupation at temperatures in the range of 20 to 30 ºC (time decreases with high temperatures). The pupal stage may last up to 90 days during periods of low temperatures (10 to 12 ºC). In regions with cool winters, this may account for winter survival. In contrast to *L. trifolii*, the species *L. bryoniae* and *L. huidobrensis* can have a diapause (delay of development) and can tolerate lower temperatures (Malais and Ravensberg, 1992). Adults will first appear in early spring, after over-wintering as pupae in the litter or soil beneath infested plants.

As with all insects, temperature greatly affects survival, fecundity, length of life stages and therefore population growth. The complete life cycle of leafminers can be as short as 14 days at 30 ºC, 24 days at 20 ºC, and 65 days at 14 ºC. There might be many overlapping stages of the insect life cycle within a greenhouse or field-grown host crop in warm climate regions. In these environments, leafminer reproduction is continuous and 10 to 14 generations per year may occur. In Canada and northern regions of Europe and Asia, the key *Liriomyza* leafminers are not known to overwinter except in heated greenhouse environments.

General images of leafminer life stages can be located at the web links that are listed below. Additional web links of mine images in several host species are listed in Section 1.2.5.

**Adult** images

*L. sativae* adult (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-AD.013.html>

*L. trifolii* adult (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LTRI-AD.002.html>

*L. trifolii* adult (Coutin R. / OPIE)
<http://www.inra.fr/hyppz/IMAGES/7032120.jpg>

*L. huidobrensis* adult (Rasplus J.-Y. / INRA Versailles)
<http://www.inra.fr/hyppz/IMAGES/7032100.jpg>

*L. bryoniae* female laying eggs (Coutin R. / OPIE)
<http://www.inra.fr/hyppz/IMAGES/7032091.jpg>

*C. horticola* adult (Shigenobu Aoki)
<http://aoki2.si.gunma-u.ac.jp/youtyuu/HTMLs/namoguribae.html>

*C. horticola* adult and mines and pupa in lettuce (Jarmo Holopainen)
<http://www.pbase.com/holopain/image/53849432/medium>

**Larva and leaf mine** images

Leafminer larva (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-LV.004.html>

*L. trifolii* larvae and mines in bean leaf (Lyon J.-P. / INRA)
<http://www.inra.fr/hyppz/IMAGES/7032124.jpg>

*C. horticola* mines in pea leaves (Fukushima Perfecture)
<http://www.pref.fukushima.jp/fappi/byougai_library/yasai/hamoguri-library/namo-higai-enndou.JPG>

**Leaf mine and punctures** images

Leafminer mine and feeding punctures (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LISP-CD.012.html>

*L. huidobrensis* damage on lettuce seedlings (Rasplus J.-Y. / INRA Versailles)
<http://www.inra.fr/hyppz/IMAGES/7032102.jpg>

## **Egg and punctures** images

*L. huidobrensis* egg extracted out from an oviposition puncture in a lettuce leave (Rasplus J.-Y. / INRA Versailles)
<http://www.inra.fr/hyppz/IMAGES/7032101.jpg>

## **Leaf mine** images

*L. sativae* mine on tomato (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-CD.016.html>

*C. horticola* mine (Shigenobu Aoki)
<http://aoki2.si.gunma-u.ac.jp/youtyuu/HTMLs/namoguribae.html>

## **Pupa** images

Leafminer pupa on a leaf (Jack Kelly Clark, UC IPM Online)
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-PU.005.html>

*L. huidobrensis* pupae on an onion leaf (Merle Shepard, Gerald R. Carner, and P.A.C. Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia, Bugwood.org)
<http://www.forestryimages.org/browse/detail.cfm?imgnum=5368097>

*L. huidobrensis* puparium formed at the end of the larval gallery (Coutin R. / OPIE)
<http://www.inra.fr/hyppz/IMAGES/7032103.jpg>

*L. trifolii* puparium extracted from the larval gallery (Lyon J.P. / INRA)
<http://www.inra.fr/hyppz/IMAGES/7032125.jpg>

*C. horticola* puparium within the leaf mine (Merle Shepard, Gerald R. Carner, and P.A.C. Ooi, Insects and their Natural Enemies Associated with Vegetables and Soybean in Southeast Asia, Bugwood.org)
<http://www.forestryimages.org/browse/detail.cfm?imgnum=5368108>

*C. horticola* pupa; the top pupa was purposely uncovered (Shigenobu Aoki)
<http://aoki2.si.gunma-u.ac.jp/youtyuu/HTMLs/namoguribae.html>

The Lucid key by Malipatil and Ridland (2008) includes factsheets for all the key exotic leafminers as well as for leafminers that occur in Australia (e.g. *L. chenopodii*, *L. brassicae* and *C. syngenesiae*). Additional information on the life cycles of each species is included in the leafminer contingency plan for the Australian Grains Industry prepared by Ridland et al. (2008). Short descriptions of leafminer life cycles and effects of temperature on insect development in each species can be located at the web links of the references listed below. For *Liriomyza* species refer to Biology section in the EPPO datasheet on quarantine pests [links below]. For *C. horticola* refer to Bionomics section for the species in Dempewolf (2004) [link below].

*L. sativae*:

EPPO. 1992. Datasheet on quarantine pests: *Liriomyza sativae.* European and Mediterranean Plant Protection Organisation. Paris, France.
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_sativae/LIRISA_ds.pdf>

Capinera, J.L. 2001. Vegetable leafminer, *Liriomyza sativae*. Featured creatures. Dept. of Entomology and Nematology, Univ. of Florida & Division of Plant Industry, Fla. Dept. of Agriculture and Consumer Services, FL, U.S. (Revised Oct. 2007)
<http://entnemdept.ifas.ufl.edu/creatures/veg/leaf/vegetable_leafminer.htm>

*L. huidobrensis*:

EPPO. 1992. Datasheet on quarantine pests: *Liriomyza huidobrensis.* European and Mediterranean Plant Protection Organisation. Paris, France.
<http://www.eppo.org/QUARANTINE/insects/Liriomyza_huidobrensis/LIRIHU_ds.pdf>

Steck, G.J. 1999. Pea leafminer, *L. huidobrensis.* Featured creatures. Dept. of Entomology and Nematology, Univ. of Florida & Division of Plant Industry, Fla. Dept. of Agriculture and Consumer Services, FL, U.S. (Revised April 2004) <http://entnemdept.ufl.edu/creatures/veg/leaf/pea_leafminer.htm>

*L. trifolii*:

EPPO. 1992. Datasheet on quarantine pests: *Liriomyza trifolii*. European and Mediterranean Plant Protection Organisation. Paris, France. <http://www.eppo.org/QUARANTINE/insects/Liriomyza_trifolii/LIRITR_ds.pdf>

Capinera, J.L. 2001. American Serpentine leafminer, *Liriomyza trifolii.* Featured creatures. Dept. of Entomology and Nematology, Univ. of Florida & Division of Plant Industry, Fla. Dept. of Agriculture and Consumer Services, FL, U.S. (Revised Dec. 2007) <http://www.entnemdept.ufl.edu/creatures/veg/leaf/a_serpentine_leafminer.htm>

*C. bryoniae*:

EPPO. 1992. Datasheet on quarantine pests: *Liriomyza bryoniae.* European and Mediterranean Plant Protection Organisation. Paris, France. <http://www.eppo.org/QUARANTINE/insects/Liriomyza_bryoniae/LIRIBO_ds.pdf>

Dempewolf, M. 2004. *Liriomyza bryoniae* (Celery miner fly). CD-ROM on Agromyzidae (Diptera) of economic importance. Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum Amsterdam. <http://nlbif.eti.uva.nl/bis/agromyzidae.php?menuentry=soorten&id=67>

*C. horticola*:

Dempewolf (2004) (link below) <http://ip30.eti.uva.nl/bis/agromyzidae.php?selected=beschrijving&menuentry=soorten&id=54>

CAB International. 2007. Crop Protection Compendium, 2007 Edition. CAB International, Wallingford, UK. <http://www.cabicompendium.org/>

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CAB International. 2007. Crop Protection Compendium, 2007 Edition. CAB International, Wallingford, UK. <http://www.cabicompendium.org/>

Dempewolf, M. 2004. CD-ROM on Agromyzidae (Diptera) of economic importance. Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum Amsterdam. Available online at <http://ip30.eti.uva.nl/bis/agromyzidae.php>

EPPO. 2009. European and Mediterranean Plant Protection Organisation. Paris, France. <http://www.eppo.org/>

EPPO. 2009. EPPO A2 List of pests recommended for regulation as quarantine pests (version 2008-09). Datasheets; Geographical distribution; Diagnostic protocols; Pictures. <http://www.eppo.org/QUARANTINE/listA2.htm>

Malais, M. and W.J. Ravensberg. 1992. Knowing and recognizing: the biology of glasshouse pests and their natural enemies. Koppert Biological Systems, the Netherlands. 109 p.

Malipatil, M. and P. Ridland. 2008. Polyphagous Agromyzid leafminers. Department of Primary Industries, Victoria. <http://keys.lucidcentral.org/keys/v3/leafminers/index.htm>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

### 1.1.4 Reference PRR / PRA datasheet

The Pest Risk Review (PRR) includes: pest identification (pest name, plant hosts, parts of the plant that are affected, and brief information on world pest distribution); likelihood of entry, establishment and spread; likely consequences (economic impact); and overall risk. Refer to the references by Plant Health Australia listed below for details on how the PRR was developed and for explanations on the assigned risk levels.

Summary table for the PRR and Pest Risk Analysis (PRA) for key *Liriomyza* leafminers (as a group of species) based on the analyses prepared by Plant Health Australia (2006) for each species.

| Common name | Scientific name/s[a] | Relevant host/s | Plant part affected | Entry potential | Establishment potential | Spread potential | Economic impact | Risk |
|---|---|---|---|---|---|---|---|---|
| Leafminers (as a group) | *Liriomyza sativae* *Liriomyza huidobrensis* *Liriomyza trifolii* *Liriomyza bryoniae* | Polyphagous. Multiple Vegetable Groups | Leaves | HIGH | HIGH | HIGH | HIGH | HIGH |

[a] *Chromatomyia horticola* was not considered in this PPR but would have likelihoods similar to those of the exotic *Liriomyza* group.

Summary tables for the PRR of each exotic leafminer species, included in the Vegetable Industry Biosecurity Plan (PHA, 2007). The key leafminer species were listed among pests of vegetable crops in the Multiple Vegetable Groups (Insects).

| Common name | Scientific name | Relevant host/s | Plant part affected | Entry potential | Establishment potential | Spread potential | Economic impact | Risk |
|---|---|---|---|---|---|---|---|---|
| Vegetable leaf miner | ***Liriomyza sativae*** | Multiple Vegetable Groups[a] | Leaves | HIGH[b] | HIGH | MEDIUM | HIGH | HIGH |
| Serpentine leaf miner | ***Liriomyza huidobrensis*** | Multiple Vegetable Groups | Leaves | HIGH[c] | HIGH | MEDIUM | HIGH | HIGH |
| American serpentine leaf miner or chrysanthemum leaf miner | ***Liriomyza trifolii*** | Highly polyphagous | Leaves | MEDIUM | HIGH | HIGH | HIGH | HIGH |
| Tomato leaf miner | ***Liriomyza bryoniae*** | Multiple Vegetable Groups | Leaves | HIGH[c] | MEDIUM | HIGH | HIGH | HIGH |
| *Chromatomyia horticola* | ***Chromatomyia horticola*** | Multiple Vegetable Groups | Leaves | MEDIUM | MEDIUM | MEDIUM | HIGH | HIGH |

[a] Species and families that are known host of leafminers are listed in Appendix 5**.**
[b] It has now been found in East Timor and been suggested that wind dispersal to Australia is possible.
[c] Most likely route will be by cut flowers where eggs could be present.
Source: PHA (2007)

## References

Plant Health Australia (PHA). 2006. Pest Risk Review of the Vegetable Industry Biosecurity Plan. Plant Health Australia, Canberra, ACT, Australia.

Plant Health Australia (PHA). 2007. Vegetable Industry Biosecurity Plan, Emergency plant pest priority list. Plant Health Australia, Canberra, ACT, Australia. <http://www.ausveg.com.au/assets/contentitems/public/6653/National_vegetable_industry_biosecurity.pdf>

Plant Health Australia (PHA). 2007. National Vegetable Industry Biosecurity Plan – Version 1 May 2007. Plant Health Australia, Canberra, ACT, Australia. <http://www.ausveg.com.au/assets/contentitems/public/6653/National_vegetable_industry_biosecurity.pdf>

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

Plant Health Australia (PHA). 2009. Industry Biosecurity Plans for the Grains Industry. Version 2.0 February 2009. Plant Health Australia, Canberra, ACT, Australia.

## 1.2 Affected hosts

### 1.2.1 Host range

Major, minor and wild hosts for the key exotic leafminers are listed in Appendix 5. Primary but not exclusive families and key vegetable crop species that are host of the exotic leafminers are indicated below.

*L. sativae*:
: Fabaceae (many legumes); Solanaceae (e.g. tomato); Asteraceae (e.g. lettuce and ornamentals such as chrysanthemums); Umbelliferae (e.g. celery).

*L. huidobrensis*:
: Cucurbitaceae (e.g. cucumber); Umbelliferae (e.g. celery); Fabaceae (e.g. faba bean and peas); Solanaceae (e.g. potato); Chenopodiaceae (e.g. spinach).

*L. trifolii*:
: Asteraceae (e.g. lettuce and ornamentals such as chrysanthemums); Umbelliferae (e.g. celery); Fabaceae (beans); Solanaceae (e.g. potato and tomato).

*L. bryoniae*:
: Brassicaceae (e.g. cabbages); Asteraceae (e.g. lettuce); Cucurbitaceae (e.g. zucchini, cucumber, melons and watermelons); Solanaceae (e.g. tomato).

*C. horticola*:
: Fabaceae (e.g. peas); Brassicaceae (e.g. cabbages); Alliaceae (e.g. onions); Asteraceae (e.g. chrysanthemum and lettuce); Chenopodiaceae (e.g. spinach); Cucurbitaceae; Solanaceae (e.g. tomato).

Cultivated herbs, such as basil (*Ocimum basilicum*), cilantro (*Coriandrum sativum*), and mint (*Mentha spicata*), are also hosts of leafminers. For information on leafminers damaging herbs refer to Horticultural Development Company, Herb Best Practice Guide, U.K. at <http://www.hdc.org.uk/herbs/page.asp?id=9>.

Common weeds present in vegetable fields can host leafminers. Weeds that host *L. trifolii* in Florida, U.S., and that are present in Australia include: *Solanum nigrum* (blackberry nightshade; black nightshade), *Bidens pilosa* (cobbler's pegs; Spanish needle), *Chenopodium album* (fat hen; lambsquarters), *Galinsoga* spp., *Sonchus* spp. (Sow thistle), and *Xanthium* spp. (cocklebur). Other weeds that are hosts of *L. trifolii* are *Eupatorium serotinum* (late eupatorium), *Erichtites hieracifolia* (American burnweed), *Gnaphalium* spp. (cudweed or rabbit tobacco), *Melothria pendula* L. (creeping cucumber), *Mikania scandens* (climbing hempweed), and *Vigna luteola* (wild cowpea). *Solanum nigrum* (blackberry nightshade; black nightshade), and *Bidens alba* (Romerillo, Spanish needle) are common hosts of *L. sativae* in Florida.

Common ornamental plant species that are hosts of leafminers are in the genera *Alstroemeria* (Alstroemeriaceae), *Chrysanthemum* (Asteraceae), *Dianthus* (Caryophyllaceae), and *Gerbera* (Asteraceae). Other ornamental species are listed in Appendix 5. Selected references that include lists of reported hosts of leafminer species are listed below.

### References


Andersen, A., T.T.A. Tran, and E. Nordhus. 2008. Distribution and importance of polyphagous *Liriomyza* species (Diptera, Agromyzidae) in vegetables in Vietnam. Norwegian Journal of Entomology 55: 149-164.

Aunu, R., M.B. Shepard, and M.W. Johnson. 2000. Leafminers in vegetables, ornamental plants and weeds in Indonesia: surveys of host crops, species composition and parasitoids. International Journal of Pest Management 46: 257-266.

CAB International. 2007. Crop Protection Compendium, 2007 Edition. CAB International, Wallingford, UK. <http://www.cabicompendium.org/>

Dempewolf, M. 2004. CD-ROM on Agromyzidae (Diptera) of economic importance. Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum Amsterdam. <http://ip30.eti.uva.nl/bis/agromyzidae.php>

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Pitkin B., W. Ellis, C. Plant, and R. Edmunds. 2008. The leaf and stem mines of British flies and other insects. Department of Entomology, Natural History Museum, London, UK. <http://www.ukflymines.co.uk/index.html>

Spencer, K.A. 1973. Agromyzidae (Diptera) of economic importance. The Hague. 418 p.

Stegmaier, C.E. 1966. Host plants and parasites of *Liriomyza trifolii* in Florida (Diptera: Agromyzidae). The Florida Entomologist 49: 75-80. <http://fulltext10.fcla.edu/DLData/SN/SN00154040/0049_002/98p09404.pdf>


### 1.2.2 Geographic distribution

Due to unintentional spread by humans, Agromyzid leafminers of economic importance have a broad geographical distribution and are present in both temperate and tropical regions. Appendix 6 includes leafminer distribution maps developed by CAB International. Maps and lists of countries were reproduced from the Crop Protection Compendium, 2007 Edition. © CAB International, Wallingford, UK, 2007. The pest status reported for each species is for the year the maps were published. Recent incursions are reported in bulletins published by the EPPO <http://www.eppo.org/>, the IPPC website <https://www.ippc.int/IPP/>, and regional pest distributions in entomology, crop protection journals, and websites maintained by biosecurity authorities.

General information on the origin and distribution of the key species is given below.

*L. sativae*:

Tropical species. Probable origin: Central and South America. Distributed in America, Africa, Asia, and Oceania. Not yet recorded in Europe. Both in open air and in greenhouses but it cannot survive cold areas except in greenhouses.

*L. huidobrensis*:

Tropical species. Origin: Central and South America. Distributed in Central and South America. Present but localised in the U.S. (California and Hawaii) and Canada, and Africa. It is now widespread in Europe. Present in Asia but with few occurrences in Oceania. In open air, even at relatively high altitudes (up to approximately 2000 m), and in greenhouses in cold regions.

*L. trifolii:*

Tropical species. Origin: Central and South America. Distributed in Central and South America, Africa, Asia, Europe and Oceania. Present in many states of the U.S. and in Canada. In open air and in greenhouses in cold regions.

*L. bryoniae*:

Probable origin: Southern Europe. Distributed in almost entire Europe. Also present in Asia and North Africa but not in Oceania. Both in open air (especially in southern Europe) and in greenhouses.

*C. horticola:*

Present in all countries in Europe, all states in India and China, and many countries in Africa. For the rest of the world, with the exception of the Americas and Australasia, omissions from the distribution map must be assumed to be due to lack of recording, not the absence of the pest (CAB International, 2007).

## References


Andersen, A., T.T.A. Tran, and E. Nordhus. 2008. Distribution and importance of polyphagous *Liriomyza* species (Diptera, Agromyzidae) in vegetables in Vietnam. Norwegian Journal of Entomology 55: 49-164.

CAB International. 2007. Crop Protection Compendium, 2007 Edition. CAB International, Wallingford, UK. <http://www.cabicompendium.org/>

Dempewolf, M. 2004. CD-ROM on Agromyzidae (Diptera) of economic importance. Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum Amsterdam, The Netherlands <http://ip30.eti.uva.nl/bis/agromyzidae.php>

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### 1.2.3 Potential entry, establishment and spread

In addition to the information below, refer to the PRR and PRA of exotic leafminers developed by PHA (PHA, 2006). PHA (2006) gives the definitions used in the PRR and PRA for rating potential levels in the assessments of exotic pests.

**Entry potential: High**

The entry to and dispersion of leafminers within countries have been associated with movement of infested ornamental host plants and propagation material (e.g. cuttings), cut flowers, and leafy vegetables (CAB International, 2007). Leafminers at the stages of larvae, pupae and eggs are frequently detected on leaves and stems during inspections of trade ornamentals and cut flowers, leafy vegetables, and pea pods (CAB International, 2007). Common ornamental plant species that are hosts of leafminers are in the genera *Alstroemeria*, *Chrysanthemum*, *Dianthus*, and *Gerbera*. While mines produced on leaves and fully-formed larvae are readily visible to quarantine officials, signs of early infestations (e.g. stipples or punctures where eggs have recently been deposited) are much less obvious and could be easily overlooked.

The risk of leafminer entry increases with importation of fresh plant organs that are a host of the pest. Some imported fresh vegetables arrive from countries where leafminers are present (see table below). Known hosts of leafminers are listed in Appendix 5. Countries where exotic leafminers are present are listed in Appendix 7. New Zealand is currently free of the key exotic leafminers.

Origin of the vegetables imported by Australia in 2002/03 [Sorted by value, in descending order; HAL (2004)] that are known hosts of leafminers (CAB International, 2007).

| Vegetable imported | Origin |
|---|---|
| Capsicum | New Zealand, Mexico, Turkey |
| Garlic | China, New Zealand, USA |
| Tomatoes | New Zealand |
| Cucumber and gherkins* | India, Sri Lanka |
| Other vegetables | Thailand, Fiji, China |
| Peas | China, Zimbabwe, India |
| Onions and shallots | U.S., New Zealand, Netherlands |
| Beans* | U.S., Canada, China |
| Carrots | New Zealand, China |
| Spinach* | Luxembourg, France, Italy |
| Beetroot (salad) | New Zealand, Tonga, China |
| Sweet potatoes | Tonga, China, U.S. |
| Leguminous vegetables | U.S., India, China |
| Lettuce | New Zealand |
| Cabbage | not indicated |
| Leeks | not indicated |

*A portion of these imports includes processed produce, which do not represent a risk for leafminer introduction.

The vase life of chrysanthemums (up to 30 days in some cultivars) is sufficient to allow completion of the life cycle of the pest. Imported cut flowers are "devitalised" (i.e. treated with an herbicide such as Glyphosate at a concentration that disables propagation) in the source country or after arrival to minimise the risk of spreading pests that might be harboured in the plant materials. If the plant materials are suitable as propagation material, there is an increased risk that the undetected eggs that survive in leaves or stems may be able to complete the insect cycle in an Australian nursery. Details in plant devitalisation protocols are given by AQIS at <http://www.aqis.gov.au/icon32/asp/ex_TopicContent.asp?TopicId=3214>. Larvae and pupae can be killed when cut flowers are treated with methyl bromide.

Distribution through movement of fruit of vegetable species is less likely because the key leafminers do not attack fruit (pods of peas attacked by some leafminer species are an exception). If vegetable fruits are brushed or washed, it is less likely that a pupa can be present on fruit. However, distribution can occur if larvae or pupae remain undetected within, for example, the truss of tomatoes, or if infested leaves remain among packaged fruits. Introduction of *L. huidobrensis* with truss tomatoes imported from The Netherlands was rated as very low by DAFF (2003).

Although soil is not accepted with imported produce, pupae could potentially be transported with the soil or media from top soil or root media underneath leafminer infested plants (*Liriomyza* species mainly pupate on soil but *C. horticola* pupates on leaves). While bulbs are not a primary host, pupae can become lodged in bulbs or could be carried in soil attached to bulbs (e.g. of imported *Alliaceae* bulbs). It is less probabe that washed tubers (e.g. potatoes) and roots, which do not carry soil attached, are will transport pupae.

Key *Liriomyza* leafminer species have already invaded East Timor and could eventually reach Australia (PHA, 2006; 2007). Iwasaki et al. (2008) suggested that wind could assist with the movement of *C. horticola* from region to region in Japan. It is thought that the leafminers can potentially enter Australia from East Timor, Indonesia or Papua New Guinea via the Australian northern border by natural or non-conventional pathways including wind currents, and in fresh produce carried on traditional vessel movements and illegal fishing activity (NAQS, 2009). Leafminers could also arrive to Australia on plant materials illegally moved by humans from overseas countries that are not intercepted by quarantine or customs officials.

The probability of entry for exotic leafminers is therefore considered to be “High”.

**Establishment potential: High**

The key exotic leafminers are able to survive in a wide range of environments. Temperate, tropical and subtropical climates in regions of Australia are suitable for leafminer establishment. In these regions there are many cultivated vegetables, ornamentals, legume grain crops and weeds that are known hosts of leafminers. Rapid establishment may be facilitated because of the high reproductive potential of the leafminers in suitable warm environments, availability of hosts, and regular transport of fresh vegetables and ornamental plants across regions. If established in cool regions, some leafminer species may become more important pests in nurseries and crops grown in greenhouses.

The key exotic leafminers may be able to establish in vegetable production regions in Australia. Refer to Section 1.2.4 for maps indicating which regions have favourable climates for leafminer establishment. These estimates were based on climate and insect stress parameters and were generated with the Climex program (Sutherst et al., 2007).

The probability of establishment for exotic leafminers is considered to be "High". However, establishment will be limited to suitable regions and differences are expected among leafminer species. The impact of parasitoids and predator insect species on new invasive leafminer species has not been estimated (for biological control, refer to Section 2.3.1.5 Control).

**Spread potential: High**

Spread and dispersal over long distances mainly occurs with movement of infested planting material (CAB International, 2007; Minkenberg, 1988). Leaves, petioles, seedlings, and pods of peas are vegetable plant parts that most likely carry the pest (eggs, larvae, and pupae) with trade and transport (CAB International, 2007). Adults will fly only short distances but they can infest a vast number of cultivated and non-cultivated hosts in nearby areas. Distribution of leafminers in field crops is generally aggregated. Dispersal within the field occurs within less than 30 m from the foci of infestation (Tryon et al., 1980). In many cases, leafminers may be found in clusters of plants along the edges of fields, near weeds that are hosts. Field crops can infest close by transplant nurseries (Tryon et al., 1980).

The weight of leafminer flies is ca. 0.4 to 0.6 mg. Laboratory studies indicate that *L. sativae* may have an average flight activity of approximately one kilometre (Lei et al., 2002). The dispersal of *C. horticola* by wind into some regions of Japan has been suggested by Iwasaki (2008). Wind, as a dispersal means, is expected to have similar effects on all key leafminer species. Movement of soil and root media (e.g. media in potted plants), and of bulbs, tubers or roots with soil attached, have the potential of carrying pupae. The risk would increase when bulbs and roots are transported with leaves (e.g. with radishes, and green onions, and carrots that are sold with leaves attached).

In China, *L. huidobrensis* was found to have spread from one location (Kunming in Yunnan province) throughout the vast Yunnan (394,100 $km^2$) over a period of approximately 6 to 7 years (He et al., 2002). This leafminer is now established in regions with temperate, subtropical and tropical climates, and found at altitudes from 500 m to 3000 m. In the year 2000, *L. sativae* was spread throuthout 27 provinces in China since the first outbreak in 1994 (Zhao and Kang, 2000). In South Africa, movement of infested plant materials within the country resulted in the dispersal of *L. huidobrensis* throughout the country in three years.

The probability of spread for exotic leafminers is therefore considered to be "High".

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### 1.2.4 Potential geographic distribution in Australia

The "Climex Model" procedure in the software CLIMEX v2 (Sutherst et al., 2007) was used to estimate the potential geographical distribution of key exotic leafminers in Australia in relation to climate. CLIMEX combines insect growth and stress indices into an Ecoclimatic Index (EI), which describes the climatic suitability of a location for a species as a single number between 1 and 100. The EI gives an overall measure of the potential of a given location to support a permanent population (Sutherst et al., 2007).

Maps with EIs were generated to indicate which geographical regions in Australia have favourable environmental conditions for pest establishment. Dot size (i.e. dot area) in the map represents the suitability of the climate to support the life of the insect. An EI close to 0 indicates that the location is not favourable for long term survival of the species. An EI greater than 30 is generally considered a suitable climate for a species to establish permanently. High EIs, close to 100 are lab or incubator conditions. Between 0-30, even if outbreaks occur, establishment is considered marginal. However, host crops grown in greenhouses are not considered in the model and it can be assumed that these environments would be generally favourable for leafminers even if outdoor environment would not sustain permanent establishment.

Cold tolerance in the exotic group is greater for *L. huidobrensis*, *L. bryoniae*, and *C. horticola*, than for *L. sativae* and *L. trifolii*. The figures below indicate the possible distribution of *L. trifolii* and *L. sativae* (two heat tolerant species), and *L. huidobrensis* (a more cold tolerant species) in Australia. The geographical distributions were based on insect growth and stress parameters and resultant Ecoclimatic Index (EI) calculated with CLIMEX v2. Insect growth parameters were obtained from laboratory studies and stress parameters were adjusted to fit known distributions of the pests overseas (e.g. in South America, U.S., Europe, and Asia).

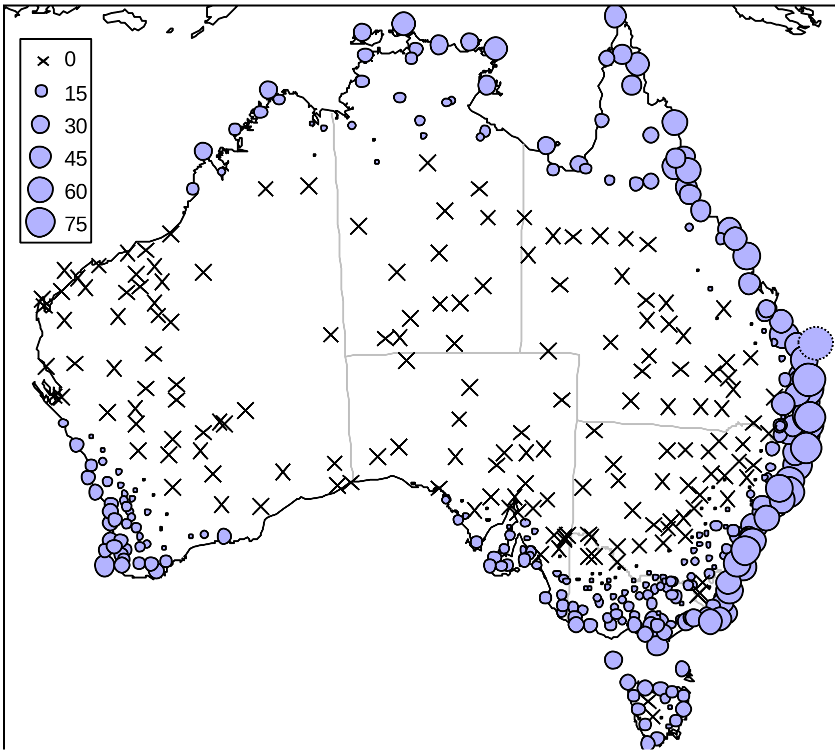
Almost all commercial vegetable crops are irrigated. Assumptions were 25 mm irrigation per week (ca. 3.6 mm/day) in summer and 10 mm per week (ca. 1.4 mm/day) in winter. Irrigation was not added if rainfall exceeded the simulated irrigation amounts. The maps with irrigation scenarios indicate that, in dry areas, the potential range of the insect increase when irrigation is included in the model. It is important to note that not all factors that can constrain pest establishment were included in these analyses. For example, not considered were the effect from natural biological control, and the establishment of leafminers in crops grown in greenhouses where outdoor environment is unfavourable for pest establishment. *Liriomyza* species in the exotic group will most likely find suitable environments and hosts in greenhouses located in cool regions of Australia.

In regions that have a suitable climate for exotic leafminers, distribution, establishment, and economic impact of the insect is associated with the extent of cultivated host species. Vegetables that overseas are known hosts of leafminers are widely grown throughout Australia. The potential area of establishment of a leafminer species based on climate (EI >30 in CLIMEX maps) needs to be followed by finding if there is an overlapping with regions where host vegetables are commonly grown in Australia. This provides an estimation of potential crops that could be affected and areas where the pest could spread and establish.

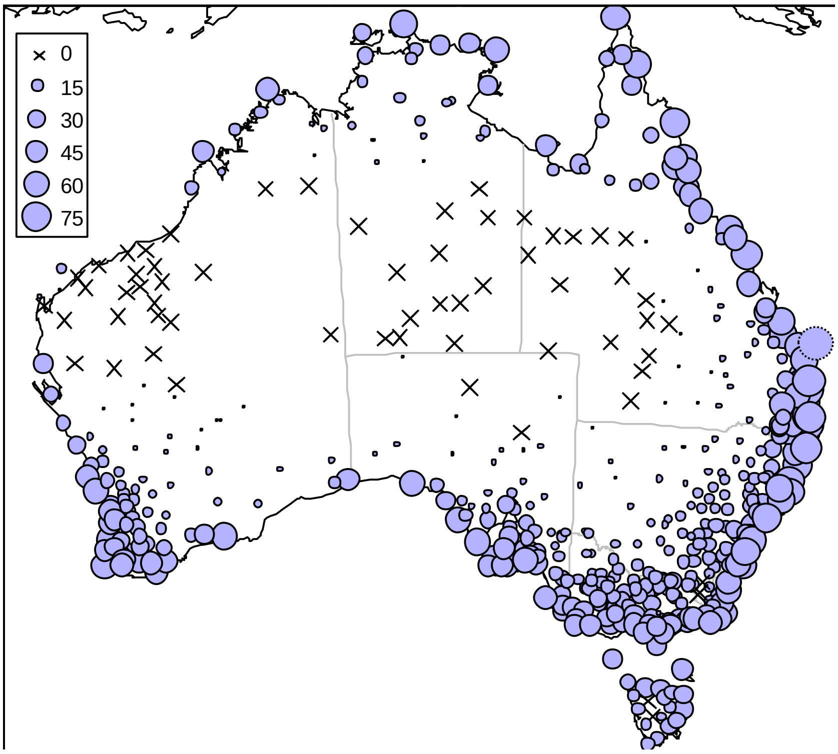
Refer to Appendix 6 for a list of the main vegetable crops grown in each state and territory of Australia with their cropped area and volume in 2007. In the list of grown crops, it is indicated if crops are major and minor hosts of key exotic leafminer species and if the damage is known to reduce cosmetic quality of the harvested product in addition to reducing yield.

Refer to Appendix 8 for a map of Australia and a table which indentifies production regions and their main vegetable species grown in 2004. The table in Appendix 8 also indicates which of the grown vegetable crops are known hosts of exotic leafminers overseas. The information was obtained from maps of Australia containing the growing regions of individual vegetable crop species, published by HAL (2004).

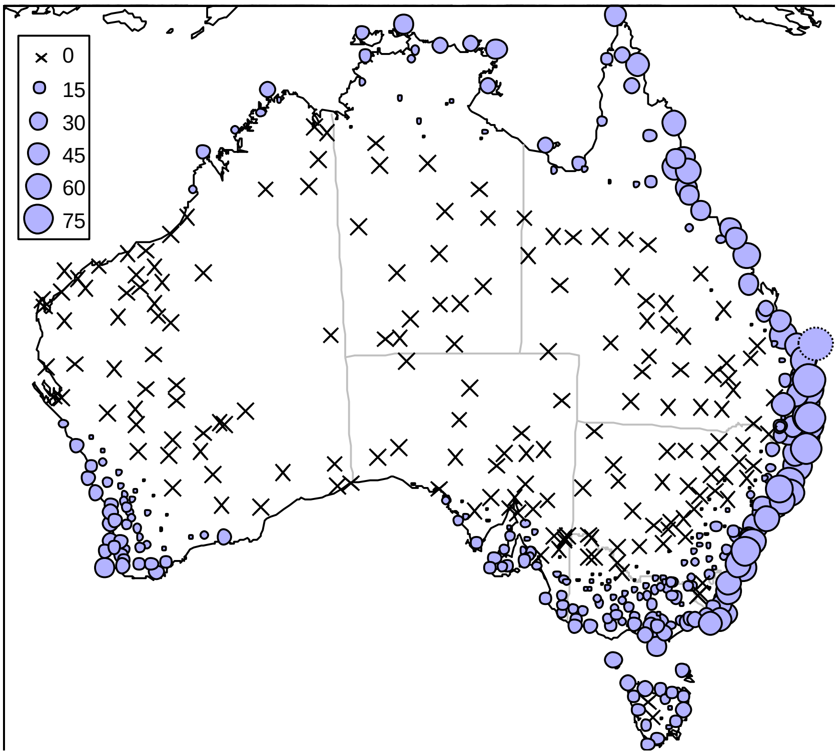
Vegetable growing regions at risk from an incursion of the key exotic leafminer species can be identified. Outcomes of these estimates indicate that one or more key exotic leafminers could establish throughout Australian vegetable growing regions. *L. sativae* and *L. trifolii* could potentially establish where vegetable crops are grown in North, North-East, East, South-East, and South-West of the Australia. *L. huidobrensis* could potentially find favourable environments in cooler South-East and South-West regions of the country, and in the East coast in warm regions, as well as in elevated cooler regions in the North-East (e.g. Tablelands in Qld.). It is expected that *L. huidobrensis* should have a more restricted limit in northern Australia than *L. sativae* or *L. trifolii* do. Northern regions may be too hot for *L. huidobrensis*. It is possible that *L. bryoniae*, native to southern regions of Europe, and *C. horticola* (present outdoors in Europe, Africa and Asia) may find favourable environments in regions that have temperatures intermediate to those estimated for *L. huidobrensis* and *L. sativae* and *L.* trifolii, therefore find favourable climates for establishment in regions such as North-East, East, South-East, and South-West of Australia. Center regions in the country may be too hot and dry, and therefore unfavourable for permanent establishment of the key leafminer species.



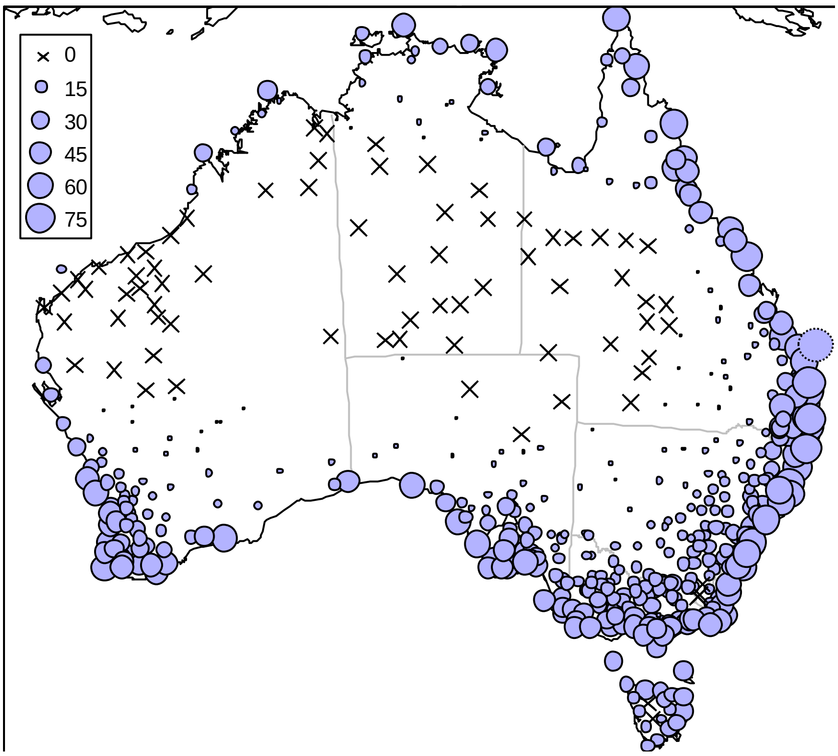

Potential geographical distribution of *L. trifolii* in Australia fitted with a CLIMEX model where no irrigation scenario was included. The insect growth parameters used were DV0: 9.7 ºC; DV1: 22 ºC; DV2: 30 ºC; DV3: 37 ºC; PPD: 314 ºC-days.



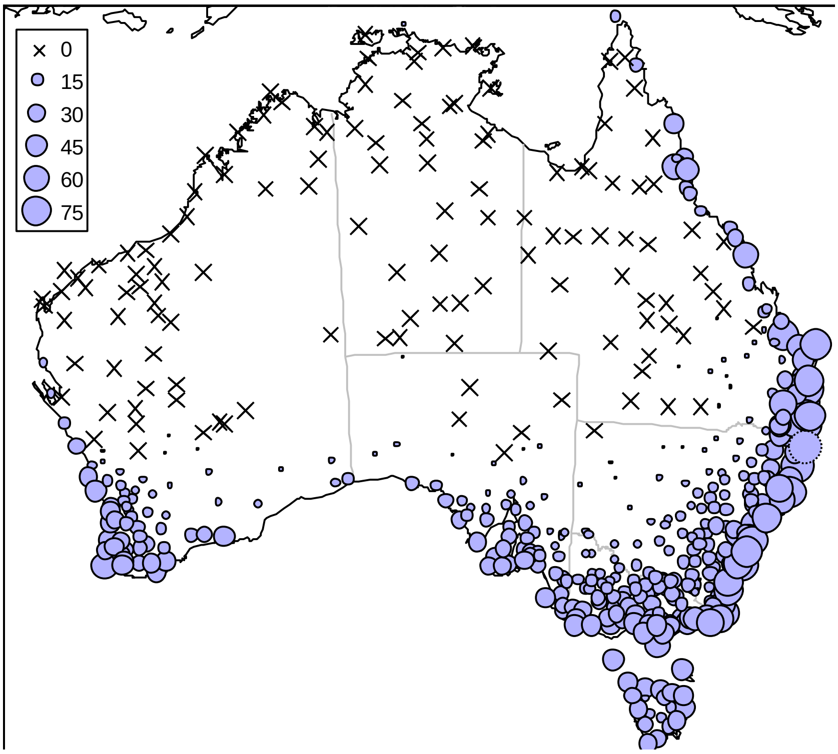

Potential geographical distribution of *L. trifolii* in Australia fitted with a CLIMEX model where an irrigation scenario was set to 25 mm irrigation per week in summer and 10 mm per week in winter. The insect growth parameters used were DV0: 9.7 ºC; DV1: 22 ºC; DV2: 30 ºC; DV3: 37 ºC; PPD: 314 ºC-days.



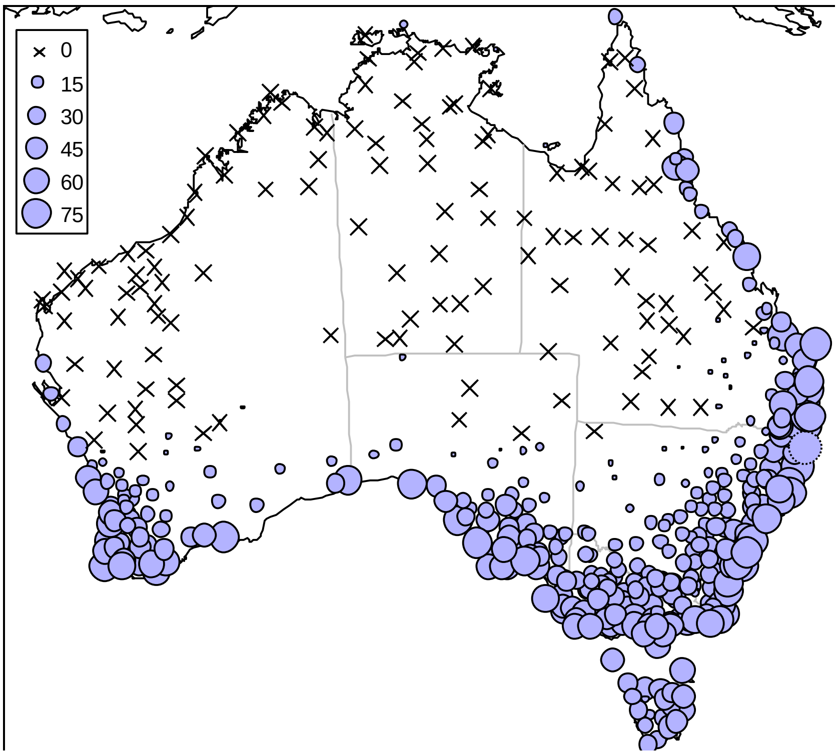

Potential geographical distribution of *L. sativae* in Australia fitted with a CLIMEX model where no irrigation scenario was included. The insect growth parameters used were DV0: 10 ºC; DV1: 22 ºC; DV2: 29 ºC; DV3: 35 ºC; PPD: 296 ºC-days.



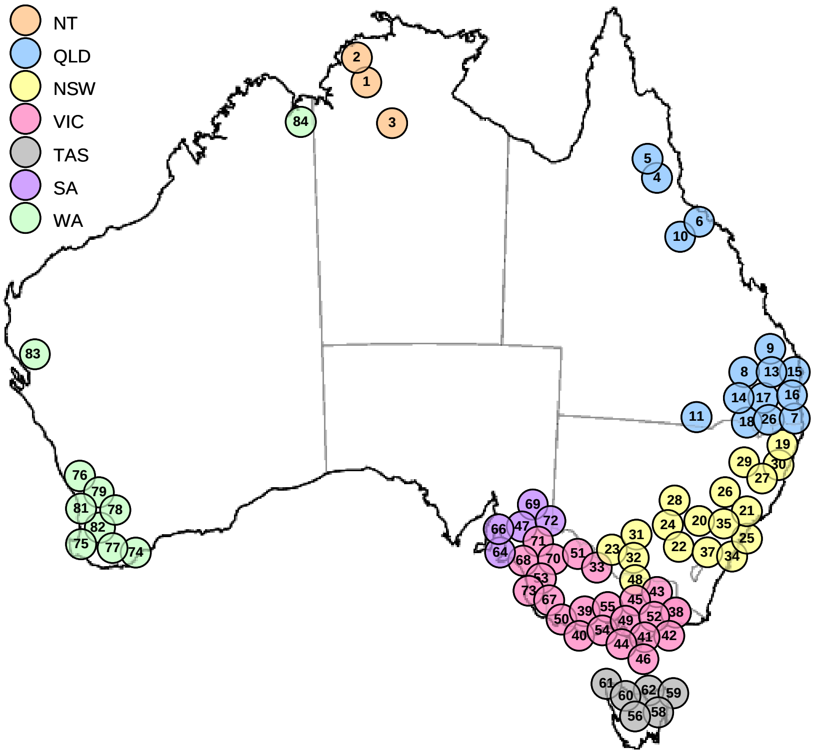

Potential geographical distribution of *L. sativae* in Australia fitted with a CLIMEX model where an irrigation scenario was set to 25 mm irrigation per week in summer and 10 mm per week in winter. The insect growth parameters used were DV0: 10 ºC; DV1: 22 ºC; DV2: 29 ºC; DV3: 35 ºC; PPD: 296 ºC-days.




Potential geographical distribution of *L. huidobrensis* in Australia fitted with a CLIMEX model where no irrigation scenario was included. The insect growth parameters used were DV0: 8.1 ºC; DV1: 22 ºC; DV2: 26 ºC; DV3: 30 ºC; PPD: 280 ºC-days.




Potential geographical distribution of *L. huidobrensis* in Australia fitted with a CLIMEX model where an irrigation scenario was set to 25 mm irrigation per week in summer and 10 mm per week in winter. The insect growth parameters used were DV0: 8.1 ºC; DV1: 22 ºC; DV2: 26 ºC; DV3: 30 ºC; PPD: 280 ºC-days.




Locations of field vegetable production regions in Australia. Refer to Appendix 8 to identify regions and crops, and which crops are known hosts of exotic leafminers. Greenhouse production areas, mainly in the south east of the country, are not plotted in this map.

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### 1.2.5 Damage and symptoms

Leafminers attack plants at all growing stages: seedling, vegetative, flowering, and fruiting. Both the adults and larvae cause damage. Inspection of the surface of a leaf will reveal punctures on the epidermis and the obvious whitish mines with linear grains of frass along the length of the mine. Damage caused to plants by the different key leafminer species is similar. However, the economic impact of the damage by leafminers depends on factors such as a favourable environment for population increase, host species, age of the plant infested, and the saleable part of the plant.

**Punctures:**
Feeding punctures of the key exotic *Liriomyza* spp. appear as white rounded speckles of approximately 0.20 mm in diameter on the upper leaf surface.

The adult females can puncture both leaf surfaces. These punctures are made to feed on sap and lay eggs. Oviposition punctures are smaller (0.05 mm) and are more uniformly round. A female can make approximately 2000 puntures throughout her life. Approximately 10 to 15% of the punctures may contain viable eggs. The adult males cannot make punctures but they can feed on sap available in the punctures made by females. Punctures destroy cells. At very high populations of adults, leaf puncturing can result in a reduction of plant vigour and the drying out and early falling of leaves. This damage can lead to the death of seedlings and young plants and, consequently, to a decrease in number of productive plants established in the field. Punctures are clearly visible to the naked eye and can lead to cosmetic damage in leafy vegetables and, therefore, decrease the value of the produce or even make the produce unmarketable.

**Mines:**
Larvae can make leaf mines on cotyledons, leaves, petioles, and pods of peas. On leaves, the larvae primarily mine the mesophyll, where chloroplasts are located. Photosynthesis by the leaves is reduced as cells containing chlorophyll are destroyed. Mines on leaves of leafy crops and on petioles or stalks (such as in celery) can greatly decrease the yield and value of crops.

With some differences among leafminer species, mines are typically white and serpentine, more or less coiled and of irregular shape. Larvae generally stay within the leaf where they were born. As the larva matures, the irregular mines increase in width from approximately 0.25 mm to 1.5 mm. Frass (larvae excrements) is of dark colour and can be observed on short intervals or strips along the mine. Patterns of mines can sometimes be used for a preliminary diagnostics of species. The mine is wider at one of the ends, and it is this sector of the mine where a larva (or pupa in *C. horticola*) may be found.

Adults do not puncture fruits and, therefore, larvae do not affect fruit. Larvae of some species, such as *L. huidobrensis* and *L. sativae*, are able to mine the surface of pea pods. Necrosis and defoliation can occur in plant canopies that had severely mined leaves. In these plants, yield loss may occur because fruit that become exposed to direct sunlight become sun-scalded (e.g. in tomato and capsicums).

**Secondary pathogens:**
Leafminers are not inherent carriers of disease. However, bacterial and fungal pathogens can infect and kill seedlings when flies transfer inoculum through the punctures made on leaves. For example, incidence of *Alternaria* leaf blight lesions in melon increased with the number of punctures made by *L. trifolii* adult females (Chandler and Thomas, 1991).

**Virus transmission:**
Occurrence of plant virus has been associated with the presence of leafminers (Costa et al., 1988; Zitter and Tsai, 1977). However, leafminers are not considered important vectors of virus.

**Images of damage symptoms in crops**
Many images of leafminers and damage caused by leafminers can be located at
<http://www.insectimages.org/browse/genus.cfm?id=Liriomyza>

Leaf mines in onion:
<http://www.insectimages.org/browse/detail.cfm?imgnum=5368098>
<http://www.insectimages.org/browse/detail.cfm?imgnum=5362731>
<http://www.infonet-biovision.org/res/res/files/687.400x400.jpeg>

Leaf mines in potato:
<http://www.insectimages.org/browse/detail.cfm?imgnum=5368099>
<http://www.potatonews.com/images/Leafminer/Australia/huidmdldamagei-image4-photo.jpg>

Leaf mines in capsicum:
<http://www.insectimages.org/browse/detail.cfm?imgnum=2510028>
<http://www.inta.gov.ar/sanpedro/info/doc/2005/mm_0506/images/plag700/Foto%2044.jpg>

Leaf mines in tomato:
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-CD.016.html>
<http://www.inta.gov.ar/sanpedro/info/doc/2005/mm_0506/images/plag700/Foto%203.jpg>
<http://www.inta.gov.ar/sanpedro/info/doc/2005/mm_0506/images/plag700/Foto%2043.jpg>

Leaf mines in melon:
<http://www.insectimages.org/browse/detail.cfm?imgnum=1327114>
<http://www.insectimages.org/browse/detail.cfm?imgnum=1327115>
<http://www.insectimages.org/browse/detail.cfm?imgnum=2511021>

Mines in pea pods and leaves:
<http://www.insectimages.org/browse/detail.cfm?imgnum=1455011>
<http://www.forestryimages.org/browse/detail.cfm?imgnum=5368109>
<http://www.leafmines.co.uk/html/Diptera/C.horticola.htm>

Leaf mines in brassicas:
<http://www.insectimages.org/browse/detail.cfm?imgnum=5368110>

Leaf mines in chrysanthemum:
<http://www.insectimages.org/browse/detail.cfm?imgnum=0660019>

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### 1.2.6 Epidemiology

Leafminer population levels are influenced by climate and host plant. The larvae stage is most susceptible to cold. Recently laid eggs and pupae are most tolerant to cold. Leafminers usually overwinter in the puparial stage. Few adults develop in winter. Lower temperatures play a more important role than short days in preventing the development of adults. Outdoors in cold regions, some leafminer species (e.g. *L. huidobrensis* and *L. bryoniae*, and possibly, *C. horticola*) survive winter in diapause. Outbreaks occur in spring and fall seasons in warm regions, and in summer in cool regions. Commonly, these outbreaks will correspond with vegetative and reproductive stages of vegetable crops. Leafminers survive year round in protected environments (heated greenhouses in cold regions and unheated greenhouses in regions with mild winter climates). *L. huidobrensis* does not tolerate high temperatures (>30 ºC) but *L. trifolii*, *L. sativae*, and *L. bryoniae* may tolerate up to near 35 ºC (Lanzoni et al. 2002; Ozawa, 2001; Tokumaru and Abe, 2003). Leafminers can survive in irrigated areas of dry regions and in regions with substantial rainfall. The emerging pupae cannot tolerate submergence under water (Zhou et al., 2000).

The species in the exotic group have different limiting temperatures for development. *L. huidobrensis*, originally from cooler highlands of Latin America, is more adapted to cool climates than *L. sativae* and *L. trifolii*. For example, *L. huidobrensis* is commonly found in potato crops in the highlands of subtropical regions in Asia and South America. *C. horticola*, also endemic in south-east Asia, also is found in highlands of subtropical regions. In contrast to *L. trifolii* and *L. sativae*, *L. huidobrensis* and *L. bryoniae* have a diapause and therefore can hibernate outside in cold winters (but not in extreme cold winters as in northern Europe) (Malais and Ravensberg, 1992). In China, the predicted critical area beyond which *L. huidobrensis* cannot overwinter successfully in the field (but can develop a population in the upcoming year from greenhouse crops), is close to the latitudinal line of 35ºN (near an isotherm of –5 ºC in January, the coldest month of the year) (Chen and Kang, 2004). The isotherm of –2 ºC in January was suggested as the overwintering range limit for *L. sativae* in China (Chen and Kang, 2005). In Canada, *L. huidobrensis* cannot overwinter in southern Ontario, except in protected areas (Martin et al., 2005). In northern Europe, *L. trifolii* cannot survive the whole year in tomato glasshouses because the temperature is too low in the spring (Malais and Ravensberg, 1992). *L. bryoniae* rarely occurs outdoors in Northern Europe and it is restricted to glasshouses in those regions.

For the same leafminer species, host species has an effect on fecundity and developmental time. Vast amounts of information exist regarding the developmental times at different temperatures and developmental temperature thresholds of *Liriomyza* leafminers, and can be found in the references listed below (Leibee, 1984; Parrella, 1984; Miller and Isger, 1985; Schuster and Patel, 1985; Minkenberg,1988; Parrella, 1987; Pettit et al., 1991; Chen et al., 1999; Tooru and Hiroshi, 1999; Ozawa, 2001; Lanzoni et al., 2002; Tokumaru and Abe, 2003; Haghani et al., 2007).

The following table gives low and upper limit temperatures for development and degree-days from egg to adult above the base temperature for development. These values can be considered representative for each species. Other researchers report similar values, with small differences mainly because of host species used and experimental settings. Little information regarding limit temperatures was found for *C. horticola*.

| Leafminer species | Lower limit temperature for development (ºC) | Upper limit temperature for development (ºC) | Degree-days above the low temperature for development | Host | References |
|---|---|---|---|---|---|
| *L. trifolii* | 9.7 - 10.5 | 35 | 314 | Celery, Beans | Leibee (1984); Ozawa (2001); Lanzoni et al. (2002) |
| *L. sativae* | 10.0 | 35 | 254[a] – 296[b] | Beans | Pettit et al. (1991) |
| *L. huidobrensis* | 7.3[c] - 8.1 | 30 | 280 | Beans | Lanzoni et al. (2002) |
| *L. bryoniae* | 8.1 | 34 | 317 | Tomato | Tokumaru and Abe (2003) |
| *C. horticola* | 6.0 | ? | 270 | Peas | Tooru and Hiroshi (1999) |

[a] 50% in 3rd larval instar (Pettit et al., 1991)
[b] Chen et al. (1999)
[c] For pupae (Lanzoni et al., 2002)

Because leafminers have a high rate of fecundity and overlapping generations under warm temperatures close to 25 ºC, they have the potential to quickly colonise surrounding plants, resulting in high density infestations. The distribution of the insects in fields is generally aggregated. Studies that report leafminer outbreaks on different vegetable crops and seasonal population dynamics are described for different regions, such as Java and Sumatra (Shepard et al., 1998), Israel (Weintraub, 2001), Vietnam (Andersen et al., 2008; Hofsvang et al., 2005), China (Chen and Kang, 2004; He et al., 2002), Japan (Ozawa, 2001), Canada (Martin et al., 2005) and the U.S. (Palumbo et al., 1994).

Flight activity of leafminers has been studied in laboratory settings and greenhouses. Lei et al. (2002) determined that for *L. sativae*, the flight distance, speed and duration increased with increased temperatures between 18 ºC and 33 ºC. Suitable temperatures for flying were in the range of 21 ºC to 36 ºC, with average flight distances that ranged from 0.32 to 0.95 km for females (about 15 to 30% less for males) in a time period that ranged from 30 to 50 minutes. Average migration distance was estimated to be approximately 0.95 km. Flies covered a maximum of 8.2 km, at an average speed of 1.1 km/h (max. speed 1.95 km/h), in a period of 4.2 h at 33 ºC. The number of survivors decreased to less than 20% after 24 hours at temperatures between 21 and 24 ºC but survival was zero after 12 h at 36 ºC (Lei et al., 2002). *L. trifolii* covered distances of 100 m inside greenhouses without difficulty (Jones and Parrella, 1986). The weight of leafminer flies is ca. 0.4 to 0.6 mg. Air currents as a means of insect transportation and dispersal has been associated with repeated appearance of *C. horticola* in cold regions of Japan, where the species is not able to survive outdoors from year to year (Iwasaki et al. 2008).

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### 1.2.7 Impact on crops

The principal impact of leafminers on crops is through larvae mining in leaves and petioles. The level of yield loss caused by leafminer infestations to vegetables is variable because it depends on the host species, plant age, environment (e.g. climate and season), pest population levels and pest management practices.

Mines in young plants can cause significant delay in plant development. Normal development of plants is prevented when mining occurs on cotyledons and on the few first leaves of seedlings. Without control, losses up to 100% may occur in nurseries that grow vegetable seedlings or in seedlings and young plants grown in fields or greenhouses. In large plants, a considerable number of leaves can be lost before a yield reduction occurs. Crop loss can be significant when mines are present in the marketable portion of the produce (e.g. leaves, stalks, or pods). The impact on yield reduction is less when mines are made late in the production cycle of those vegetables in which fruits, tubers, inflorescences, or roots, are the marketable part of the plant. Those leaves with a high number of mines can become necrotic and will senesce prematurely. Indirect damage occurs when fungi or bacteria enter the feeding areas created by larvae. In subtropical and tropical regions, heavy leafminer infestations can cause partial defoliation in adult plants, which can reduce marketable yield because of an increase of sun-scalded fruit.

In Indonesia, yield losses in potato crops from *L. huidobrensis* were up to 100% with high populations and no pest control (Shepard et al., 1998). Kroschel and Mujica (2008) indicated 40 to 60% losses caused by *L. huidobrensis* in nonsprayed potatoes in Peru. However, in a desert region (Negev, Israel), foliage of adult potato plants was affected by leaf mines created by *L. huidobrensis* but no yield reductions occurred (Weintraub, 2002). *L. huidobrensis* was not found to be a serious pest in broccoli because damage was confined to the older, outer leaves (Shepard et al., 1998).

*L. sativae* caused losses of up to 70% in field-grown tomato crops in Vanuatu in the 1980s (Waterhouse and Norris, 1987). The yield losses in greenhouse-grown tomatoes were 10% and 20% when mines present on leaves surrounding the fruit truss were 30 and 60 mines/leaf, respectively (Wyatt et al., 1984). Sharma et al. (1980) reported losses of 40 to 70% in squash yields when chemical treatments used to *L. sativae* were not effective.

In China, *L. sativae* was first found in 1993 and *L. huidobrensis* in 1995, and the range of these leafminers has expanded into many areas of the country (Chunlin et al., 2005). In 1994, many vegetable crops in Guangdong province, China, had outbreaks of *L. sativae* that caused about 30% yield reduction due to damage (Zhao and Kang, 1999). More than 2.73 million hectares have been affected by the two leafminer species and the estimated economic loss amounts to 530 million dollars (AU) annually (Chunlin et al., 2005). There, the resistance of *L. huidobrensis* to insecticides has been stronger than that of *L. sativae*.

Vegetable losses due to *L. trifolii* in the U.S. have been considerable. In celery, *L. trifolii* damages plants by several means: reducing photosynthetic material from leaves, by creating sites for entry of plant pathogens, and by causing cosmetic damage to the marketable portion of the plant (leaves and stalks). In south Florida, Foster and Sanchez (1988) found that the loss of celery quality caused by *L. trifolii* mines was mainly due to cosmetic damage, and that a low pest population was critical during the last month of the three-month crop to avoid yield loss due to reduced cosmetic quality. Losses of up to 80% in yields of celery have been reported in Florida (Spencer, 1973). In 1980, these losses in the celery industry were estimated at US$ 9 million (Spencer, 1982). *L. huidobrensis* also infests celery. In Israel, celery marketable yield was reduced by 50% because of the presence of mines on leaves and stems, which were made by *L. huidobrensis* (Weintraub, 2002).

In peas that are harvested immature, to be marketed with their pods, leafminer larvae indirectly reduce yield by reducing leaf area but also directly reduce the value of the produce by mining the surface of pods. In Cameron Highlands, Malaysia, yield loss in sugar peas was as high as 30% when *C. horticola* was not controlled (Sivapragasam et al., 1992). When larvae of *L. bryoniae* feed on tomato cotyledons or in cucumber seedlings, they can prevent normal development of plants, which are low in production.

### Environmental impact

The impact of exotic leafminers on native plant species is difficult to predict. If key exotic leafminers become established in Australia, it is possible that native plant species in the same taxonomic family of known hosts of leafminers could be affected.

Some micro hymenoptera species that parasitise key exotic *Liriomyza* spp. are present in some regions of Australia (Bjorksten et al., 2005). Although it can be expected that natural biological control will have an effect on suppressing leafminer species that invade Australia, it is difficult to predict the level of control that parasitoids will achieve.

### Thresholds for control methods used overseas

Yield reduction cannot always be predicted with symptoms of damage. For a few vegetable crops, thresholds for economic damage have been developed, and are based on specific sampling protocols that use symptoms and/or pest number of particular life stages.

The increased number of mines (*L. bryoniae*) on six leaves surrounding the fruit truss of greenhouse-grown tomato plants was correlated with yield reduction (Ledieu and Helyer, 1985; Wyatt et al., 1984). With 30 and 60 mines/leaf yield losses were 10% and 20%, respectively. In the U.S., economic thresholds on pink and kidney bean varieties have been developed and chemical treatment is recommended if 25% of the surface of older leaves is mined and mines are present in the new leaves (Godfrey and Long, 2008). With celery, catches of 15 or more pupae on trays (10 cm x 23 cm) placed in between rows of plants has been used as a threshold level for chemical control of *L. trifolii* in California, U.S. Monitoring *L. sativae* and *L. huidobrensis* with trays is less effective. A lower threshold (non-specified) was suggested if the infesting species is *L. huidobrensis* as this species has a greater tendency to infest stalks (petioles) in celery plants (Godfrey and Trumble, 2008).

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### 1.2.8 Reference PRA / PRR datasheet

Pest Risk Reviews (PRR) and Pest Risk Analysis (PRA) for key *Liriomyza* leafminers (as a group of species) have been prepared by Plant Health Australia (2006) and were included the Vegetable Industry Biosecurity Plan (PHA, 2007). Additional information is included in Section 1.2.

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## 1.3 Diagnostic Information

### 1.3.1 Collecting samples

If possible, contact the taxonomist before commencing the collection and preparation of samples. Refer to Appendix 2 for a list of experts and diagnostics laboratories. Take several pictures of leaves with mines, including closeups.

Advice on how to collect, preserve, and transport the samples (leaves or insect specimens) that will be sent for diagnostic is given by Malipatil and Ridland (2008) and can be located at <http://keys.lucidcentral.org/keys/v3/leafminers/collecting.htm>. For general guidelines on collecting samples, refer to Appendix 3 Sampling Prodedures and Protocols for Transport, Diagnosis and Confirmation of EPP, in PLANTPLAN (PHA, 2008).

The following list with advice on collecting samples has been reproduced from Malipatil and Wainer (2007):

*Number of specimens to be collected*. A large sample of specimens would be preferable. The aim is to obtain an adult male. Adult females are identifiable with certainty only to genus level; therefore males are needed to examine genitalia details to confirm species identification.

*Preferred stage to be collected*. Of the four life stages (egg, larva, pupa and adult) only adults are identifiable to species using morphological features. Larvae and pupae are identifiable to species using electrophoretic and molecular tests only.

*How to collect samples*. Adult flies can be hand collected into glass vials or vacuum collected either with vacuum sampler, or swept from foliage with a hand net. Adult flies are normally found on the foliage. However the most practical and reliable method is the collection of leaves with mines containing pupae or mature larvae in a large jar for rearing in the laboratory for obtaining adult flies.

*How to collect plant sample if required*. Leaves with suspect feeding punctures or leaf mines should be picked and placed between sheets of newspaper to permit slow drying. For laboratory rearing of adult flies, mined leaves containing pupae or mature larvae can be collected in a large jar and kept in a constant temperature room for regular checking.

*How to preserve plant sample*. Leaves with suspect feeding punctures or leaf mines can be stored between sheets of dry newspaper.

How to preserve leafminers. Adults and larvae can be placed in 70% ethanol and stored indefinitely, although their colour fades gradually with time. Specimens required for molecular diagnostic work should be killed and preserved in 100% ethanol or frozen (−80 C).

*How to transport leafminers*. Vials of ethanol should be sealed to avoid leakage and packed with cushioning material in a strong box.

*How to transport plant sample*. Leaves with suspect feeding punctures or leaf mines should be mailed as a flat package between sheets of dry newspaper.

Leaves containing larvae or pupae are suitable for species identification purposes. In addition to gathering samples from the plant with leaf mining symptoms, samples should also be collected from nearby plants (of the same and different species) that might show similar symptoms. Samples should include leaves with mines and punctures, and any leafminer pupa that may be found on the leaves, floor or soil surface. In greenhouses that have a ground cover, pupae may be found on the floor near the plant containers. In an attempt to collect pupae, white trays should be placed beneath the canopy of the plant with leaf mines. Samples should be placed individually in bags labelled with the name of crop, location, date, and collector's name. Adults can be reared from leaf samples and pupae. Leaves in bags should then be transferred to plastic containers, covered with cloth, and then retained until the emergence of adults of leafminers or parasitoids (it might happen that larvae had been parasitised by micro-hymenoptera). The emerging adults (leafminers and possibly parasitoids) should be freezed, collected, preserved, and sent to the taxonomist.

Pitkin et al. (2008) gives additional advice on procedures to follow after discovering a leaf mine. This information applies to collecting samples of invasive leafminers and was reproduced from The Leaf and Stem Mines of British Flies and other Insects, under the section Methods, Collecting Mines, at <http://www.ukflymines.co.uk/methods.html#Collecting>

- On discovering a leaf mine, you should try to identify its host plant in situ, preferably by reference to a field guide.
- If possible, take a photograph or digital image of the host plant in situ.
- Remove mined leaves and transfer the mined leaves to a polyethylene bag in which you have placed a sheet of white paper to absorb excessive moisture.
- If you have been unable to identify the host plant, collect a flowering stem and some undamaged leaves and place them in the polythene bag with the mined leaves for later examination.
- If you have been able to identify the host plant make a note of its identity.
- Write collection data, such as the name of the host plant, location, date of collection, using a pencil on a slip of paper and place this inside the bag. Keep the bagged mines out of sunlight to avoid overheating.

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### 1.3.2 Diagnostic Protocol

Leafminer samples must be examined by an insect taxonomist with expertise in Agromizidae for correct identification. Standard diagnostic protocols are listed in Appendix 1. Experts and diagnostic laboratories are listed in Appendix 2.

Because adult morphology, larvae morphology, and patterns of mines and punctures on leaves are similar among leafminer species, misidentification can occur when diagnosis relies on only these characteristics (EPPO, 2005). Only adult males of the key exotic leafminers can be identified with certainty to the level of species on basis of their genitalia. Molecular diagnostic tests are required for definitive diagnosis of immature stages (egg, larva and pupa) and adult females.

Starch gel electrophoresis, enzyme staining, and PCR-like techniques are used overseas for identification of leafminers to the level of species. For example, the RAPD-PCR (Random Amplification of Polymorphic DNA - Polymerase Chain Reaction) technique can be used in addition to morphological examinations (Andersen et al., 2002). *Liriomyza* spp. obtained from overseas laboratory colonies can be used as standards. Primers give distinct bands for the different species of key exotic leafminers. The results obtained from the collected *Liriomyza* specimens can be compared with results from the standards.

Different leafminer species can exist in a region or even in the same crop/plant host. It is important to determine if the detected leafminer belongs to a species that is endemic to Australia or if it is a new invasive species. Three agromyzid leafminers, *L. brassicae* (Riley), *L. chenopodii* (Watt) and *Chromatomyia syngenesiae* Hardy, which are not considered main pests of vegetables, are present in Australia. *Chromatomyia horticola* has a much wider host range than *C. syngenesiae*, and both flies are morphologically similar.

Molecular diagnostics are the only means to differentiate biotypes or very similar species of leafminers. There is recent evidence that in some regions of United States the fly previously believed to be pea leaf miner is not *Liriomyza huidobrensis*. Research has identified the fly present in the U.S. as *Liriomyza langei*. The fly was differentiated by molecular diagnosis from pea leaf miner but is morphologically almost identical. See the reference USDA (2008) for more details on the regulation of *L. huidobrensis* in the U.S.

Other reasons may also justify identification to species level. For example, in the San Joaquin Valley, California, U.S., it is important to distinguish between *L. trifolii* and *L. sativae,* which can occur in the same areas because *L. trifolii* is more resistant to chemical controls (Natwick et al., 2008). In northern Italy, *L. huidobrensis* is a serious pest of lettuce crops grown in open fields. In lettuce crops, it coexists with other species of the Agromyzidae family, in particular *L. bryoniae*, *L. trifolii* and *C. horticola* but these species have not been reported there to cause yield losses. The rapid detection of *L. huidobrensis* is crucial for effective management strategies. Masetti et al. (2006) found that a RFLP-PCR (Restriction Fragment Length Polymorphism - Polymerase Chain Reaction) assay was rapid and reliable for distinguishing *L. huidobrensis* (using adults, pupae or larvae) from *L. bryoniae, L. trifolii* and *C. horticola*.

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### 1.3.3 Reference documents


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## 1.4 Response and question checklist

### 1.4.1 Checklist

Guidelines for Response Checklists have yet to be developed and endorsed. The following checklist provides a summary of generic requirements to be identified within a Response Plan:

- Destruction methods for plant material
- Disposal procedures
- Quarantine restrictions and movement controls
- Zoning
- Decontamination and farm cleanup procedures
- Diagnostic protocols and laboratories
- Trace back/forward procedures
- Protocols for delimiting intensive and ongoing surveillance
- Reporting and communication strategy

### 1.4.2 Reference documents

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## 1.5 Delimiting Survey and Epidemiological Study

See Section 2.2.3 in PLANTPLAN (PHA, 2008) and Appendix 10 Delimiting Surveys, in PLANTPLAN (PHA, 2008).

Delimiting surveys should comprise local surveys carried around the area of initial detection. Because of the polyphagous nature of the leafminer group, the search for host plants that have leaves with mines should be carried in commercial and non-commercial fields, greenhouses, and nurseries, and in weeds in noncultivated areas, and gardens. Since leafminers could have arrived to the area with infested plant material (e.g. seedlings and ornamental plants), it is critical to gather information about the recent history of plant material moved into and out of the initial area of detection. A survey should trace the source of the plants that were hosts of the new leafminer species. In addition, the survey team should inspect properties in a wider area. Initially, this could be set at a 1 km radius in an urban area or 10 km radius in the countryside. Depending on the outcomes of the survey, it can be extended to cover a wider area. An area wide survey should consider factors such as estimated flight times, wind speed, direction, spatial distribution patterns in crops, and host plant distribution. The presence of hosts in the region of initial detection, favourable environmental conditions for insect population increase and spread, and recent movements of plant material, will be information required for determining the first quarantine zone (RA, or Restricted Area and CA, or Control Area).

The weight of flies is ca. 0.4 to 0.6 mg, and flight activity is not considered critical (ca. 1 to 2 km) for long distance dispersal. Knowledge of the predominant direction of winds may give indication of down wind areas where flies could have been transported. Up wind areas should be inspected as the flies may have arrived to the initial detection site carried by wind.

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### 1.5.1 Sampling method and regime

In addition to the information below, refer to Appendix 3 General Sampling Procedure, and Appendix 4 Preliminary Information Data Sheet, in PLANTPLAN (PHA, 2008).

Mines on leaves are the first indicator of leafminer presence. After the species is identified, surveillance should comprise all known hosts of leafminers in the survey area. Both, leaf sampling and sticky traps should be used in combination in order to detect insect presence, monitor population levels, and obtain specimens for diagnostics. Samples of leaves with mines will be needed in order to assess the level of parasitism by natural biological control agents and for collecting specimens of parasitoids. Mature larvae drop from foliage in *Liriomyza* species that pupariate in the soil. Placing trays under the canopy should be used to catch and count pupae.

The following methods are used overseas to assess leafminer abundance:

- *Counting mines in leaves or leaves with mines*. These are good indicators of past activity because many mines may be already vacant at the time of the assesment.
- *Counting live larvae in mines*. This is a time consuming activity, but indicative of future damage.
- *Counting puparia*. These can be collected by placing trays beneath foliage to capture larvae as they evacuate mines (adequate for *Liriomyza* species, as they will pupate in the soil below the plant canopy). To measure infestation levels of the leafminer, trays should be placed between the crop rows to catch dropping pupae. Trays of ca. 10 cm long by 20 cm wide fit well between the rows (for an image see <http://www.ipm.ucdavis.edu/PMG/L/I-DP-LSAT-MC.001.html>. The captures are highly correlated with the number of active miners. Care should be taken as wind may blow pupae from the trays and the trays away and farm equipment may run over the trays when they are placed between plant rows.
- *Adults captured by using adhesive applied to yellow cards (sticky traps)*.
- *Sweeping an entomological net in vegetable fields to capture flies, in addition to hatching flies from infested leaves*. Used in field surveys.

Sweeping nets have to be used on dry vegetation. They may not be effective on windy days when adults stay at lower levels of the plant canopy. For monitoring purposes, sampling has to be done consistently at approximately the same time in the mornings.

**Leaf sampling**

Samples can consist of leaves of vegetable crops, ornamental plants, and weeds. Plants should be inspected for leaves with mines at the bottom and mid height of the canopies. Sampling of leaves with mines is suitable for rearing and obtaining flies, as adult males are required for visual diagnosis of species. Molecular diagnosis can be carried out using adults and larvae. Leaf sampling also can be used to estimate abundance when one or more leafminer species are present and to detect the presence of parasitoids. Leaves may show stipples (feeding or ovipositing sites) and mines.

The collected leaves can be placed in a cooler and taken to the laboratory where they are examined using a stereomicroscope with transmitted light. These leaves may contain one or all of the following leafminer development stages: eggs, larvae, and/or pupae. The mines should be opened and pupae and larvae dissected. The number of mines, healthy leafminer instars, dead larvae, and larvae and pupal stages of endoparasitoids and ectoparasitoids should be recorded. Live leafminer larvae appear yellow; dead ones are dark brown to black. An example for sampling larvae on tomato leaves is provided by University of Florida (2008). Weintraub, (2001) sampled leaves and shoots with 5 to 6 leaves which were placed in paper bags that were sealed and stored for at least 5 weeks at room temperature before evaluating the contents.

Scouting should be done by walking and following a transect through the crop area and by inspecting crop plants and weeds along the margins of the planted area (Masetti et al., 2004).

**Sticky traps sampling**

Adults are attracted to yellow colour and can be captured by placing yellow sticky cards in the field or area being monitored. The traps are analogous to those used to monitor populations of whiteflies (*Bemisia* spp.). The number of captured flies can be used as an indicator of leafminer presence and movement of adults throughout a field. Sticky traps, however, are poor indicators of parasitoid activity.

In a crop, cards (10 x 20 cm) should be placed over the crop and between plant rows at mid-height of the canopy. Cards should be held by stakes. Trap height experiments indicated that captures of adults varied in number with the positioning of the sticky cards, crop species, and canopy architecture. For detection purposes in crops, cards could be located at low (30 cm off the ground), and 20-30 cm above the top of the plant canopy. Cards should be monitored weekly because dust and other trapped insects will make detection more difficult. Rain will ruin cards. Cards should be inspected with the aid of a magnifying lens and taken to the laboratory to examine under a stereoscope. Insects other than adult leafminers are attracted to yellow sticky cards. For descriptions and photos of insects on sticky cards refer to Casey

(2000). This author provides advice on scouting in greenhouses and on using sticky cards.

The time of the day when sampling is carried is important. Using yellow sticky cards, the peak of *L. huidobrensis* was observed to occur just after sunrise and to decline throughout the day until late afternoon. Decline in activity in the morning was significantly inversely correlated with temperature (Weintraub and Rami, 1996). If a detection of leafminers precedes a cold season, adults and larvae may not be noticed later during the cold season, as only pupae will remain in the ground beneath the plant canopy.

In greenhouses and nurseries, the cards should be placed at a rate of one card per 100 $m^2$. Adults captured on a series of cards during a 24-hour period indicate the relative abundance of leafminers. In the field, card density suggested is 20 to 50 per ha. Trapping should be repeated at least weekly.

Sticky traps images:
University of California
<http://www.ipm.ucdavis.edu/PMG/S/S-FL-SCEN-MO.030.html>

Captured adult image:
University of California
<http://www.ipm.ucdavis.edu/PMG/L/I-DP-LTRI-TR.001.html>

Advice and comments on the use of sticky traps for monitoring:
University of California
<http://www.ipm.ucdavis.edu/PMG/r280390411.html>
Cornell University
<http://www.nysipm.cornell.edu/publications/bpguide99/files/scout.pdf>

**Sampling regime**

Spread from infestation foci occurs rapidly under warm temperatures. Once the leafminer species is identified, leaf sampling based on damage can be carried weekly to monitor populations. Sticky cards also should be monitored weekly. Adults can fly to neighbour host plants, up to approximately one km, and can be carried by wind. Developmental times of leafminers range from 14 to 65 days depending on temperature (shorter with higher temperatures) and species. In cool environments, if mines are found on leaves and there are no signs of adults, pupae may be present in the soil beneath the plant. These pupae may be in diapause and winter generations of pupae will remain in the soil until warmer conditions occur again.

The information in the references below can be of use when developing survey protocols for pest-free areas. In crops such as chrysanthemums, celery, lettuce, and tomato, the distribution of larvae and pupae from field samples is generally clumped or aggregated (Burgio et al., 2005; Foster, 1986; Parrella, 1987 and references therein: Beck et al., 1981; Jones and Parrella, 1986a; Schuster and Beck, 1981; Zehnder and Trumble, 1985). Sequential sampling plans were developed for tomatoes (Ozawa, 2001; Schuster and Beck, 1992; Zehnder and Trumble, 1985), celery (Heinz and Chaney, 1995), and lettuce (Burgio et al., 2005). Some of these sampling plans were based on predetermined damage thresholds, which greatly vary depending on host, environment, and damage significance (i.e. if the injury leads to decrease in production or decreases aesthetic quality). Burgio et al. (2005) describe a sampling plan for *L. huidobrensis* that estimates the mean density of the population relative to a predetermined level of precision. The authors present constant precision stoplines for mines and live larvae (and for parasitoids). Foster (1986) describes a sampling method for pupae in celery. In a survey of leafminers in weeds near crop fields, Masetti et al. (2004) used a scouting protocol in which they looked for plants with mines in a determined area for a predetermined time.

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### 1.5.2 Hosts to be sampled

Plants to be sampled should comprise all developmental stages of plants that are known hosts. These will include vegetables and herbs, ornamental plants (identified in the National Nursery and Garden Biosecurity Plan), agronomic crops (grain legume crops such as chickpeas, peanuts, dry beans, and lupin; and cotton) and weeds (see Appendix 5). It is possible that exotic leafminers attack certain native plant species. Leaves from native plants that show mines in the area of detection also should be sampled. Samples of leaves with mines taken from different plant species should be placed in separate bags.

### 1.5.3 Epidemiological study

Refer also to Appendix 17 Functions in LPCC (Local Pest Control Centre) sections, in PLANTPLAN (2008).

Population increase after an incursion will depend on factors such as environmental conditions, leafminer species, and plant host abundance. Incursions that occur in warm weather regions or during spring or summer in cool regions may lead to rapid increases in population, rapid spread of the pest, and greater impact on host crops. Incursions that occur in greenhouses may be limited to crops under these structures in cold regions. In heated greenhouses that become infested, conditions for continuous breeding of leafminers may exist year round and insect populations will overlap. Outdoors, winter generations of pupae will remain in the soil until warmer conditions occur again.

The seasonal activity of the leafminer and its parasitoids should be monitored on vegetables and other hosts by collecting weekly leaf samples. In the laboratory leaf mines can be inspected under a stereomicroscope and leaves can be keept in containers until flies or parasitoids emerge. Adult activity should be monitored weekly on yellow sticky traps. Changes in leafminer population densities will be affected by factors such as environmental conditions, hosts, area cropped with hosts and their presence throughout the year, effect of natural biological control, and control methods used. Selected references of epidemiological studies (Andersen et al., 2008; Aunu et al., 2000, He et al., 2002; Hofsvang et al., 2005; Shepard et al., 1998; Weintraub, 2001) are listed below.

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### 1.5.4 Models of spread and establishment potential

Refer also to section 1.2.4. Potential areas for establishment in relation to favourable climate were estimated for *L. trifolii*, *L. sativae*, and *L. huidobrensis* (two “warm” tolerant leafminer species and a “cold” tolerant species, respectively) in Australia using the software CLIMEX (Sutherst et al., 2007).

In addition to the pest establishment predictions based on climatic conditions, maps with growing regions of host vegetables, ornamentals, grain legumes and other relevant hosts present further important information. A map with vegetable production regions in Australia is included in Appendix 8. This information can be of use when developing delimiting surveys and epidemiological studies. Overseas, Central Science Laboratory (2001), Milla

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### 1.5.5 Survey strategy sensitivity

Refer to Appendix 10 Delimiting Surveys, in PLANTPLAN (PHA, 2008).

A survey strategy plan with appropriate confidence limits should include the following information (PHA, 2008):

- Pest biology – survival, reproductive rate, spread and dispersal and influence of environmental factors;
- Host plant – extent of host range, distribution of hosts around restricted areas (RAs) and control areas (CAs), significance of developmental growth stage of hosts;
- Survey and sampling methods – ease of symptom recognition, sampling strategy (this should take into account the area of expected occurrence);
- A predictive analysis of areas where the pest is likely to occur;
- Expected prevalence of the pest if unrestricted; and
- Biometric methods to specify the different confidence limits for targeted and general surveillance.

In the event of a leafminer incursion, surveillance procedures can be prepared with advice from Biosecurity Australia, PHA, and CRC Plant Biosecurity.

### 1.5.6 Pest Free Area (PFA) guidelines

Guidelines for the establishment of pest free areas for Australia quarantine have yet to be developed. Refer to Appendix 10 Delimiting Surveys, in PLANTPLAN (PHA, 2008).

Advice from biosecurity officers involved in the eradication efforts and surveillance after detection of *L. sativae* was detected on a tomato plant on Warraber Island, Torres Strait (IPP, 2008) can be of assistance.

### 1.5.7 Reference documents

Plant Health Australia. 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <[http://www.planthealthaustralia.com.au/plantplan](http://www.planthealthaustralia.com.au/plantplan)>

International Plant Protection Convention (IPPC). 2009. Australia: Detection of vegetable leafminer in Torres Strait. International Phytosanitary Portal. Report AU-13/1. <[https://www.ippc.int/id/206356?language=en](https://www.ippc.int/id/206356?language=en)>

## 1.6 Availability of control methods

For the implementation of control methods, refer also to Section 3.3 Local Pest Control Centre, in PLANPLAN (PHA, 2008). Australian and international scientists with expertise in management of leafminer pests can provide additional advice in the event of an incursion (Refer to Appendix 2).

### 1.6.1 Control if small areas are affected

Practical only in a small scale area, the removal of plants (vegetables and/or weeds) with infested leaves may minimise the leafminer populations at a manageable level. The plants should be placed in bags and destroyed. A combination of cultural and chemical controls should be used in the area.

### 1.6.2 Control if large areas are affected

Eradication outdoors, in large areas, will be difficult if the presence of hosts and environmental conditions favour reproduction and establishment. An assessment of existing parasitoids, selective chemicals, and cultural methods should be considered when deciding on strategies to restrict the spread of the pest.

### 1.6.3 Cultural control

Adults experience difficulty in emerging if they are buried deep in soil (>30 cm). Disking fields to turn plant residues into the soil or burning plant residues in order to reduce infestation of neighbouring fields by emerging adults have been recommended as cultural control practices. These methods may be difficult to implement in large areas of legumes that are planted as cover crops or grain crops. In greenhouses where plants are grown in soil, laying a weed barrier fabric over the ground should be used to prevent adult *Liriomyza* leafminers from emerging after they have pupated in the soil.

Small field areas and plant canopies removed from greenhouse crops should be burned after being sprayed with an insecticide. Potting mix in containers that had infested plants may contain pupae that can be killed by sterilising media with water vapour or methyl bromide. The media also can be buried deep in soil.

Overseas, greenhouse-grown crops have been exposed to cold (subzero ºC temperatures) by opening greenhouse vents for a minimum period of two weeks during winter. In greenhouses, large surfaces that work as yellow sticky traps have been used to capture large number of adults. High temperatures (>40ºC) can be achieved in spring/summer by closing greenhouses during a week; this practice will kill adults.

If possible, field-grown vegetable crops that are hosts of leafminers should be rotated with crops that are not hosts, for example grasses. A reduction of nitrogen levels in plant tissue (i.e. avoiding excess of nitrogen fertilisers) is less favourable for leafminers to increase in number. Overseas, the use of vegetable crops bred for resistance to leafminers is a cultural management strategy that is been developed. Recently, leafminer resistant cultivars have been bred for spinach and lettuce in the U.S. (Mou and Liu, 2002; Mou, 2003).

### References

Mou, B. 2003. Screening and breeding for resistance to leafminer in spinach. Abstracts of the National Spinach Conference, Fayetteville, AR, U.S., p. 32. <http://www.ars.usda.gov/research/>

Mou, B., and Y. Liu. 2002. Leafminer resistance in lettuce. HortScience 38: 570-572. <http://www.ars.usda.gov/research/>

### 1.6.4 Chemical control / APVMA emergency use permits

Refer also to section 2.2.4 in PLANTPLAN (PHA, 2008).

Leafminer larvae are not reached by many pesticides because larvae develop inside the leaf and pupate in the soil. Thus, sprays that target adults do not provide effective management of the pest. Overseas, current chemical control methodhosetarget larvae, and the few effective active ingredients have translaminar activity. Those that currently provide effective control and that are recommended as part of integrated pest management (IPM) programs include cyromazine (e.g. Trigard® in U.S. and Citation 75WP® in Canada, from Syngenta Group Company), spinosad (e.g. Success Naturalyte Insect Control from Dow AgroSciences Australia Limited), abamectin [e.g. eChem Abamectin from eChem (Australia) Pty Ltd and several other chemical companies in Australia] and azadirachtin (several companies overseas). These products will also have some effect on adults.

Cyromazine is a triazine insecticide used as chitin-synthesis-inhibitor (insect growth regulator, IGR), which disrupts the molting of larval and pupal cuticles. It is less toxic to natural enemies compared with IGRs such as diflubenzuron. The current uses of cyromazine in the U.S. are for *Liriomyza* species in cole crops, lettuce, capsicums, spinach, celery, tomatoes and cucurbits. Multiple treatments are often required. To delay resistance, use of cyromazine should be alternated with pesticides of different chemistry (Grafton-Cardwell et al., 2005).

Spraying with larvicides is recommended when larvae are actively feeding in their mines. Because *Liriomyza* leafminers drop out of the mine to pupate, spraying mines after pupation is ineffective. Contact sprays used against adults every three to four days for about 10 days will kill those that emerge after the initial spray (Casey, 2000). Contact sprays (broad spectrum adulticides) have been used to control adults and include organophosphates (e.g. malation, dimethoate, diazinon) and pyrethroids (e.g. permethrin, bifenthrin, and tralomethrin). Control with broad spectrum insecticides is not effective against all leafminer stages, and their overuse has lead to resistant leafminer populations and destruction of leafminer parasitoids.

The Australian Pesticides and Veterinary Medicines Authority (APVMA) provides information on the status of use of these formulations. At the time of this report, cyromazine (used overseas as an insecticide and acaricide) was not registered for use on plants in Australia. Spinosad is registered for management of certain insect pests (e.g. thrips) in numerous vegetable species in Australia but permits will need to be obtained so that it can be used for leafminer control. Amabectin will require obtaining permits for use in some vegetable crop species. Azadirachtin (neem oil) is registered for use in ornamental crops in Australia but attempts to register the insecticide for use on food crops have failed in the past. In Australia, azadirachtin can be used for the control of certain species of mites, aphids and whitefly in ornamentals (several ornamental species are also hosts of the exotic leafminers), and fungus gnats in potting soil in the home garden.

In the U.S., it is recommended that cyromazine be alternated with different active ingredients. The first case of cyromazine resistance in leafminers (*L. trifolii*) occurred in celery in south Florida in 1990. Some strains of *L. trifolii* have been found to be resistant to spinosad or have moderate resistance to abamectin or cyromazine. However, resistances were unstable (reverted in the absence of insecticides) and there was no cross-resistance among cyromazine, abamectin, and spinosad (Ferguson, 2004). The systemic effects from a soil drench using a neem-based insecticide (1 ppm azadirachtin for 24 h) had an adverse effect on pupation and adult eclosion (0% adult eclosion) (Weintraub and Horowitz, 1997). It is important to note that the profile of resistance to active ingredients can differ among exotic leafminers.

### APVMA emergency use permits

The Australian Pesticides and Veterinary Medicines Authority (APVMA) is the national authority responsible for the registration and deregistration of chemicals. The APVMA Permit Section deals specifically with emergency registrations for chemicals. Any of the chemicals indicated here should be used only if they are approved by APVMA. All queries regarding the use of these chemicals should be directed to APVMA. For further information on chemical pesticide use in an Australian context visit the APVMA website at <http://www.apvma.gov.au/index.asp>. Contact for obtaining information on emergency use permits:

Peter Prammer
Team Leader (Permits)
APVMA
Phone: (02) 6272-3216
Email: pprammer@nra.gov.au.

The Agricultural Manual of Requirements and Guidelines (Ag MORAG) has information on data requirements and guidelines for applications to register or approve agricultural chemical products, labels, active constituents and issue permits. Ag MORAG is located at <http://www.apvma.gov.au/MORAG_ag/MORAG_ag_home.shtml>

Emergency use permits (Category 22 application) will be required to use chemicals for controlling leafminers. More information on this type of permit is located at <http://www.apvma.gov.au/MORAG_ag/vol_2/category_22.html>. An application form can be found at the following URL under Permit and Category 22 application <http://www.apvma.gov.au/MORAG_ag/applications_ag_home.shtml>

Selected overseas information sources that list chemicals recommended for use on leafminers in vegetable crops:

UC IPM Online of the University of California for chemicals used in California, U.S. <http://www.ipm.ucdavis.edu/PMG/r116300911.html>

Vegetable Production Guide of the University of Florida for chemicals used in Florida, U.S. <http://edis.ifas.ufl.edu/features/handbooks/vegetableguide.html>

Florida Insect Management Guide: Vegetables. IFAS, University of Florida, FL, U.S. <http://edis.ifas.ufl.edu/TOPIC_GUIDE_IG_Vegetables> [Leafminer management in several vegetable crops]

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Prijono D., M. Robinson, A. Rauf, T. Bjorksten, and A.A. Hoffmann. 2004. Toxicity of chemicals commonly used in Indonesian vegetable crops to *Liriomyza huidobrensis* populations and the Indonesian parasitoids *Hemiptarsenus varicornis, Opius* sp., and *Gronotoma micromorpha*, as well as the Australian parasitoids *Hemiptarsenus varicornis* and *Diglyphus isaea*. Journal of Economic Entomology 97: 1191-1197.

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Saito, T., M. Doi, H. Katayama, S. Kaneko, Y. Tagami and K. Sugiyama. 2008. Seasonal abundance of hymenopteran parasitoids of the leafminer *Chromatomyia horticola* (Diptera: Agromyzidae) and the impact of insecticide applications on parasitoids in garden pea field. Applied Entomology and Zoology 43: 617-624.

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### 1.6.5 Biological control

Early use of oil-based and chlorinated insecticides in the 1950s had more detrimental effects on natural hymenopteran parasitoid species (small wasps) than on leafminers. Over a period of few years, leafminers became resistant to many active ingredients; including pyrethroids (see Parrella and Keil, 1984). Nowadays, biological control strategies (natural or augmentative) and selective use of insecticides (e.g. IGR larvicides) that have a low impact on parasitoids are used in integrated leafminer management programs. Commercial breeding of leafminer parasitoids and entomophagous nematodes is a common practice in Europe and North America, with augmentative releases mainly used in greenhouse-grown crops. Refer also to the biological control section in the contingency plan for exotic leafminers affecting the Australian grain industry (Ridland et al., 2008).

#### Research work on biological control carried out by Australian scientists

After a leafminer incursion, pest surveys should also monitor the effect that native parasitoids have on the invasive species. An online guide to parasitoids of *Liriomyza* leafminers in Southeast Asia was developed by Fisher et al. (2008), as part of the ACIAR project CP/2000/090. A vast number of references are listed within that guide. John La Salle is the Australian scientist that may be contacted regarding leafminer parasitoids and biological control. Other Australian and overseas contact names that can provide information on taxonomy and biology and control of leafminer parasitoids are listed in Appendix 2.

The community of natural enemies of leafminers in a newly colonized area may be limited. However, common leafminers that are present in southern

Australia, such as *Liriomyza chenopodii*, *L. brassicae* and *C. syngenesiae*, on weeds and other non-crop plants would act as important reservoirs for populations of parasitoids of any invasive polyphagous agromyzids (Bjorksten et al., 2005; Malipatil and Ridland, 2008).

Control strategies that included biological control and the release of male-sterile leafminer flies have been used in California, U.S. (Parrella, 2005). A recent review of biological control of *Liriomyza* leafminers was prepared by Liu et al. (2009). Much of the work on integrated leafminer management of leafminers evaluate the effect of insecticides on parasitoids (Kaspi and Parrella, 2005; Prijono et al., 2004; Weintraub, 2001). Parasitoids of leafminer species are also listed by Pitkin et al. (2008).

## References


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Kaspi, R. and M.P. Parrella. 2005. Abamectin compatibility with the leafminer parasitoid *Diglyphus isaea*. Biological Control 35: 172-179.

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### 1.6.6 Reference documents

Plant Health Australia. 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

## 2 Course of action – Eradication methods

The feasibility of eradication need to be assessed on technical and economic grounds. Initial surveys can provide an indication of how widespread the invasion is. Refer also to Appendix 12 Eradication or Alternative Action and Appendix 14 Planning Eradication at Affected Properties, in PLANTPLAN (PHA, 2008).

No successful eradication programs from widespread leafminer invasions have been reported from warm-climate regions. The success of eradication programs conducted in the EPPO region (Europe) cannot be confirmed (CAB International, 2007). CSL (2001a) and Powell (1981) describe the challenges for *L. huidobrensis* eradication attempts in the U.K. Some of the leafminer eradication programs in Europe were succesful in cooler regions of northern Europe where the pest could survive only in glasshouses or during very short periods of the warmer season in the open environment. If an incursion occurs in Australia, it can be expected that eradication from regions that have favourable environments for the establishment and presence of numerous hosts will be difficult, if not impossible.

Biosecurity Australia has records of actions taken when *L. sativae* was detected on a tomato plant on Warraber Island, Torres Strait (IPPC, 2008).

References to projects that investigate potential integrated strategies for eradicating *Liriomyza* species in the U.K. are listed below.

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## 2.1 Destruction strategy

Destruction strategy should target plants and soil or root media beneath the plant canopies. Treatment of plants and soil may vary depending whether on-site destruction or off-site transportation and burial is implemented (e.g. for outdoor crops or greenhouse-grown plants). To destroy plants that carry leafminer eggs, larvae, and pupae (mainly for *C. horticola* but also for *Liriomyza* pupae that may remain on leaf surfaces), plants should be sprayed with an insecticide that will have a knock down effect on adults and one with translaminar activity that will kill larvae. Plants could then be destroyed with methods such as incineration or deep burial.

If it is convenient, low temperatures can be used to kill leafminers on harvested produce. All stages of the key leafminers can be killed within a few weeks by cold storage at 0°C (EPPO, 1992). Newly laid eggs, however are the most resistant stage. In chrysanthemums, newly laid eggs of *L. trifolii* survived for up to 3 weeks at 0°C (Webb and Smith, 1970). If eggs are left to hatch, subsequent storage of the plants at 0°C for 1-2 weeks should kill the larvae (Webb & Smith, 1970).

Methyl bromide (with a concentration time product of 54 $mg \cdot L^{-1}h$) was effective for killing eggs, larva and pupae of *L. huidobrensis* and *L. trifolii* in crysanthemums cuttings (EPPO, 1993; Macdonald and Mitchell, 1996).

Media in plant containers can be sterilised (vapour steam or methyl bromide) or buried deeply. It may be more difficult to treat larger areas with soil that potentially contain pupae. Small areas could potentially be covered and treated with methyl bromide or flooded to kill pupae. Covering the soil with a fabric will impede the escape of emerging adults.

Refer also to Appendix 18: Disinfection and Decontamination, in PLANTPLAN (PHA, 2008). It includes guidelines for Destruction of Infested/Infected Plants, Organisation of Destruction, and Decontamination. Refer also to the destruction section in the contingency plan for exotic leafminers affecting the Australian grain industry (Ridland et al., 2008).

### References

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### 2.1.1 Destruction protocols

Refer also to Appendix 18: Disinfection and Decontamination, in PLANTPLAN (PHA, 2008). It includes guidelines for Destruction of Infested/Infected Plants, Organisation of Destruction, and Decontamination.

In large areas, infested plant material should be sprayed with an effective insecticide before they are tilled into the soil. If plants are removed from its place (e.g. in a greenhouse) or are in a small number, they should be sprayed with an insecticide, bagged and buried, or incinerated. Plants should not be composted, as pupae may survive. Sterilisation (by steam or a fumigant, such as methyl bromide) could also be used for media and soil that is beneath plants.

### 2.1.2 Priorities

Refer also to Appendix 18: Disinfection and Decontamination, in PLANTPLAN (PHA, 2008). Priority is to limit the movement of the pest, which can be achieved by:

- Confirmation of the presence of the leafminer and species identity.
- Restriction of the movement of leafminers by preventing the movement of plants and soil, including machinery or tools that can transport/spread plant material or soil within the infested premises.
- Application of insecticides that kill leafminers.
- Elimination of plant material (burial or incineration) to avoid further spread.

- Management of water flows (e.g. with furrow irrigation systems and canals; disposed water used for washing produce) that could transport pupae or infested plant material.
- Sterilisation of soil or covering of soil to prevent emergence of new adults.
- Decontamination of premises, vehicles, equipment and materials.

### 2.1.3 Processing of plants and waste

Harvesting and transportation of plant material to processing facilities can lead to the dissemination of the pest. Depending on the type of produce, the plant material could be frozen or processed at high temperature onsite, if it is to be suitable for consumption.

Packaged fresh plant material (for example whole leaves of vegetables, pea pods, celery petioles) originating from plants that were infested with leafminers has the potential of hosting a living stage of the insect.

Waste plant material removed during packaging (e.g. outer leaves of lettuce plants) should be destroyed.

Waste water that can carry plant material (e.g. leafy produce in packing/processing facilities) should be contained and plant residues destroyed.

### 2.1.4 End-use of plant products

Consumption of produce will be dependant on the control treatments used to limit the spread of the pest. The end-use of fruit from plants infested with leafminers is not affected. Cosmetic quality will be decreased when mines are present on leafy produce and celery. If the produce will be processed, the cosmetic damage by leafminers will not be of importance.

Leafy vegetables and pea pods from infested premises are key carriers of all life stages of leafminers. Heat treatments (e.g. 44ºC) that would kill leafminers in plant material are not suitable as they will damage fresh market produce (Cuthbertson et al., 2009).

Although it is unlikely, truss or peduncle of fruit, or the fruit surface, could carry pupae if these insect stages were formed on the plant instead of the soil, and dropped over fruits. Roots and tubers with soil attached and bulbs could potentially harbour pupae. Washing and brushing these plant organs should reduce the risk.

#### References

Cuthbertson, A.G.S., L.F. Blackburn, P. Northing, J.J. Mathers, W. Luo, K.F., and A. Walters. 2009. Environmental evaluation of hot water treatments to control *Liriomyza huidobrensis* infesting plant material in transit. International Journal of Environmental Science and Technology 6: 167-174. <http://www.ceers.org/ijest/issues/full/v6/n2/602001.pdf>

### 2.1.5 Disposal issues

The elimination of plant material through deep burial or incineration should not pose any disposal problem. Plant material to be destroyed should not be composted, because the insects will not be killed. Plant material collected from small areas can also be bagged and then buried.

### 2.1.6 Reference documents

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

## 2.2 Quarantine and movement controls

Refer to information on the implementation of barrier quarantine at all levels of the vegetable industry, including national (importation restrictions), state (movement restrictions), regional (movement restrictions), and farm (exclusion activities). This is specified in the National Vegetable Industry Biosecurity Plan (Risk Mitigation Plan) (PHA, 2007).

### 2.2.1 Quarantine priorities

Quarantine priorities should include the following issues:

- Confirmation of the pest species.
- Plant material and soil at the site of the infection to be subject to movement restrictions.
- Machinery and equipment that came in contact with plant material and soil at the site to be subject to movement restrictions.
- Small flies are capable of limited flight but wind may transport them over greater distances.

### 2.2.2 Movement control of people, plant material and machinery

Movement control of people, plant materials and machinery will mostly limit the movement of eggs, larvae and pupae. Adult leafminers can fly even short distances and may be air-transported.

**People**

If people are not carrying host plants, it is unlikely that they would be carriers of leafminers. To minimise the risk of transporting pupae that may be present in the soil beneath leafminer infested plants (*Liriomyza* species in the group pupate mostly in soil), soil on boots should be cleaned after walking in infested crops.

**Plant material**

The most probable means of movement of egg, larvae, and pupae is on plants, fresh produce (e.g. leafy vegetables), and cuttings intended for propagation. Movement of top soil or root media underneath infested plants may contain pupae.

**Machinery**
Soil, leaves, and pea pods held on agricultural machinery have the potential of carrying pupae (via soil or leaves of *C. horticola*), and eggs and larvae (on leaves).

### 2.2.3 Infected premises (IP)

The Infested Premises are defined as the premises (or locality) at which the Emergency Plant Pest (EPP) is confirmed or presumed to exist (PHA, 2008).

### 2.2.4 Restricted area (RA)

The Restricted Area is defined as the relatively small area (compared to the Control Area) around infected premises and suspected premises that are subject to intense surveillance and movement controls (PHA, 2008). Movement out of the area, in general, should be prohibited, while movement into the Restricted Area should be only by permit. Multiple Restricted Areas may exist within one Control Area.

### 2.2.5 Control area (CA)

A Control Area should be imposed around the Restricted Area and should include all Suspected Premises. The purpose of a Control Area is to regulate movement of susceptible plant species (leafminer hosts) for as long as is necessary to complete trace back and epidemiological studies. Movement controls should apply and the area should be surveyed regularly. Once the limits of the pest have been confidently defined, the Control Area boundaries and movement restrictions should be reduced or removed (PHA, 2008).

### 2.2.6 Pest quarantine area (PQA)

The Pest Quarentine Area is defined as the area where compulsory or voluntary restraints upon activities are put into place in an affected property, imposed as part of an EPP Response Plan and in accordance with relevant State/Territory plant health legislation to prevent the spread of an EPP(s) (PHA, 2008). This area includes restrictions on access to and removal of plants from an affected property, and movement controls on plants, plant products, people, machinery and other items except as approved in accordance with the EPP Response Plan.

### 2.2.7 Reference documents

Merriman, P. and S. McKirdy. 2005. Technical guidelines for development of pest specific response plans. Plant Health Australia, Canberra, ACT, Australia.

Plant Health Australia. 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

OEPP/EPPO. 1990. Specific quarantine requirements. *EPPO Technical Documents* No. 1008.

Plant Health Australia (PHA). 2007. National Vegetable Industry Biosecurity Plan – Version 1 May 2007. Plant Health Australia, Canberra, ACT, Australia.

<http://www.ausveg.com.au/assets/contentitems/public/6653/National_vegetable_industry_biosecurity.pdf>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

## 2.3 Zoning

### 2.3.1 Zones and sizes

The size of the zones will be determined by a number of factors, including the extent of the infestation when initially detected, location of the incursion, the climatic conditions at the time, the biology of the exotic leafminer, the abundance and diversity of hosts, and the proximity among properties where the leafminer species has been confirmed.  For information regarding establishing zones refer also to Appendix 10 Delimiting Surveys in PLANTPLAN (PHA, 2008).  Information in this section was obtained from Malipatil and PHA (2008).

Warm weather regions, and spring and summer seasons, in general will have a favourable effect on the increase of leafminer populations.  High wind circumstances, the presence of extensive and diverse host vegetable crops, and recent movement of produce in the area are factors that will spread the pest.

#### 2.3.1.1 Destruction

The size of the Destruction zone will depend on the ability of the pest to spread, the distribution of the pest as determined by delimiting surveys, the time of the season and pest life cycle targeted, and the factors that can aid in spreading the pest (e.g. the availability of hosts, movement of plant material, and high winds).

#### 2.3.1.2 Quarantine

To determine the size of the area of the Quarantine zone refer to the checklist below under the section “Risk mitigation protocols for the development of quarantine zones and movement controls” in Merriman and McKirdy (2005).

- Identify the risk of introducing strains particularly with resistance to insecticides
- Identify the likely generation time (egg to adult, including number of life stages) under degree day formula
- For climatic zones, predict the number of generations per season and numbers per generation
- Identify preferred environment (plant, seed, soil) for maturation of life stages and known sites of survival over summer and winter
- Analyse the scientific literature to identify the range of cultivated and Australian plants and weeds which are recorded as naturally occurring hosts of the emergency plant pest; identify their significance in Australia

- Identify methods and the likely extent of natural dispersal, including factors which trigger development of alate forms
- Identify risks of mechanical dispersal on equipment, plant parts, soil, people
- Identify risks of the emergency plant pest acting as a vector for plant pathogens
- Predict the limits of the distribution of the organism in Australia as determined by vegetation and climate analyses.

#### 2.3.1.3 Buffer

Buffer zones are areas where the pest does not occur but where movement controls or restrictions for removal of plants, people, soil, or equipment from this area is still judged necessary. These areas may enclose the infested area or may be adjacent to the infested area. The buffer zones established around affected premises may require having healthy host plants destroyed to prevent the spread of a pest outbreak. This may be difficult in many circumnstances because of the large number of plant species that are hosts of leafminers. Refer also to Appendix 10 Delimiting Surveys, and Appendix 18: Disinfection and Decontamination, in PLANTPLAN (PHA, 2008).

#### 2.3.1.4 Restricted

The size of the Restricted Area (RA) is established following initial surveys that confirm the presence of the pest. This area will be subject to intense surveillance and movement control with movement out of the RA to be prohibited and movement into the RA to occur by permit only. Multiple RAs may be required within a Control Area (CA).

#### 2.3.1.5 Control

The Control Area includes all areas affected with the incursion. It includes the Restricted Area, all infected premises and suspected premises and should be defined as the minimum area necessary to prevent the spread of the pest from the Quarantine Zone. It also should be used to regulate the movement of all susceptible plant species to allow trace back, trace forward and epidemiological studies to be completed.

### References


Malipatil, M. and Plant Health Australia (PHA). 2008. Sunn Pest, *Eurygaster integriceps*. Grains National Biosecurity Plan, Threat Specific Contingency Plan. PHA, GRDC, and CRC Plant Biosecurity. Australia.

Merriman, P. and S. McKirdy. 2005. Technical guidelines for development of pest specific response plans. Plant Health Australia, Canberra, ACT, Australia.

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia*

*horticola*. Plant Health Australia, Canberra, ACT, Australia.

### 2.3.2 Reference documents

Merriman, P. and S. McKirdy. 2005. Technical guidelines for development of pest specific response plans. Plant Health Australia, Canberra, ACT, Australia.

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

## 2.4 Decontamination and farm clean-up

### 2.4.1 General guidelines for decontamination procedures

Refer also to Appendix 18: Disinfection and Decontamination, in PLANTPLAN (PHA, 2008). It includes guidelines for Destruction of Infested/Infected Plants, Organisation of Destruction, and Decontamination

If eradication is considered feasible, the first priorities will involve destruction of the invasive pest. Leafminers will be flying around plants, in leaves (as egg, larvae and/or pupae), and as pupae on the soil/floor surface and/or within the first 5 cm of soil depth.

Decontamination procedures will differ if dealing with a few plants, an open field crop, or a greenhouse crop. The plant/s may require to be sprayed with an insecticide, bagged, removed, and then buried or tilled directly into the soil. In addition, plants in the area that are known to be hosts of the leafminer species or that show symptoms should be inspected and treated following the same procedures as plants where the pest was first detected. Soil and plant media in greenhouses should be sterilised.

### 2.4.2 Reference documents

Plant Health Australia. 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

## 2.5 Surveillance and tracing

A surveillance plan should be developed so that systematic examination of plants is followed in order to determine if leafminers are present or absent in a determined area. Tracing should be concentrated in recent movements of plant material (that are known hosts of leafminers) in and out of the infected premises. Refer also to Appendix 15 Functions of SPCHQ Sections, in PLANTPLAN (PHA, 2008). The methods described in Section 1.5.1 can be used to monitor leafminer populations.

Observations of susceptible plants will indicate the pest presence. The pupal rearing method involves collecting samples of leaves or leaflets in a screened container for several days and then counting the number of puparia that have emerged from the leaves (approx. a week after sampling, at 23ºC) (Foster, 1986). The method provides information on leafminer ovipositional activity during some previous period of time. It can be used to monitor population trends and to evaluate the effectiveness of previous control measures. One advantage is that it can be used to estimate parasitism.

It takes approximately 30 minutes to take 10 sets of 10 leaflet samples from an 11-ha field of tomatoes (Foster, 1986). For an idea of the time consumed in counting pupae, counting for a density of 10 pupae per 10 leaflets can take 15 minutes. The counting is done a week after incubation, thus there is a lag time before the information becomes available.

Adults are attracted to yellow sticky cards placed over the top of the plant canopy in host crops. Cards are available commercially and they can be held on stakes above the plant canopy. One card every 100 $m^2$ throughout susceptible host plants is used for monitoring adult flies in greenhouses. The number of flies captured on a series of cards during a 24-hour period indicates the relative abundance of leafminers. Trapping should be repeated at least weekly. Consider prevailing winds when placing and positioning the cards in the field.

Distribution of leafminers in field crops is generally aggregated. Dispersal within the field occurs within less than 30 m from the foci of infestation. In many cases, leafminers may be found in clusters of plants along the edges of fields, near weeds that are hosts (Masetti et al., 2004). Field crops can infest transplant nurseries located close by (Tryon et al., 1980).

### References

Foster, R.E. 1986. Monitoring populations of *Liriomyza trifolii* (Diptera: Agromyzidae) in celery with pupal counts. Florida Entomologist 69: 292-298.

Masetti, A., A. Lanzoni, G. Burgio, and L. Süss. 2004. Faunistic study of the Agromyzidae (Diptera) on weeds of marginal areas in northern Italy agroecosystems. Annals of the Entomological Society of America 97: 1252-1262.

Tryon E.H., S.L. Poe, and H.L. Cromroy. 1980. Dispersal of vegetable leafminer onto a transplant production range. Florida Entomologist 63: 292-296.

## 2.6 Surveillance

A survey protocol for confirmation of pest free area status consistent with national guidelines has yet to be developed. Guidelines for the development of Pest Free Areas for Australian Quarantine are currently in draft form (PHA, 2008). These will be available from PHA. The references below may be of assistance for developing a survey protocol for invasive leafminers. An outline of the steps that form the basis of a surveillance plan is reported by Ridland et al. (2008) in the contingency plan for exotic leafminers affecting the Australian grain industry, and by Malipatil and PHA (2008).

### References

Asia-Pacific Economic Cooperation (APEC). 2007. Capacity building in surveillance and diagnosis for leafminer, whitefly, thrips, and mealybug pests in developing APEC economies for improved market access. 22-25 May 2006, Kuala Lumpur, Malaysia. ATC 01/2006A. <http://www.apec.org>

Malipatil, M. and Plant Health Australia (PHA). 2008. Sunn Pest, *Eurygaster integriceps*. Grains National Biosecurity Plan, Threat Specific Contingency Plan. PHA, GRDC, and CRC Plant Biosecurity. Australia.

McMaugh, T. 2005. Guidelines for surveillance for plant pests in Asia and the Pacific. Australian Centre for International Agricultural Research (ACIAR), ACT, Australia. Online at <http://www.aciar.gov.au/publication/MN119>

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

## 2.7 Survey regions

Survey areas should take into consideration areas with leafminer hosts and favourable climate. This should include host plants in commercial crops in field and greenhouses, home gardens, and urban and periurban areas. Establishment predictions and advice from scientists with expertise in leafminers will be of assistance in determining limits.

## 2.8 Post invasion surveillance

The post invasion surveillance should consider statistical deployment and scheduled weekly inspection of yellow traps and leaf sampling. Known hosts that are preferred by the leafminer species can be used as sentinel plants.

## 2.9 Post eradication surveillance

The post eradication surveillance should consider statistical deployment and scheduled weekly inspection of leaves in host canopies and of yellow traps placed in areas with hosts. Indicator plants (ornamental plants that are hosts, such as chrysanthemums) may be placed in crops. These plants are of a different species than the crop and are used because they have distinctive symptoms of a pest or are especially attractive to that pest.

In regions with cold weather, monitoring should continue after the cold season because adults from pupae in soils will appear later in the warm season. Refer to Program to confirm eradication in Appendix 14 in PLANTPLAN (PHA, 2008).

## 2.10 Reference documents

Merriman, P. and S. McKirdy. 2005. Technical guidelines for development of pest specific response plans. Plant Health Australia, Canberra, ACT, Australia.

## 3 References

Consulted and cited references were included at the end of each section.

# 4 Appendices

## Appendix 1. Standard diagnostic protocols

Malipatil and Ridland (2008) developed a web-based graphic Lucid3 key which allows entomologists to make a preliminary identification of pest agromyzids and to distinguish these species from non-pest endemic agromyzids. The information portal also contains numerous images of the pest and plant damage symptoms, plant hosts, important diagnostic characters, factsheets, bibliography as well as a number of web links to images. Molecular diagnostic tests and references indicated by Malipatil and Ridland, (2008) can be located at <http://keys.lucidcentral.org/keys/v3/leafminers/molecular.htm>.

The European and Mediterranean Plant Protection Organization (EPPO) published Standards on Diagnostics, which provide information necessary for a named pest to be detected and positively identified by an expert. Standard diagnostic protocols are available for *L. bryoniae*, *L. huidobrensis*, *L. sativae* and *L. trifolii* from EPPO (2005) and de Goffau et al. (2005); web links to these publications are included below. The protocols describe adult morphology and distinct patterns of mines on leaves, and provide procedures for biochemical and molecular tests required for identification.

For differentiation between *C. horticola* and *C. syngenesiae* refer to Ellis (2007). Both species are morphologically similar and polyphagous. *C. syngenesiae* lives almost exclusively on Asteraceae, while *horticola* has been found on at least 24 families of flowering plants, with a marked preference for Asteraceae, Brassicaceae and Fabaceae (Ellis, 2007).

High quality images and morphological descriptions of leaf miner species can be found in the web links of the following references:

Dempewolf, M. 2004. CD-ROM on Agromyzidae (Diptera) of economic importance. Institute for Biodiversity and Ecosystem Dynamics/Zoological Museum Amsterdam. The Netherlands. <http://ip30.eti.uva.nl/bis/agromyzidae.php>

Edmunds, R. 2003. British leaf miners. U.K. <http://www.leafmines.co.uk/index.htm>

Ellis, W.N. 2007. Bladmineerders van Europa / Leafminers of Europe. Zoölogisch Museum, Universiteit van Amsterdam. The Netherlands. <http://www.bladmineerders.nl/minersf/dipteramin/chromatomyia/horticola/horticola.htm>

Malipatil, M. and P. Ridland. 2008. Polyphagous Agromyzid leafminers. Department of Primary Industries, Victoria, Australia. <http://keys.lucidcentral.org/keys/v3/leafminers/index.htm>

PaDIL. 2008. Pests and Diseases Image Library. Museum Victoria, Plant Health Australia, the Department of Agriculture, Fisheries and Forestry, and Western Australian Department of Agriculture. <http://www.padil.gov.au>

Pitkin B., W. Ellis, C. Plant, and R. Edmunds. 2008. The leaf and stem mines of British flies and other insects. Department of Entomology, Natural History Museum, London. <http://www.ukflymines.co.uk/index.html>

## References


Ellis, W.N. 2007. Bladmineerders van Europa / Leafminers of Europe. Zoölogisch Museum, Universiteit van Amsterdam. The Netherlands. <http://www.bladmineerders.nl/minersf/dipteramin/chromatomyia/horticola/horticola.htm>

EPPO. 2005. EPPO Standards - Diagnostic protocols for regulated pests - PM7/53 *Liriomyza* spp. Bulletin OEPP/EPPO Bulletin 35: 335-344. <http://www.eppo.org/QUARANTINE/insects/Liriomyza_huidobrensis/pm7-53(1)%20LIRISP%20web.pdf>

Kox, L.F.F., H. E. van den Beld, B.I. Lindhout, and L.J.W.de Goffau. 2005. Identification of economically important *Liriomyza* species by PCR-RFLP analysis. Bulletin OEPP/EPPO Bulletin 35: 79-85. <http://www3.interscience.wiley.com/journal/118695550/abstract>

Malipatil, M. and P. Ridland. 2008. Polyphagous Agromyzid Leafminers. Identifying polyphagous agromyzid leafminers (Diptera: Agromyzidae) threatening Australian primary industries. Department of Primary Industries, Victoria, Australia. <http://keys.lucidcentral.org/keys/v3/leafminers/index.htm>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

Shiao, S.F. 2004. Morphological diagnosis of six *Liriomyza* species (Diptera: Agromyzidae) of quarantine importance in Taiwan. Applied Entomology and Zoology 39: 27-39.

U.S. Department of Agriculture. 2008. Request for Comments on Regulatory Options for Pea Leaf Miner. (and two attached files: Regulatory options for pea leaf miner and *Liriomyza langei.* Is *Liriomyza langei* a real species or a biotype of *L. huidobrensis*?). U.S. Department of Agriculture and Animal and Plant Health Inspection Service, U.S. <http://www.nationalplantboard.org/docs/spro/spro_pea_leaf_miner_2008_12_19.pdf>

## Appendix 2. Experts and diagnostic laboratories

The following scientists with expertise in leafminers have been identified from the literature and may provide professional advice services in case of an incursion.  Entomologists trained in insect taxonomy in official State/Territory laboratories may obtain advice from diagnosticians that have expertise in Agromizid leafminers.

*Australian expert diagnostician:*

**Mali Malipatil**
Section Leader – Taxonomy (Biosystematics)
Department of Primary Industries (Vic)
621 Burwood Highway
Knoxfield Vic 3180
Phone: (03) 9210 9222
Fax: (03) 9800 3521
Email: mallik.malipatil@nre.vic.gov.au

*International expert diagnostician and diagnostics laboratories:*

**Sonja Jean Scheffer**
Molecular Biologist
Systematic Entomology Laboratory, USDA
Room 314
10300 Baltimore Avenue
BLDG 011A BARC-WEST
Beltsville, MD, 20705-0000, U.S.A.
<http://www.ars.usda.gov/main/site_main.htm?modecode=12-75-41-00>
Phone: +1 (301) 504-5317
Fax: +1 (301) 504-6482
Email: sonja.scheffer@ars.usda.gov

**Central Science Laboratory**
CSL, York, UK
The Food and Environment Research Agency (Fera)
<http://www.fera.defra.gov.uk/>

**Plant Research International**
Wageningen UR
P.O. Box 16
6700 AA Wageningen, The Netherlands
Contact: **Carolien Zijlstra**

Phone: 31 (0)317 486001
Fax: 31 (0)317 418094
Email: carolien.zijlstra@wur.nl
<http://www.pri.wur.nl/UK/research/research+themes/Interaction+between+plants+pests+and+diseases/Characterization+identification+and+detection/>

*Australian scientists with extensive expertise in leafminers:*

**John La Salle**
Head of the Australian National Insect Collection
CSIRO Entomology
GPO Box 1700, Canberra
ACT 2601
Phone: (02) 6246 4262
Fax: (02) 6246 4264
Email: John.LaSalle@csiro.au

**Peter Ridland**
Formerly Section Leader, Invertebrate Sciences at the Department of Primary Industries in Knoxfield, Victoria.
Phone: (03) 9486 3679
Email: peter.ridland@iinet.net.au
Project leader of the ACIAR project (CP/2000/090; <http://www.aciar.gov.au/project/CP/2000/090>) "*Liriomyza huidobrensis* leaf miner: developing effective pest management strategies for Indonesia and Australia".

**Tracey A. Bjorksten**
Department of Primary Industries, Knoxfield, Private Bag 15, Ferntree Gully Delivery Centre, Vic. 3156, Australia.
CESAR: Centre for Environmental Stress and Adaptation Research, La Trobe University, Bundoora, Vic. 3086, Australia.
Email: t.bjorksten@latrobe.edu.au

**Ary A. Hoffmann**
CESAR Director
Melbourne University
Level 2
Bio21 Institute
Phone: (03) 8344 2282
Fax: (03) 8344 2279
Email: ary@unimelb.edu.au

*International scientists with extensive expertise in leafminers*

**Michael P. Parrella**
Professor, Department Chair
College of Agricultural and Environmental Sciences, Division of Agricultural Sciences, Department of Entomology, University of California,
One Shields Avenue, Davis, CA, USA.
<http://entomology.ucdavis.edu/faculty/facpage.cfm?id=parrella>
<http://entomology.ucdavis.edu/faculty/parrella/index.cfm>

**Kevin M. Heinz**
Professor, Department Chair
Department of Entomology
Texas A&M University
TAMU 2475
College Station, TX 77843-2475, U.S.A.
Phone: +1 (979) 845-2510
Email: kmheinz@tamu.edu
<http://insects.tamu.edu/people/faculty/heinz_lab.cfm>

*Australian and International scientists with expertise in monitoring distribution of leafminer species*

**Peter Ridland** and **Mali Malipatil** (see contacts above)

**Merle B. Shepard**
Professor
Clemson University
Coastal REC, 2700 Savannah Highway,
Charleston, SC 29414, U.S.A.
Phone: +1 (843) 402-5393
Fax: +1 (843) 571-4654
Email: mshprd@clemson.edu
<http://entweb.clemson.edu/faculty/shepard.htm>

**Arild Andersen**
Professor
Norwegian University of Life Sciences (UMB)
Department of Plant and Environmental Sciences
Høgskolev.7, N-1432 Ås, Norway
Email: arild.andersen@bioforsk.no

The following table was reproduced from Malipatil and PHA (2008) and Ridland et al. (2008) and lists facilities that are available for general diagnostic services in Australia.  Contact expert diagnostician/s for facilities that will provide leafminer diagnosis to the level of species.

| Facility | State | Details |
|---|---|---|
| DPI Victoria Knoxfield Centre | Vic | 621 Burwood Highway<br>Knoxfield VIC 3684<br>Ph: (03) 9210 9222<br>Fax: (03) 9800 3521 |
| DPI Victoria Horsham Centre | Vic | Natimuk Rd<br>Horsham VIC 3400<br>Ph: (03) 5362 2111<br>Fax: (03) 5362 2187 |
| DPI New South Wales<br>Elizabeth Macarthur Agricultural Institute | NSW | Woodbridge Rd<br>Menangle NSW 2568<br>PMB 8 Camden NSW 2570<br>Ph: (02) 4640 6327<br>Fax: (02) 4640 6428 |
| DPI New South Wales<br>Tamworth Agricultural Institute | NSW | 4 Marsden Park Rd<br>Calala NSW 2340<br>Ph: (02) 6763 1100<br>Fax: (02) 6763 1222 |
| DPI New South Wales<br>Wagga Wagga Agricultural Institute | NSW | PMB Wagga Wagga<br>NSW 2650<br>Ph: (02) 6938 1999<br>Fax: (02) 6939 1809 |
| SARDI Entomology Group – Waite Main Building, Waite Research Precint | SA | Hartley Grove<br>Urrbrae 5064<br>South Australia<br>Ph: (08) 8303 9400<br>Fax: (08) 8303 9403 |
| Grow Help Australia | QLD | Entomology Building<br>80 Meiers Road<br>Indooroopilly QLD 4068<br>Ph: (07) 3896 9668<br>Fax: (07) 3896 9446 |
| Department of Agriculture and Food, Western Australia<br>(AGWEST) Plant laboratories | WA | 3 Baron-Hay Court<br>South Perth WA 6151<br>Ph: (07) 9368 3721<br>Fax: (03) 9474 2658 |

## References


Malipatil, M. and Plant Health Australia (PHA). 2008. Sunn Pest, *Eurygaster integriceps*. Grains National Biosecurity Plan, Threat Specific Contingency Plan. PHA, GRDC, and CRC Plant Biosecurity. Australia.

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.

## Appendix 3. Communications strategy

A communication strategy is described in Appendix 6 Communications, in PLANTPLAN (PHA, 2008). PLANTPLAN contains an updated list with key agents and contacts, which includes the Chief Plant Protection Officer and Chief Plant Health Managers for each State/Territory, and the Chief Executive Officer of Plant Health Australia.

Anybody finding a plant that they believe may be infested with a new leafminer species should report it immediately to the Exotic Plant Pest Hotline (1800 084 881) or can directly contact the nearest office of relevant State/Territory Department of Agriculture/Primary Industries.

State/Territory contacts for reporting suspected exotic pests

| State | Relevant authority | Contact |
|---|---|---|
| ACT | Environment ACT | **13 22 81** |
| NSW | New South Wales Department of Primary Industries | Phone **(02) 6394 3174** and ask for the Manager, Plant Biosecurity Risk Management |
| NT | Department of Primary Industry, Fisheries and Mines | Phone **(08) 8999 2337** and ask for the Manager of Plant Health |
| Qld | Primary Industries and Fisheries, Queensland | PI&F Call Centre on **(07) 3404 6999** or the Call Centre on **13 25 23.** |
| SA | Primary Industries and Resources of South Australia | **1300 666 010** |
| Tas | Department of Primary Industries and Water, Tasmania | **(03) 6233 3352** |
| Vic | Victorian Department of Primary Industries | **1800 084 881** or **(03) 8371 3500** |
| WA | Department of Agriculture and Food, Western Australia | Phone **(08) 9368 3333** and ask for the Manager of Plant Health |

The office contacted should get in touch immediately with an experienced entomologist and a taxonomist on Agromizidae (See Appendix 2). The taxonomist will provide the entomologist with details on how samples should be collected and dispatched.

To minimise the risk of the pest spreading, samples should not be moved until they have been checked by the entomologist. The infested plants and soil beneath these plants should not be removed from the infested premises. If there is some delay before an entomologist can visit the site to inspect the suspect plant/s, the suspect plant/s should be covered with bags (paper or cloth preferably) that should be tied tightly around the base of the stems (if practically possible).

The expert taxonomist will confirm that the plant is infested with a new leafminer species. Preliminary diagnosis will be carried through observation on insect morphology and leaf symptoms. However, it is likely that confirmation of species will require molecular tests. The entomologist must notify the State/Territory Chief Plant Biosecurity Officer (Plants) in the

State/Territory Department of Agriculture/Primary Industries, and also should prepare a brief report on the known details of the introduction [Refer to Appendix 7, in PLANTPLAN (PHA, 2008)]. Actions should be initiated immediately after the taxonomist has confirmed the identification of the new pest leafminer species.

The State/Territory Chief Plant Biosecurity Officer (Plants) will notify the State Minister (through the head of the department) and the Chief Plant Protection Officer in Canberra. The Chief Plant Protection Officer will notify the Federal Minister. A strategic Management Group should be convened at this stage in the affected State/Territory to coordinate the initial response.

In the event of a leafminer incursion affecting the vegetable industry, AUSVEG will be the key industry contact point and will be responsible for industry communication and media relations. The PHA Vegetable Biosecurity Plan (PHA, 2007) outlines the general decision-making and communication chain for a plant pest emergency response. It also outlines the industry specific response procedures which include lists for key contacts for 1) Vegetable industry communication, at the National, State and Territory, and Regional levels, 2) Counselling and 3) Counselling financial services. These lists of key contacts include information such as organisation, position, name, address, and contact details.

Australian personnel that should be alerted in the case of an incursion have been listed for the following categories:

a) Australian biosecurity authorities and State or Territory plant health agencies;
b) *Liriomyza* diagnostic experts and key insect taxonomists;
c) Scientists with experience in *Liriomyza* biology and biological control (e.g. DPI Victoria, Nat. Museum, and CSIRO).
d) Industry

Because leafminers are polyphagous, the incursion may affect several plant industry groups, such as Vegetables, Onion, Potato, Grains, and Nursery and Garden. It is of key importance that biosecurity plans that address different plant industries, invasive weeds and pests on native plants, include mechanisms that rapidly and effectively communicate with each industry so they can coordinate actions to make the response as effective as possible in the case of a leafminer incursion.

## References

Plant Health Australia (PHA). 2007. Contingency plans and response management arrangements. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/>

Plant Health Australia (PHA). 2008. PLANTPLAN: Australian Emergency Plant Pest Response Plan. Version 1. Plant Health Australia, Canberra, ACT, Australia. <http://www.planthealthaustralia.com.au/plantplan>

## Appendix 4. Market access impacts

See role of DAFF in Section 3 of PLANTPLAN (PHA, 2008). DAFF will provide technical briefings and other information to trading partners as part of trade negotiations and addressing market access issues. BA may seek information on pest free area and disinfestation requirements for current and potential international markets.

### Domestic market

The impact of leafminers on the domestic market will depend on the affected commodity and region where the incursion occurs, the area of spread, and the efficacy of containment. In the case of an incursion of key exotic leafminer species, restrictions for movement of field or greenhouse-grown produce from an infested area to a pest-free area should be put in place within Australia. Pre-shipment treatments, produce inspections, and phytosanitary certificates should be required for transporting vegetables across regions.

Refer to Section 1.2.3 Potential geographic distribution in Australia, Appendix 6 Vegetables grown in Australia, which are known hosts of leafminers, and Appendix 8 Vegetable Production Regions in Australia.

### Exports

Fresh vegetables are exported from Australia to markets in Asia, Oceania, and Europe. [See "Australian Exports of Fresh Vegetables by Major Markets", in HAL (2004)].

Many of the commonly exported fresh vegetables are known host species of one or more leafminers in the key exotic group. Phytosanitary requirements by import countries are expected to be more rigorous for vegetable commodities that include leaves or pea pods than those that only include fruit.

Countries that have leafminer species classified as quarantine pests may require pre-shipment inspections of crops, phytosanitary certificates, and if the pest is intercepted, the consignment may have to be treated (if possible), reshipped, or destroyed.

For updated import restrictions and requirements from overseas countries refer to AQIS/PHYTO at <http://www.aqis.gov.au/Phyto/asp/ex_search.asp>.

Leafminer species in the key exotic group are not present in New Zealand. Refer to Importing Countries Phytosanitary Requirements from Biosecurity NZ at <http://www.biosecurity.govt.nz/> and Importation and Clearance of Fresh Fruit and Vegetables into New Zealand (Standard 152.02 by MAF Biosecurity New Zealand, 2009) at <http://www.biosecurity.govt.nz/files/ihs/152-02.pdf>. As an example, see New Zealand MAF mandatory required pre-export measures for *L. trifolii*, which is associated with cucurbits (squash and butternut) in Tonga, located at: <http://www.biosecurity.govt.nz/files/ihs/squash-ton.pdf>.

For exports of plants or plant parts that are known hosts of leafminers to Europe, the EPPO recommends that propagating material (except seeds) from a region where leafminers are present must be inspected at least monthly during the previous three months of shipping and found free of the pest. A phytosanitary certificate should be required for harvested and transported vegetables with leaves. Requirements for exports to the EU of nursery material intended to be used for propagation can be found at: <http://www.aqis.gov.au/PhytoPublish/Documents%5CHerbaceous%20plants%20-%20cuttings.doc>

The following table lists the main fresh vegetables exported in 2002/03 and the top list destination countries and total value (Note: with the exception of asparagus, all other exported fresh vegetables can be hosts of leafminers).

| Vegetable | Top 3 Markets (2002/03) | | | Value (2002/03) AU$ '000 | Value (2002/03) % Total |
|---|---|---|---|---|---|
| Carrot | Malaysia | Singapore | United Arab Emirates | 47,477 | 22.4 |
| Asparagus | Japan | Taiwan | Hong Kong | 33485 | 15.8 |
| Onions | Netherlands | UK | France | 25463 | 12.0 |
| Cauliflower | Malaysia | Singapore | Hong Kong | 23409 | 11.1 |
| Melons | Singapore | Hong Kong | New Zealand | 16787 | 7.9 |
| Broccoli | Singapore | Malaysia | Japan | 13310 | 6.3 |
| Potatoes | Korea | Malaysia | Mauritius | 12658 | 6.0 |
| Other vegetables | Japan | New Zealand | Singapore | 8,038 | 3.8 |
| Tomatoes | New Zealand | Hong Kong | Singapore | 7475 | 3.5 |
| Lettuce | Singapore | Philippines | Hong Kong | 5882 | 2.8 |
| Chinese cabbage | Singapore | Taiwan | Hong Kong | 3632 | 1.7 |
| Celery | Malaysia | United Arab Emirates | Singapore | 3088 | 1.5 |
| Cabbage | Japan | Taiwan | Singapore | 1918 | 0.9 |
| Beans | New Zealand | Malaysia | Papua New Guinea | 1912 | 0.9 |
| Capsicum | New Zealand | Indonesia | Fiji | 1844 | 0.9 |
| Beetroot (salad) | New Zealand | Taiwan | Japan | 1833 | 0.9 |
| Leeks | Japan | Singapore | Hong Kong | 1550 | 0.7 |
| Brussels sprouts | Netherlands | New Zealand | Japan | 829 | 0.4 |
| Artichokes | Japan | Singapore | New Caledonia | 247 | 0.1 |
| Garlic | New Caledonia | Fiji | French Polynesia | 189 | 0.1 |
| Cucumber | New Zealand | Singapore | Mauritius | 157 | 0.1 |
| Chicory | New Caledonia | French Polynesia | Indonesia | 147 | 0.1 |
| Leguminous vegetables | India | Brunei | Malaysia | 61 | 0.0 |
| Spring onions | New Caledonia | New Zealand | French Polynesia | 60 | 0.0 |
| Peas | Fiji | French Polynesia | New Zealand | 47 | 0.0 |
| Spinach | Philippines | French Polynesia | New Zealand | 24 | 0.0 |
| Aubergines | Malaysia | Japan | New Caledonia | 17 | 0.0 |
| Total | | | | 211,539 | 100.0 |

Source: HAL (2004).
Refer to Appendices 5, 6, and 9 for information on leafminer hosts and production in vegetable growing regions in Australia.

## Contacts

### Market Access at DAFF

<http://www.daff.gov.au/market-access-trade/market-access/specific-commodities>

**Australian Government Department of Agriculture, Fisheries and Forestry (DAFF)**
<http://www.daff.gov.au/about/contactus>

**AQIS Canberra**
Phone numbers
Free call (within Australia): 1800 020 504
Switchboard: +61 2 6272 3933

Email
Import Clearance: import.clearance@aqis.gov.au
ICON (Import CONditions database): ICON.Admin@aqis.gov.au

Import Clearance: +61 2 6272 5888

Postal address
AQIS
GPO Box 858
Canberra ACT 2601
Australia

## References

Horticulture Australia Limited (HAL). 2004. The Australian Horticulture Statistics Handbook 2004. Horticulture Australia Limited. <http://www.horticulture.com.au/>

## Appendix 5. Host list

Vegetable and herb species appear in **red** font. When the name of a family or genus are listed, many cultivated and non cultivated species within the family or genus may be able to support leafminer life cycles. Most of the information here was reproduced from the Crop Protection Compendium, 2007 Edition. © CAB International, Wallingford, UK, 2007. Common names for some plant species may differ in Australia.

Some of the listed wild hosts may not be present in Australia. National weeds lists may be located in Weeds in Australia web site from the Australian Government <http://www.weeds.gov.au/index.html>. Databases on Australian plants (located at <http://www.cpbr.gov.au/index.html>) can be used to find if listed of host plant species are present in Australia.

### ***Liriomyza sativae*** **(vegetable leafminer)**

**Major hosts**

*Abelmoschus esculentus* (okra)
*Allium* (onions, garlic, leek, etc.)
*Apium graveolens* (celery)
*Arachis hypogaea* (groundnut)
*Beta vulgaris* var. saccharifera (sugarbeet)
*Brassica oleracea* (cabbages, cauliflowers)
*Brassica rapa* subsp. rapa (turnip)
*Brassicaceae* (cruciferous crops)
*Cajanus cajan* (pigeon pea)
*Capsicum* (peppers)
*Capsicum annuum* (bell pepper)
*Citrullus lanatus* (watermelon)
*Cucumis melo* (melon)
*Cucumis sativus* (cucumber)
*Cucurbita* (pumpkin)
*Cucurbita maxima* (giant pumpkin)
*Cucurbita pepo* (squash, ornamental gourd)
*Cucurbitaceae* (cucurbits)
*Daucus carota* (carrot)
*Fabaceae* (leguminous plants)
*Gossypium* (cotton)
*Lactuca sativa* (lettuce)
*Lathyrus odoratus* (sweet pea)
*Lycopersicon esculentum* (tomato)
*Medicago sativa* (lucerne)
*Nicotiana tabacum* (tobacco)
*Ocimum basilicum* (basil)
*Phaseolus* (beans)
*Phaseolus vulgaris* (common bean)
*Pisum* (pea)
*Pisum sativum* (pea)
*Raphanus sativus* (radish)
*Solanaceae*
*Solanum melongena* (aubergine)
*Solanum tuberosum* (potato)
*Spinacia oleracea* (spinach)
*Trifolium* (clovers)
*Vigna* (cowpea)

**Minor hosts**

Amaranthaceae
*Aster*
*Cestrum* (jessamine)
*Dahlia pinnata* (garden dahlia)
*Datura* (thorn-apple)
*Indigofera* (indigo)
*Lathyrus* (Vetchling)
*Melilotus* (melilots)
*Phlox*
*Physalis* (Groundcherry)
*Ricinus communis* (castor bean)

## *Liriomyza huidobrensis* (serpentine leafminer)

### Major hosts

*Allium cepa* (onion)
*Allium sativum* (garlic)
*Apium graveolens* (celery)
*Chrysanthemum morifolium* (chrysanthemum (florists'))
*Cucurbita pepo* (squash, ornamental gourd)
*Galinsoga*
*Gypsophila paniculata* (babysbreath)
*Lactuca sativa* (lettuce)
*Phaseolus vulgaris* (common bean)
*Pisum sativum* var. arvense (Austrian winter pea)

### Minor hosts

*Amaranthus* (grain amaranth)
*Amaranthus retroflexus* (redroot pigweed)
*Aster*
*Beta vulgaris* (beetroot)
*Calendula* (marigolds)
*Capsicum annuum* (bell pepper)
*Chenopodium quinoa* (quinoa)
*Cucumis melo* (melon)
*Cucumis sativus* (cucumber)
*Datura* (thorn-apple)
*Gerbera* (Barbeton daisy)
*Lathyrus* (Vetchling)
*Linum* (flax)
*Lycopersicon esculentum* (tomato)
*Medicago sativa* (lucerne)
*Melilotus* (melilots)
*Petunia*
*Solanum melongena* (aubergine)
*Solanum tuberosum* (potato)
*Spinacia oleracea* (spinach)
*Tagetes* (marigold)
*Tropaeolum*
*Valerianella locusta* (common cornsalad)
*Verbena* (vervain)
*Vicia faba* (broad bean)
*Zinnia elegans* (zinnia)

### Wild hosts

*Bidens pilosa* (blackjack)
*Emilia sonchifolia* (red tasselflower)
*Galinsoga parviflora* (gallant soldier)
*Oxalis* (wood sorrels)
*Portulaca oleracea* (purslane)
*Sonchus* (Sowthistle)

### Hosts where status is unknown

*Gypsophila* (baby's breath)

## *Liriomyza trifolii* (American serpentine leafminer)

### Major hosts

*Abelmoschus esculentus* (okra)
*Ageratum*
*Allium* (onions, garlic, leek, etc.)
*Allium sativum* (garlic)
*Arachis hypogaea* (groundnut)
*Aster*
*Beta vulgaris* var. saccharifera (sugarbeet)
*Bidens* (Burmarigold)
*Brassica rapa* subsp. chinensis (Chinese cabbage)
*Callistephus*
*Capsicum annuum* (bell pepper)
*Chrysanthemum* (daisy)
*Chrysanthemum morifolium* (chrysanthemum (florists'))
*Cucumis melo* (melon)
*Cucumis sativus* (cucumber)
*Cucurbita pepo* (squash, ornamental gourd)
Cucurbitaceae (cucurbits)
*Dahlia*
*Dianthus* (carnation)
*Gaillardia*
*Gerbera* (Barbeton daisy)
*Glycine max* (soyabean)
*Gossypium* (cotton)
*Gypsophila* (baby's breath)
*Helianthus* (sunflower)
*Lactuca sativa* (lettuce)
*Lathyrus* (Vetchling)
*Lycopersicon*
*Lycopersicon esculentum* (tomato)
*Medicago sativa* (lucerne)
*Phaseolus* (beans)
*Phaseolus lunatus* (lima bean)
*Phaseolus vulgaris* (common bean)
*Pisum sativum* (pea)
*Polyphagous* (polyphagous)
*Salvia* (sage)
*Senecio* (Groundsel)
*Solanum melongena* (aubergine)
*Solanum tuberosum* (potato)
*Spinacia oleracea* (spinach)
*Tagetes* (marigold)
*Trifolium* (clovers)
*Trifolium repens* (white clover)
*Tropaeolum*
*Vicia* (vetch)
*Vigna unguiculata* (cowpea)
*Zinnia*

### Minor hosts

*Allium cepa* (onion)
*Allium schoenoprasum* (chives)
*Apium graveolens* var. dulce (celery)
*Bellis*
*Cassia* (sennas)
*Centaurea* (Knapweed)
*Chenopodium* (Goosefoot)
*Citrullus*
*Daucus carota* (carrot)
*Erigeron* (Fleabane)
*Gazania* (treasure-flower)
*Gladiolus hybrids* (sword lily)
*Glycine*
*Hordeum* (barleys)
*Linaria* (Toadflax)
*Macrotyloma*
*Medicago* (medic)
*Primula* (Primrose)
*Xanthium* (Cocklebur)

### Wild hosts

*Alstroemeria* (Inca lily)
*Ambrosia* (Ragweed)
*Antirrhinum* (snapdragon)
*Arachis*
*Artemisia* (wormwoods)
*Avena sativa* (oats)
*Baccharis*
*Basella*
*Carthamus*
*Cestrum* (jessamine)
*Crataegus* (hawthorns)
*Crotalaria*
*Eupatorium*
*Ipomoea* (morning glory)
*Malva* (mallow)
*Melilotus* (melilots)
*Mollucella*
*Ocimum*
*Phlox*
*Physalis* (Groundcherry)
*Ricinus*
*Sonchus* (Sowthistle)
*Taraxacum* (dandelion)
*Tithonia*
*Tragopogon* (goat's-beard)
*Tribulus* (caltrop)
*Trigonella*
*Typha* (reedmace)
*Verbena* (vervain)

## ***Liriomyza bryoniae*** **(tomato leafminer)**

### Major hosts

*Brassica juncea* var. juncea (Indian mustard)
*Brassica oleracea* var. capitata (cabbage)
*Citrullus*
*Citrullus lanatus* (watermelon)
*Cucumis melo* (melon)
*Cucumis sativus* (cucumber)
*Cucurbita pepo* (zucchini, squash)
*Lactuca sativa* (lettuce)
*Polyphagous* (polyphagous)

### Minor hosts

*Amaranthus* (grain amaranth)
*Apium* (celery)
*Atropa* (Deadly nightshade)
*Callistephus*
*Capsicum* (peppers)
*Celosia argentea* (celosia)
*Chenopodium* (Goosefoot)
*Coriandrum sativum* (coriander)
*Datura* (thorn-apple)
*Gerbera jamesonii* (African daisy)
*Hyoscamus*
*Lamium* (deadnettle)
*Levisticum*
*Linaria* (Toadflax)
*Lupinus* (lupins)
*Lycium* (boxthorn)
*Lycopersicon esculentum* (tomato)
*Nicandra physalodes* (apple of Peru)
*Petroselinum* (parsley)
*Petunia*
*Phaseolus vulgaris* (common bean)
*Pisum sativum* (pea)
*Ricinus*
*Saponaria* (soapwort)
*Solanum melongena* (aubergine)
*Spinacia oleracea* (spinach)
*Verbena* (vervain)
*Withania*

## *Chromatomyia horticola* (pea leaf miner)

### Major hosts

Alliaceae
*Allium* (onions, garlic, leek, etc.)
Anacardiaceae
Asteraceae (Plants of the daisy family)
Brassicaceae
*Brassica* (cruciferous crops)
Caryophyllaceae
Chenopodiaceae (Beet family)
*Chrysanthemum* (daisy)
*Cicer*
Convolvulaceae (Plants of the bindweed and sweet potato family)
*Cucurbita* (pumpkin)
Cucurbitaceae (cucurbits)
Fabaceae (leguminous plants)
*Lactuca sativa* (lettuce)
*Lycopersicon esculentum* (tomato)
Malvaceae
*Mentha* (mints)
*Phaseolus* (beans)
*Pisum* (pea)
Ranunculaceae
*Raphanus sativus* (radish)
Solanaceae
Umbelliferae (Plants of the parsley family)
*Vicia* (vetch)

### Minor hosts

Amaranthaceae
Euphorbiaceae
Onagraceae
Rutaceae



For weed hosts of *C. horticola* refer also to:
Masetti, A., A. Lanzoni, G. Burgio, and L. Süss. 2004. Faunistic study of the Agromyzidae (Diptera) on weeds of marginal areas in northern Italy agroecosystems. Annals of the Entomological Society of America 97: 1252-1262.

## Appendix 6. Vegetables grown in Australia that are known hosts of leafminers

Source for vegetable statistics is Australia Bureau of Statistics (www.abs.gov.au/). Crops listed as major (●) or minor (○) host of the leafminer species in the CAB International Crop Protection Compendium, (2007). Mines and punctures lead to cosmetic damage that reduces marketability (■). Heavy infestations may cause reduced photosynthesis, leaf drop, and secondary fungal infections, which lead to yield loss from fewer plants being established (e.g. seedlings and young plants) in the field and/or severe damage in older plants (□).

| | | | Area and Production in 2007 | | | | | | | | Damage | | Major (●) and minor (○) host of exotic leafminer species | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Cosmetic | Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
| Alliaceae | **Onions** (*Allium cepa*) | | | | | | | | | | | □ | ○ | ● | ● | | ● |
| | Onions - red | ha | 40 | 26 | 62 | 237 | 37 | 132 | - | 534 | | | ○ | ● | ● | | ● |
| | | t | 1,724 | 1,034 | 2,309 | 13,649 | 2,316 | 6,836 | - | 27,869 | | | | | | | |
| | Onions – white, brown | ha | 493 | 286 | 704 | 1,209 | 409 | 1,380 | - | 4,479 | | | ○ | ● | ● | | ● |
| | | t | 15,066 | 12,974 | 24,836 | 72,407 | 25,141 | 76,070 | - | 226,494 | | | | | | | |
| | Onions - brown | ha | 473 | 270 | 654 | 1,083 | 395 | 1,363 | - | 4,237 | | | ○ | ● | ● | | ● |
| | | t | 14,534 | 12,427 | 23,487 | 64,167 | 24,261 | 75,309 | - | 214,186 | | | | | | | |
| | Onions - white | ha | 20 | 15 | 50 | 126 | 14 | 17 | - | 242 | | | ○ | ● | ● | | ● |
| | | t | 532 | 547 | 1,349 | 8,239 | 880 | 761 | - | 12,308 | | | | | | | |
| Alliaceae | **Leeks** (*Allium porrum*) | ha | 26 | 221 | 22 | 24 | 42 | 4 | - | 339 | ■ | □ | ● | ● | ● | | ● |
| | | t | 196 | 4,476 | 467 | 599 | 516 | 82 | - | 6,337 | | | | | | | |
| Alliaceae | **Garlic** (*Allium sativum*) | ha | 28 | 9 | 10 | - | 15 | 152 | - | 213 | | | ● | ● | ● | | ● |
| | | t | 149 | 30 | 14 | - | 43 | 538 | - | 773 | | | | | | | |
| Alliaceae | **Spring, bunching onions, shallots** (*Allium* spp.) | ha | 59 | 125 | 266 | 14 | 70 | 3 | - | 537 | ■ | □ | ○ | ● | ● | | ● |
| | | t | 581 | 1,355 | 3,607 | 420 | 1,845 | 10 | - | 7,818 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Area and Production in 2007** | | | | | | | | | | **Major (●) and minor (○) host of exotic leafminer species** | | | | |
| Asteraceae | **Lettuce** | | | | | | | | | | ■ | □ | ● | ● | ● | ● | ● |
| | Lettuce - outdoor and undercover | ha | 1,020 | 2,846 | 2,072 | 357 | 842 | 167 | 3 | 7,307 | | | ● | ● | ● | ● | ● |
| | | t | 23,827 | 53,612 | 57,670 | 10,918 | 20,986 | 1,690 | 6 | 168,707 | | | | | | | |
| | Lettuce (head) (*Lactuca sativa*) | | | | | | | | | | | | | | | | |
| | Lettuce (head - outdoor and undercover) | ha | 777 | 1,679 | 1,353 | 290 | 604 | 167 | - | 4,870 | | | ● | ● | ● | ● | ● |
| | | t | 17,146 | 39,203 | 44,509 | 9,168 | 17,017 | 1,690 | - | 128,733 | | | | | | | |
| | Lettuce (head) - outdoor | ha | 774 | 1,679 | 1,353 | 290 | 604 | 167 | - | 4,866 | | | ● | ● | ● | ● | ● |
| | | t | 17,114 | 39,203 | 44,405 | 9,166 | 17,017 | 1,690 | - | 128,594 | | | | | | | |
| | Lettuce (head) - undercover | ha | 4 | - | 0.4 | 0.02 | - | - | - | 4 | | | ● | ● | ● | ● | ● |
| | | t | 32 | - | 104 | 3 | - | - | - | 139 | | | | | | | |
| | Lettuce *(loose-leaf, butterheads and colour fancy)* | | | | | | | | | | | | | | | | |
| | Lettuce (loose-leaf, butterheads and colour fancy - outdoor and undercover) | ha | 243 | 1,167 | 719 | 67 | 238 | - | 3 | 2,437 | | | ● | ● | ● | ● | ● |
| | | t | 6,681 | 14,408 | 13,160 | 1,749 | 3,969 | - | 6 | 39,974 | | | | | | | |
| | Lettuce (loose-leaf, butterheads and colour fancy) - outdoor | ha | 204 | 1,145 | 702 | 38 | 225 | - | 3 | 2,316 | | | ● | ● | ● | ● | ● |
| | | t | 3,752 | 13,734 | 12,384 | 1,281 | 3,067 | - | 6 | 34,223 | | | | | | | |
| | Lettuce (loose-leaf, butterheads and colour fancy) - undercover | ha | 39 | 22 | 17 | 30 | 13 | - | - | 121 | | | ● | ● | ● | ● | ● |
| | | t | 2,929 | 675 | 776 | 468 | 902 | - | - | 5,750 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | Area and Production in 2007 NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | Major (●) and minor (○) host of exotic leafminer species: *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asteraceae | **Artichokes** (*Cynara cardunculus*) | ha | 3 | 49 | 8 | - | 2 | - | - | 62 | | | | | | | |
| | | t | 23 | 282 | 4 | - | 19 | - | - | 328 | | | | | | | |
| Brassicaseae | **Cabbages** (*Brassica oleraceae*) | ha | 452 | 673 | 386 | 97 | 247 | 33 | - | 1,888 | ■ | □ | ● | | ● | ● | ● |
| | | t | 15,548 | 26,867 | 15,081 | 4,410 | 8,532 | 1,104 | - | 71,540 | | | | | | | |
| Brassicaseae | **Broccoli** (*B. oleraceae*) | ha | 839 | 2,769 | 1,671 | 99 | 572 | 376 | - | 6,326 | | □ | | | ● | | ● |
| | | t | 4,875 | 19,411 | 12,228 | 724 | 6,235 | 2,652 | - | 46,125 | | | | | | | |
| Brassicaseae | **Cauliflower** (*Br. oleraceae*) | ha | 493 | 965 | 691 | 163 | 298 | 282 | - | 2,893 | | □ | | | ● | | ● |
| | | t | 10,285 | 19,385 | 15,117 | 5,986 | 7,627 | 5,895 | - | 64,294 | | | | | | | |
| Brassicaseae | **Radish (red and white)** (*Raphanus sativus*) | ha | 85 | 69 | 13 | 8 | 55 | 1 | - | 231 | | □ | | | ● | | ● |
| | | t | 1,002 | 710 | 138 | 75 | 645 | 16 | - | 2,586 | | | | | | | |
| Brassicaseae | **Brussels sprouts** (*B. oleraceae*) | ha | - | 86 | 4 | 99 | - | 72 | - | 261 | ■ | □ | | | ● | | ● |
| | | t | - | 1,752 | 122 | 3,482 | - | 1,003 | - | 6,359 | | | | | | | |
| Brassicaseae | **Swedes and turnips** (*B. rapa*) | ha | 51 | 38 | 24 | 32 | 29 | 128 | - | 301 | | □ | | | ● | | ● |
| | | t | 716 | 521 | 225 | 289 | 375 | 3,889 | - | 6,016 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | Area and Production in 2007: NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Potential yield reduction | Major (●) and minor (○) host of exotic leafminer species: *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Asteraceae | **Artichokes** (*Cynara cardunculus*) | ha | 3 | 49 | 8 | - | 2 | - | - | 62 | | | | | | | |
| Brassicaseae | **Asian vegetables** (including chinese cabbage, bok choy and wong bok) (*Brassica* spp.) | ha | 521 | 259 | 403 | 19 | 100 | 5 | 35 | 1,342 | ■ | □ | ● | | ● | | ● |
| | | t | 8,519 | 3,513 | 8,136 | 100 | 2,902 | 7 | 241 | 23,419 | | | | | | | |
| Chenopodiaceae | **Beetroot** (*Beta vulgaris*) | ha | 154 | 78 | 1,315 | 10 | 19 | 1 | - | 1,577 | | □ | ● | ○ | ● | | ● |
| | | t | 2,743 | 1,966 | 38,124 | 304 | 185 | 10 | - | 43,331 | | | | | | | |
| Chenopodiaceae | **Silver beet and spinach** (*Beta vulgaris*; *Spinaceae oleracea*) | ha | 266 | 344 | 449 | 12 | 118 | 9 | - | 1,197 | ■ | □ | ● | ○ | ● | ○ | ● |
| | | t | 2,340 | 3,591 | 3,184 | 216 | 540 | 140 | - | 10,011 | | | | | | | |
| Convolvulaceae | **Sweet potatoes** (*Ipomea batatas*) | ha | 257 | - | 1,140 | - | 33 | 11 | - | 1,441 | | | | | | | ○ |
| | | t | 5,877 | - | 31,554 | - | 530 | 446 | - | 38,407 | | | | | | | |
| Cucurbitaceae | **Zucchini and button squash** (*Cucurbita* spp.) | ha | 262 | 174 | 1,290 | 24 | 98 | 4 | 7 | 1,858 | | □ | ● | ● | ● | ● | ● |
| | | t | 2,225 | 3,566 | 12,980 | 279 | 1,136 | 129 | 67 | 20,382 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Area and Production in 2007** | | | | | | | | | | **Major (●) and minor (○) host of exotic leafminer species** | | | | |
| Cucurbitaceae | **Pumpkins** (including butternut) (*Cucurbita* spp.) | ha | 2,057 | 369 | 2,751 | 188 | 876 | 102 | 52 | 6,393 | | □ | ● | ● | ● | ● | ● |
| | | t | 40,718 | 6,775 | 43,783 | 2,586 | 17,303 | 1,478 | 1,775 | 114,418 | | | | | | | |
| Cucurbitaceae | **Cucumbers** (*Cucumis sativus*) | | | | | | | | | | | □ | ● | ○ | ● | ● | |
| | Cucumbers - outdoor and undercover | ha | 71 | 17 | 191 | 75 | 37 | 1 | 17 | 409 | | | | | | | |
| | | t | 3,398 | 268 | 6,149 | 4,672 | 1,144 | 39 | 257 | 15,927 | | | | | | | |
| | Cucumber - outdoor | ha | 31 | 3 | 144 | 11 | 21 | - | 5 | 216 | | | ● | ○ | ● | ● | |
| | | t | 354 | 24 | 1,752 | 218 | 309 | - | 81 | 2,739 | | | | | | | |
| | Cucumber - undercover - | ha | 39 | 14 | 47 | 64 | 16 | 0.5 | 11 | 193 | | | ● | ○ | ● | ● | |
| | | t | 3,044 | 243 | 4,397 | 4,454 | 835 | 39 | 175 | 13,188 | | | | | | | |
| Cucurbitaceae | **Melons** | | | | | | | | | - | | □ | ● | ○ | ● | ● | ● |
| | Melons | ha | 1,632 | 297 | 2,933 | 40 | 1,473 | 3 | 642 | 7,021 | | | ● | ○ | ● | ● | ● |
| | | t | 61,757 | 9,477 | 83,969 | 682 | 38,914 | 51 | 24,210 | 219,062 | | | | | | | |
| | Melons - honeydews - (*Cucumis melo*) | ha | 106 | - | 100 | 2 | 134 | - | - | 342 | | | ● | ○ | ● | ● | ● |
| | | t | 2,923 | - | 2,537 | 75 | 1,580 | - | - | 7,115 | | | | | | | |
| | Melons - rock and cantaloupe - (*Cucumis melo*) | ha | 647 | 67 | 796 | 6 | 577 | - | 115 | 2,208 | | | ● | ○ | ● | ● | ● |
| | | t | 25,054 | 2,176 | 18,935 | 190 | 9,668 | - | 2,892 | 58,915 | | | | | | | |
| | Melons - watermelons - (*Citrullus lanatus*) | ha | 873 | 230 | 2,032 | 27 | 745 | - | 524 | 4,430 | | | ● | ○ | ● | ● | ● |
| | | t | 33,659 | 7,301 | 62,474 | 327 | 27,118 | - | 21,262 | 152,141 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | Area and Production in 2007 NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | Major (●) and minor (○) host of exotic leafminer species: *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabaceae | **Peas (green)** (*Pisum sativum*) | | | | | | | | | | | □ | ● | ● | ● | ○ | ● |
| | Peas - green - processing and fresh market - Total | ha | 61 | 56 | 133 | 5 | 1 | 2,401 | - | 2,656 | | | | | | | |
| | | t | 99 | 173 | 862 | 9 | 1 | 38,156 | - | 39,300 | | | | | | | |
| | Peas - green (for fresh market) | ha | 49 | 56 | 90 | 5 | 1 | 0.4 | - | 200 | ■ | □ | ● | ● | ● | ○ | ● |
| | | t | 48 | 173 | 374 | 9 | 1 | 1 | - | 605 | | | | | | | |
| | Peas - green (for processing) | ha | 12 | - | 43 | - | - | 2,401 | - | 2,456 | | □ | ● | ● | ● | ○ | ● |
| | | t | 23 | - | 222 | - | - | 17,343 | - | 17,589 | | | | | | | |
| Fabaceae | **Snow peas and sugarsnap peas** (*Pisum sativum*) | ha | 7 | 1,623 | 309 | 2 | 2 | - | - | 1,944 | ■ | □ | ● | ● | ● | ○ | ● |
| | | t | 7 | 2,698 | 2,110 | 9 | 11 | - | - | 4,835 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | Area and Production in 2007: NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Potential yield reduction | Major (●) and minor (○) host of exotic leafminer species: *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fabaceae | **Beans** | | | | | | | | | | | □ | ● | ● | ● | | ● |
| | Butter beans (processing and fresh market) (*Phaseolus lunatus*) | ha | 20 | 64 | 422 | 4 | 12 | 252 | - | 774 | | □ | ● | ● | ● | | ● |
| | | t | 53 | 117 | 898 | 9 | 39 | 2,423 | - | 3,538 | | | | | | | |
| | Beans - French and runner | | | | | | | | | | | □ | ● | ● | ● | | ● |
| | French and runner beans Total (fresh market and processing) (*Phaseolus vulgaris*) | ha | 53 | 817 | 2,758 | 33 | 238 | 1,064 | - | 4,962 | | | ● | ● | ● | ○ | ● |
| | | t | 100 | 3,284 | 12,507 | 52 | 1,147 | 9,828 | - | 26,917 | | | | | | | |
| | French and runner beans (fresh market) | ha | 46 | 746 | 2,588 | 28 | 232 | 97 | - | 3,739 | ■ | □ | ● | ● | ● | ○ | ● |
| | | t | 88 | 2,831 | 12,033 | 49 | 1,135 | 267 | - | 16,403 | | | | | | | |
| | French and runner beans (processing) | ha | 6 | 71 | 169 | 5 | 6 | 967 | - | 1,224 | | □ | ● | ● | ● | ○ | ● |
| | | t | 12 | 453 | 474 | 2 | 11 | 9,561 | - | 10,514 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | Area and Production in 2007 NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Graminae | **Sweet corn** (*Zea mays*) | | | | | | | | | | | | | | | | |
| | Sweet corn - processing and fresh market | ha | 788 | 533 | 1,791 | 17 | 374 | 2 | - | 3,505 | | | | | | | |
| | | t | 12,853 | 10,327 | 22,600 | 167 | 8,190 | - | - | 54,138 | | | | | | | |
| | Sweet corn - fresh market | ha | 197 | 462 | 1,688 | 17 | 374 | 2 | - | 2,740 | | | | | | | |
| | | t | 1,636 | 8,471 | 21,671 | 167 | 8,190 | - | - | 40,135 | | | | | | | |
| | Sweet corn - processing | ha | 591 | 71 | 103 | - | - | - | - | 765 | | | | | | | |
| | | t | 11,218 | 1,856 | 929 | - | - | - | - | 14,003 | | | | | | | |
| Liliaceae | **Asparagus** (*Asparagus officinalis*) | ha | 49 | 1,496 | 36 | - | 23 | - | - | 1,604 | | | | | | | |
| | | t | 70 | 9,515 | 98 | - | 96 | - | - | 9,779 | | | | | | | |
| Mixed families | **Herbs excluding parsley; e.g. Basil** (*Ocimum basilicum*) | ha | 76 | 93 | 72 | 5 | 24 | 245 | 6 | 520 | ■ | □ | | | ● | | |
| | | t | 1,200 | 697 | 1,178 | 24 | 295 | 1,050 | 15 | 4,458 | | | | | | | |

Major (●) and minor (○) host of exotic leafminer species

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | Major (●) and minor (○) host of exotic leafminer species: *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Area and Production in 2007** | | | | | | | | | | | | | | |
| Solanaceae | **Potatoes** (*Solanum tuberosum*) | | | | | | | | | | | □ | ● | ○ | ● | | |
| | Potatoes - processing and fresh market | ha | 4,070 | 10,720 | 3,354 | 12,124 | 1,949 | 5,969 | 4 | 38,190 | | | | | | | |
| | | t | 104,448 | 322,446 | 99,241 | 477,062 | 85,761 | 311,218 | 30 | 1,400,206 | | | | | | | |
| | Potatoes (fresh market) | ha | 1,904 | 4,398 | 2,239 | 7,339 | 1,150 | 778 | - | 17,809 | | □ | ● | ○ | ● | | |
| | | t | 48,428 | 102,851 | 62,876 | 272,981 | 50,320 | 26,133 | - | 563,589 | | | | | | | |
| | Potatoes (processing) | ha | 2,166 | 6,322 | 1,114 | 4,785 | 799 | 5,190 | 4 | 20,381 | | □ | ● | ○ | ● | | |
| | | t | 56,019 | 219,596 | 36,365 | 204,081 | 35,441 | 285,085 | 30 | 836,617 | | | | | | | |
| Solanaceae | **Tomatoes** (*Lycopersicum esculentum*) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Tomatoes - processing and fresh market | ha | 903 | 2,996 | 2,543 | 85 | 259 | 8 | 1 | 6,795 | | | | | | | |
| | | t | 46,848 | 174,379 | 132,444 | 14,808 | 12,317 | 997 | 30 | 381,821 | | | | | | | |
| | Tomatoes - processing - | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Tomatoes - processing - | ha | 409 | 2,076 | 78 | 4 | 16 | - | - | 2,583 | | □ | ● | ○ | ● | ○ | |
| | | t | 17,935 | 126,946 | 2,297 | 93 | 273 | - | - | 147,544 | | | | | | | |
| | Tomatoes - fresh market | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Tomatoes - fresh market | ha | 494 | 919 | 2,466 | 81 | 244 | 8 | 1 | 4,213 | | □ | ● | ○ | ● | ○ | |
| | | t | 28,913 | 47,433 | 130,147 | 14,715 | 12,044 | 997 | 30 | 234,277 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Damage: Cosmetic | Damage: Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Area and Production in 2007 | | | | | | | | | | Major (●) and minor (○) host of exotic leafminer species | | | | |
| Solanaceae | **Tomatoes** (*Lycopersicum esculentum*) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Tomatoes – fresh market – outdoor | ha | 436 | 878 | 2,452 | 11 | 240 | 2 | 1 | 4,020 | | | | | | | |
| | | t | 21,787 | 41,335 | 127,087 | 202 | 11,987 | 537 | 30 | 202,964 | | | | | | | |
| | Tomatoes – fresh market – undercover | ha | 58 | 41 | 14 | 70 | 4 | 6 | - | 193 | | □ | ● | ○ | ● | ○ | |
| | | t | 7,125 | 6,098 | 3,060 | 14,513 | 57 | 460 | - | 31,313 | | | | | | | |
| Solanaceae | **Tomatoes** (*Lycopersicum esculentum*) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| Solanaceae | **Capsicums, chillies and peppers** (*Capsicum* spp.) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Capsicum chillies and peppers – outdoor and undercover | ha | 74 | 246 | 1,671 | 152 | 163 | 0.4 | 1 | 2,306 | | | | | | | |
| | | t | 1,085 | 6,574 | 41,003 | 6,710 | 3,836 | 12 | 3 | 59,223 | | | | | | | |
| | Capsicums (excluding chillies) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Capsicums (excl chillies – outdoor and undercover) | ha | 62 | 228 | 1,512 | 124 | 152 | 0.4 | 1 | 2,078 | | | | | | | |
| | | t | 1,029 | 6,334 | 38,881 | 6,596 | 3,706 | 12 | 3 | 56,561 | | | | | | | |
| | Capsicums outdoor | ha | 57 | 220 | 1,507 | 23 | 120 | 0.4 | 1 | 1,927 | | □ | ● | ○ | ● | ○ | |
| | | t | 725 | 5,700 | 38,736 | 205 | 1,655 | 12 | 3 | 47,035 | | | | | | | |
| | Capsicums undercover | ha | 5 | 9 | 5 | 101 | 31 | - | - | 151 | | □ | ● | ○ | ● | ○ | |
| | | t | 304 | 635 | 145 | 6,391 | 2,051 | - | - | 9,526 | | | | | | | |

Appendix 6 Table continued….

| Family | Vegetable Crops | Units | NSW | VIC | QLD | SA | WA | TAS | NT | TOTAL | Cosmetic | Potential yield reduction | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Area and Production in 2007 | | | | | | | | Damage | | Major (●) and minor (○) host of exotic leafminer species | | | | |
| Solanaceae | **Capsicums, chillies and peppers** (*Capsicum* spp.) | | | | | | | | | | | □ | ● | ○ | ● | ○ | |
| | Chillies (excluding capsicums) | ha | 12 | 18 | 160 | 28 | 11 | - | - | 228 | | | | | | | |
| | | t | 55 | 240 | 2,122 | 114 | 130 | 0.1 | - | 2,662 | | | | | | | |
| Solanaceae | **Eggplants** (*Solanum melongena*) | ha | 67 | 21 | 236 | 11 | 37 | - | 3 | 375 | | □ | ● | ○ | ● | ○ | ● |
| | | t | 1,075 | 211 | 3,284 | 114 | 525 | - | 81 | 5,289 | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| Umbelliferae | **Carrots** (*Daucus carota*) | ha | 370 | 1,193 | 703 | 775 | 1,072 | 820 | - | 4,934 | | □ | ○ | | ● | | ● |
| | | t | 14,893 | 53,623 | 25,316 | 48,314 | 65,320 | 65,136 | - | 272,601 | | | | | | | |
| Umbelliferae | **Celery** (*Apium graveolens*) | ha | 14 | 637 | 145 | 36 | 195 | 18 | - | 1,046 | ■ | □ | ○ | ● | ● | ○ | ● |
| | | t | 211 | 40,349 | 6,868 | 235 | 6,942 | 973 | - | 55,577 | | | | | | | |
| Umbelliferae | **Parsnips** (*Pastinaca sativa*) | ha | 10 | 434 | 0.2 | 20 | 31 | 4 | - | 501 | | □ | ○ | ○ | ○ | ○ | ● |
| | | t | 182 | 10,299 | 2 | 563 | 478 | 44 | - | 11,568 | | | | | | | |
| Umbelliferae | **Parsley** (*Petroselinum crispum*) | ha | 50 | 120 | 27 | 12 | 6 | 2 | - | 217 | ■ | □ | ○ | ○ | ○ | ○ | ● |
| | | t | 636 | 1,336 | 556 | 294 | 73 | 8 | - | 2,903 | | | | | | | |
| Umbelliferae | **Fennel bulb** (*Foeniculum vulgare*) | ha | - | 153 | - | - | 1 | - | - | 155 | | □ | | | | | ● |
| | | t | - | 2,080 | - | - | 11 | - | - | 2,091 | | | | | | | |

## Appendix 7. World distribution of the key exotic leafminers

Maps were reproduced from the Crop Protection Compendium, 2007 Edition.


Pest distributions are dynamic. Updated information may be available online in websites maintained by the IPPC, EPPO, and CAB International.

### References

IPPC. 2009. International Plant Protection Convention. <https://www.ippc.int/IPP/>.

EPPO. 2009. European and Mediterranean Plant Protection Organisation. Paris, France. <http://www.eppo.org/>

CAB International. 2007. Crop Protection Compendium, 2007 Edition. CAB International, Wallingford, UK. <http://www.cabicompendium.org/>

### Description of labels

Distribution in countries

- Present, no further details
- Widespread
- Present, localised
- Distribution given on regional map
- Confined and subject to quarantine
- Occasional or few reports
- Unconfirmed or uncertain
- Absent: eradicated

Distribution in climate regions

**Tropical climates**
- Rain forest
- Savannah

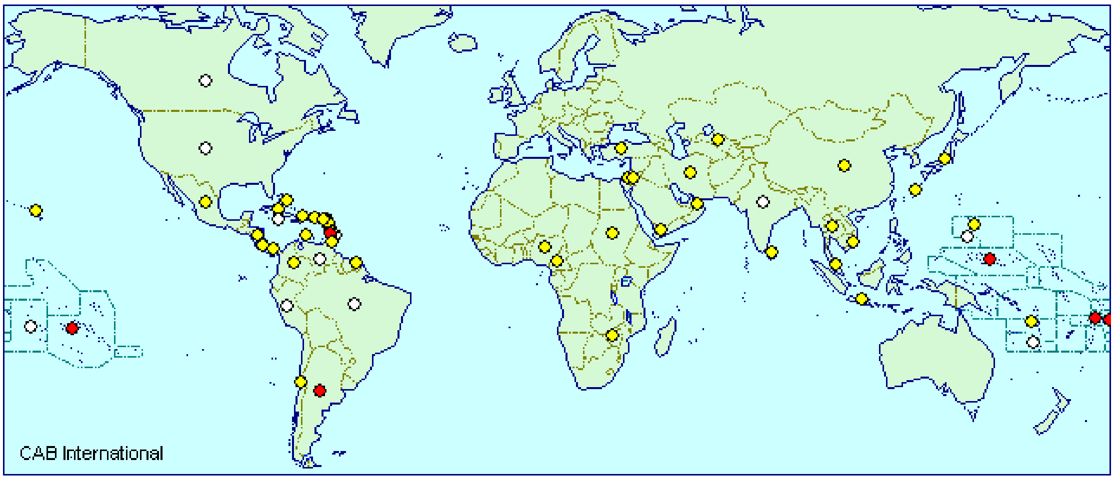
**Dry climates**
- Desert
- Steppe

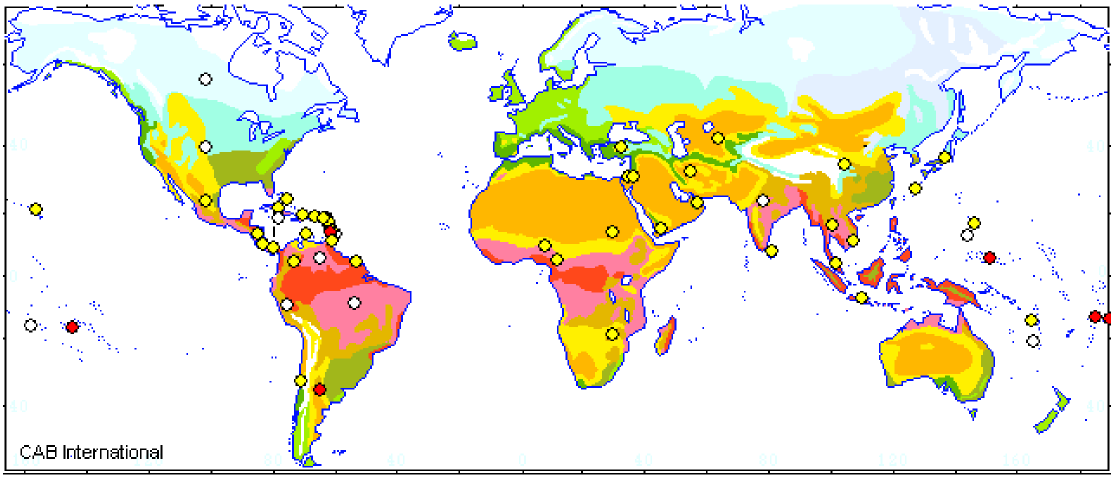
**Temperate climates**
- Warm with dry winter
- Warm with dry summer
- Humid with hot summer
- Humid with cool summer

**Continental climates**
- Cold winter
- Cold, wet winter
- Cold, dry winter

**Polar & mountain climates**
- Tundra
- Perpetual frost

**_Liriomyza sativae_ (vegetable leafminer)**
**Distribution maps - 2006**



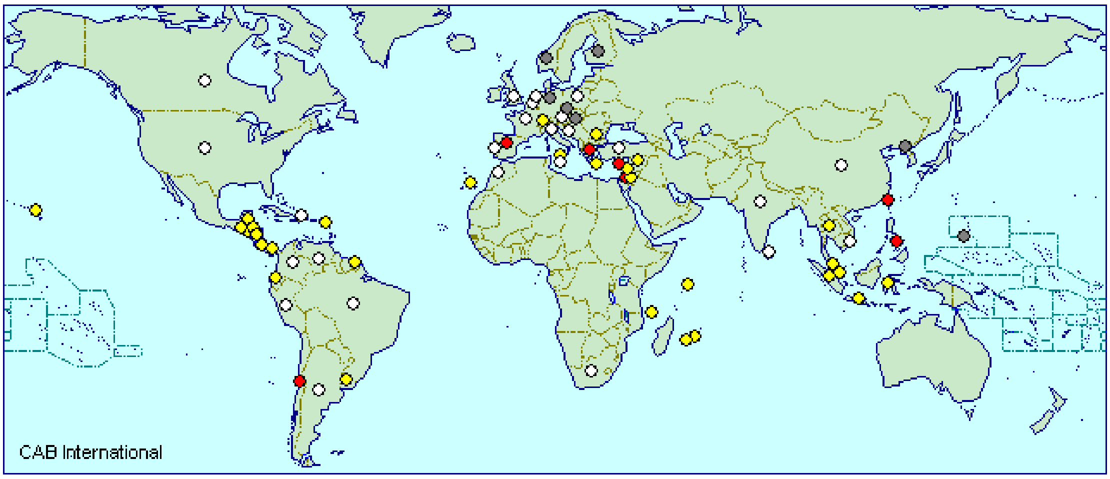


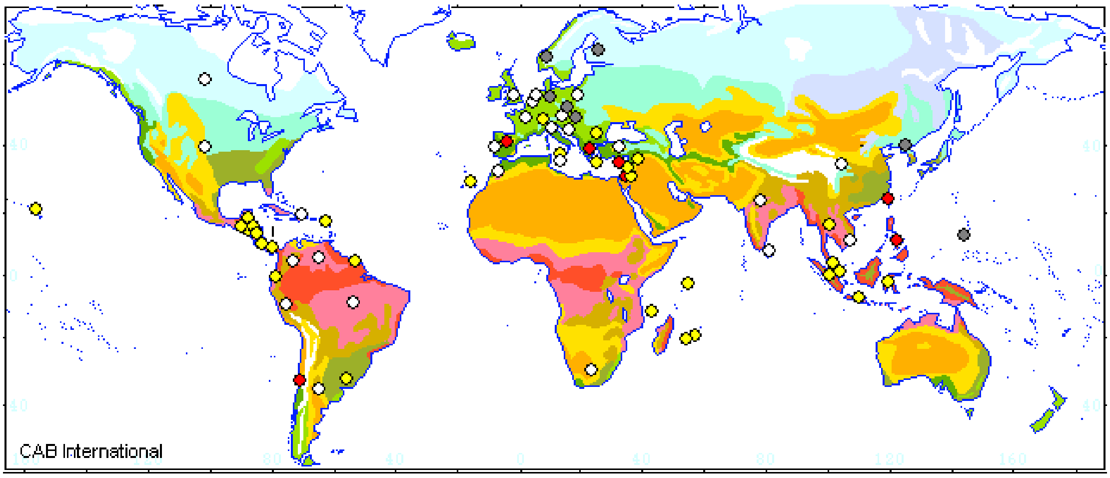

Distribution Notes by CAB International: "It is difficult to give accurate distributional notes on *L. sativae* at present, as there is evidence that the fly is rapidly expanding its presence and colonising most habitats to which it is introduced. An example is its present status in China, where it is widespread (Institute of Zoology, Beijing, China; report in preparation). Originally recognized as present in Sanya, Hainan Provinces in 1993 (Xie-Qonh Hua et. al., 1997), it has quickly spread north and west to most Provinces since that time, causing serious damage in some areas. This is probably the true situation in most countries where it has been introduced. It will take some years before a more settled picture can be given, where a combination of natural climatic restrictions and man's effort at eradication will stabilize the flies progress. *L. sativae* has been identified as an A1 risk in the Netherlands (OEPP/EPPO, 1984) and the UK (EPPO, 1984)."

# *Liriomyza sativae* (vegetable leafminer)
# Distribution list

| | |
|---|---|
| **Asia** | |
| China | present, no further details |
| Anhui | present, no further details |
| Fujian | present, no further details |
| Guangdong | present, no further details |
| Hainan | present, no further details |
| Hebei | present, no further details |
| Henan | present, no further details |
| Hunan | present, no further details |
| Shanxi | present, no further details |
| Sichuan | present, no further details |
| Yunnan | present, no further details |
| Zhejiang | present, no further details |
| India | restricted distribution |
| Uttar Pradesh | present, no further details |
| Indonesia | present, no further details |
| Java | present, no further details |
| Iran | present, no further details |
| Israel | present, no further details |
| Japan | present, no further details |
| Honshu | present, no further details |
| Kyushu | present, no further details |
| Ryukyu Archipelago | present, no further details |
| Jordan | present, no further details |
| Malaysia | present, no further details |
| Peninsular Malaysia | present, no further details |
| Oman | present, no further details |
| Sri Lanka | present, no further details |
| Thailand | present, no further details |
| Turkey | present, no further details |
| Uzbekistan | present, no further details |
| Vietnam | present, no further details |
| Yemen | present, no further details |
| **Europe** | |
| Croatia | absent, never occurred |
| Estonia | absent, never occurred |
| Finland | absent, intercepted only |
| Poland | absent, invalid record |
| United Kingdom | absent, intercepted only |
| **Africa** | |
| Cameroon | present, no further details |
| Nigeria | present, no further details |
| South Africa | absent, unreliable record |
| Sudan | present, no further details |
| Zimbabwe | present, no further details |
| **North America** | |
| Canada | restricted distribution |
| Ontario | present, no further details |
| Mexico | present, no further details |
| USA | restricted distribution |
| Alabama | present, no further details |
| Arizona | present, no further details |
| Arkansas | present, no further details |
| California | present, no further details |
| Florida | present, no further details |
| Georgia (USA) | present, no further details |
| Hawaii | present, no further details |
| Indiana | present, no further details |
| Louisiana | present, no further details |
| Maryland | present, no further details |
| New Jersey | present, no further details |
| Ohio | present, no further details |
| Pennsylvania | present, no further details |
| South Carolina | present, no further details |
| Tennessee | present, no further details |
| Texas | present, no further details |
| **Central America** | |
| Antigua and Barbuda | present, no further details |
| Bahamas | present, no further details |
| Barbados | restricted distribution |
| Costa Rica | present, no further details |
| Cuba | present, no further details |
| Dominica | present, no further details |
| Dominican Republic | present, no further details |
| Guadeloupe | present, no further details |
| Jamaica | restricted distribution |
| Martinique | widespread |
| Montserrat | present, no further details |
| Netherlands Antilles | present, no further details |
| Nicaragua | present, no further details |
| Panama | present, no further details |
| Puerto Rico | present, no further details |
| Saint Kitts and Nevis | present, no further details |
| Saint Lucia | present, no further details |
| Saint Vincent and the Grenadines | widespread |
| Trinidad and Tobago | present, no further details |
| **South America** | |
| Argentina | widespread |
| Brazil | restricted distribution |
| Ceara | present, no further details |
| Parana | present, no further details |
| Pernambuco | present, no further details |
| Rio Grande do Norte | present, no further details |
| Rio de Janeiro | present, no further details |
| Chile | present, no further details |
| Colombia | present, no further details |
| French Guiana | present, no further details |
| Peru | restricted distribution |
| Venezuela | restricted distribution |
| **Oceania** | |
| American Samoa | widespread |
| Cook Islands | restricted distribution |
| Federated states of Micronesia | widespread |
| French Polynesia | widespread |
| Guam | restricted distribution |
| New Caledonia | restricted distribution |
| Northern Mariana Islands | present, no further details |
| Samoa | widespread |
| Vanuatu | present, no further details |

**Liriomyza huidobrensis (serpentine leafminer)**
**Distribution maps - 2006**



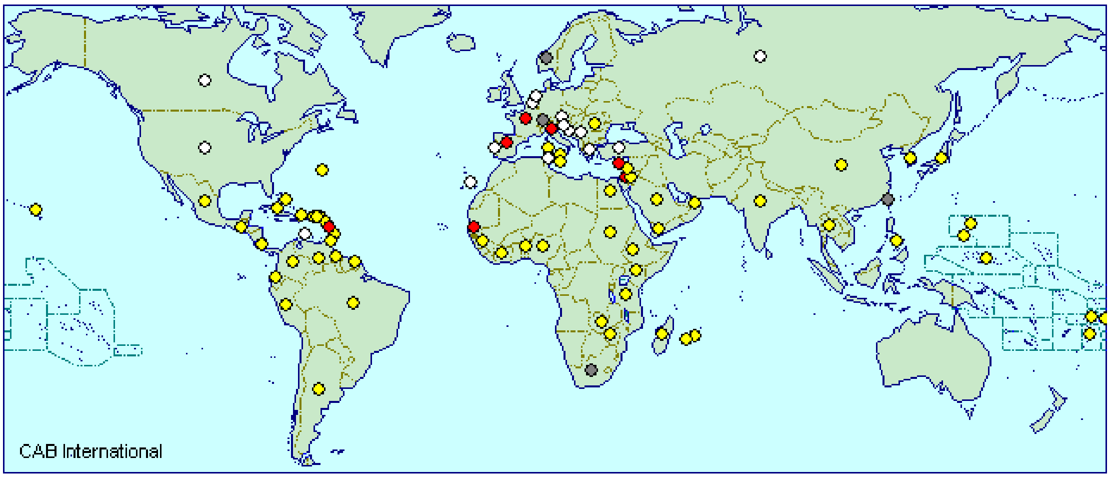


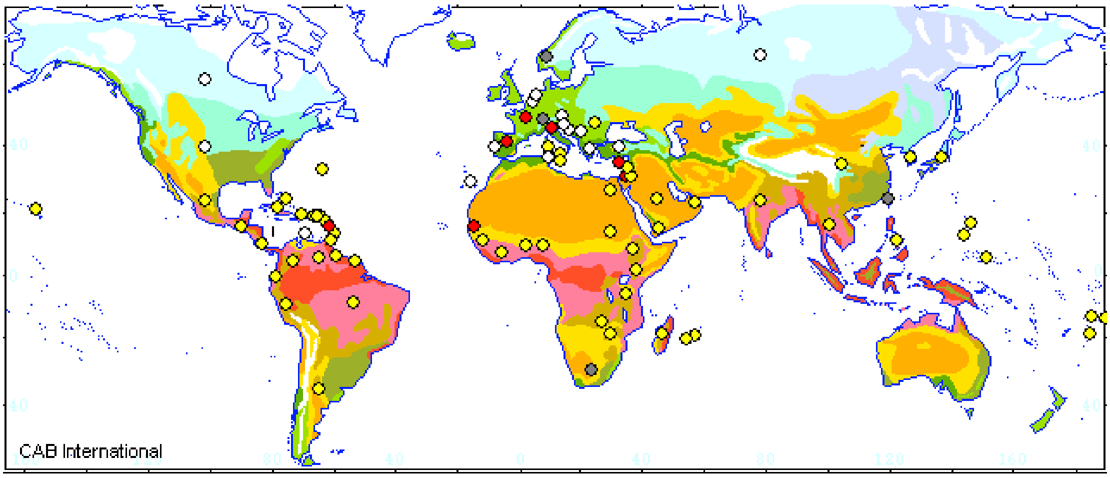

Distribution Notes by CAB International: "*L. huidobrensis* originates in Central and South America and was absent from other continents until the 1980s. It was first detected in Europe in 1987 in the Netherlands where it was found on glasshouse lettuces; it is presumed to have been imported directly from South America. It has since spread considerably in Europe and especially the Mediterranean region, but particularly significant is the spread in central and eastern Europe where climatic conditions would be expected to deter its presence. In North America it is confined to California and Hawaii (USA), and it has been a glasshouse pest in Florida and Virginia and is erratically reported from other eastern seaboard states. It has been intercepted, but is not established in Australia. There are also reports from Italy, Guam, Comoros, Seychelles, Morocco, Syria, Java (east and west) and Korea. Records for the Canary Islands, Spain and French Guiana have not been confirmed."

## *Liriomyza huidobrensis* (serpentine leafminer)
## Distribution list

| | | |
|---|---|---|
| **Asia** | | |
| China | | restricted distribution |
| | Fujian | present, no further details |
| | Gansu | present, no further details |
| | Guangdong | present, no further details |
| | Guizhou | present, no further details |
| | Hebei | present, no further details |
| | Hubei | present, no further details |
| | Nei Menggu | present, no further details |
| | Shaanxi | present, no further details |
| | Shandong | present, no further details |
| | Sichuan | present, no further details |
| | Taiwan | widespread |
| | Xinjiang | present, no further details |
| | Yunnan | present, no further details |
| India | | restricted distribution |
| | Uttar Pradesh | present, no further details |
| Indonesia | | restricted distribution |
| | Java | present, no further details |
| | Sulawesi | present, no further details |
| | Sumatra | present, no further details |
| Israel | | widespread |
| Japan | | absent, intercepted only |
| Jordan | | present, no further details |
| Korea, DPR | | present, few occurrences |
| Lebanon | | present, no further details |
| Malaysia | | present, no further details |
| | Peninsular Malaysia | present, no further details |
| Philippines | | widespread |
| Singapore | | present, no further details |
| Sri Lanka | | restricted distribution |
| Syria | | present, no further details |
| Thailand | | present, no further details |
| Turkey | | restricted distribution |
| Vietnam | | restricted distribution |
| **Europe** | | |
| Austria | | restricted distribution |
| Belgium | | restricted distribution |
| Bulgaria | | present, no further details |
| Croatia | | restricted distribution |
| Cyprus | | widespread |
| Czech Republic | | present, few occurrences |
| Denmark | | eradicated |
| Estonia | | absent, never occurred |
| Finland | | present, few occurrences |
| France | | restricted distribution |
| | France [mainland] | restricted distribution |
| Germany | | present, few occurrences |
| Greece | | widespread |
| | Crete | present, no further details |
| | Greece [mainland] | widespread |
| Hungary | | present, few occurrences |
| Ireland | | eradicated |
| Italy | | restricted distribution |
| | Italy [mainland] | restricted distribution |
| | Sicily | present, no further details |
| Malta | | restricted distribution |
| Netherlands | | restricted distribution |
| Norway | | present, few occurrences |
| Poland | | restricted distribution |
| Portugal | | restricted distribution |
| | Portugal [mainland] | restricted distribution |
| Slovenia | | eradicated |
| Spain | | widespread |
| | Canary Islands | present, no further details |
| | Spain [mainland] | widespread |
| Sweden | | absent, intercepted only |
| Switzerland | | present, no further details |
| United Kingdom | | restricted distribution |
| | England and Wales | restricted distribution |
| | Northern Ireland | eradicated |
| | Scotland | eradicated |
| **Africa** | | |
| Comoros | | present, no further details |
| Kenya | | absent, unreliable record |
| Mauritius | | present, no further details |
| Morocco | | restricted distribution |
| Réunion | | present, no further details |
| Seychelles | | present, no further details |
| South Africa | | restricted distribution |
| Zambia | | absent, unreliable record |
| Zimbabwe | | absent, unreliable record |
| **North America** | | |
| Canada | | restricted distribution |
| | Ontario | restricted distribution |
| Mexico | | absent, unreliable record |
| USA | | restricted distribution |
| | California | present, no further details |
| | Florida | absent, formerly present |
| | Hawaii | present, no further details |
| | Utah | absent, formerly present |
| | Virginia | absent, formerly present |
| **Central America** | | |
| Belize | | present, no further details |
| Costa Rica | | present, no further details |
| Dominican Republic | | restricted distribution |
| El Salvador | | present, no further details |
| Guadeloupe | | present, no further details |
| Guatemala | | present, no further details |
| Honduras | | present, no further details |
| Nicaragua | | present, no further details |
| Panama | | present, no further details |
| **South America** | | |
| Argentina | | restricted distribution |
| Brazil | | restricted distribution |
| | Goias | present, no further details |
| | Minas Gerais | present, no further details |
| | Sao Paulo | present, no further details |
| Chile | | widespread |
| | Easter Island | present, no further details |
| Colombia | | restricted distribution |
| Ecuador | | present, no further details |
| French Guiana | | present, no further details |
| Peru | | restricted distribution |
| Uruguay | | present, no further details |
| Venezuela | | restricted distribution |
| **Oceania** | | |
| Australia | | absent, intercepted only |
| Guam | | present, few occurrences |

**_Liriomyza trifolii_ (American serpentine leafminer)**
**Distribution map - 2006**

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Distribution Notes by CAB International: "*L. trifolii* has not yet been reported from many countries where it is actually present. It is generally recognized that all the countries bordering the Mediterranean have *L. trifolii* in varying degrees and that it occurs in all mainland states of the USA. *L. trifolii* has been recorded from the Juan Fernandez Islands (an offshore territory of Chile)."

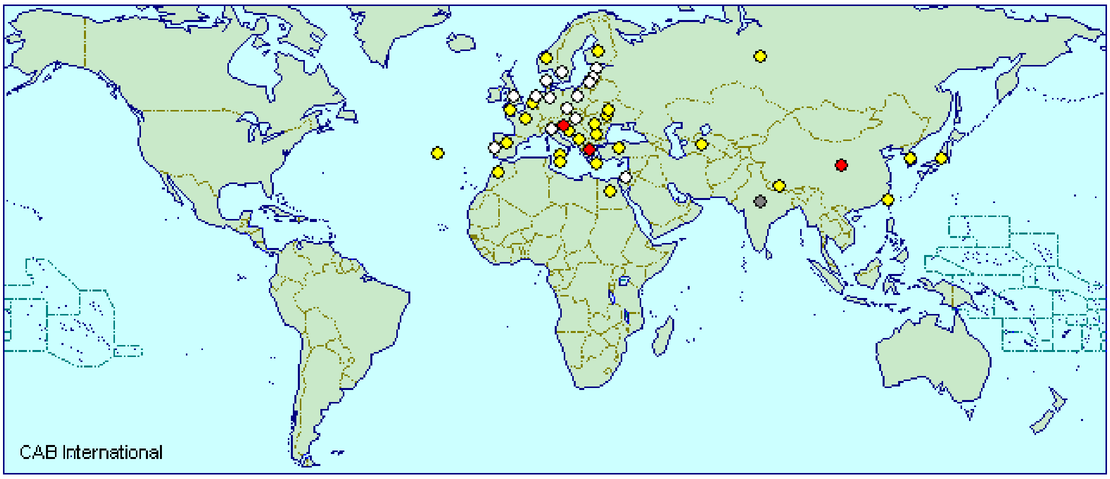
## *Liriomyza trifolii* (American serpentine leafminer)
## Distribution list

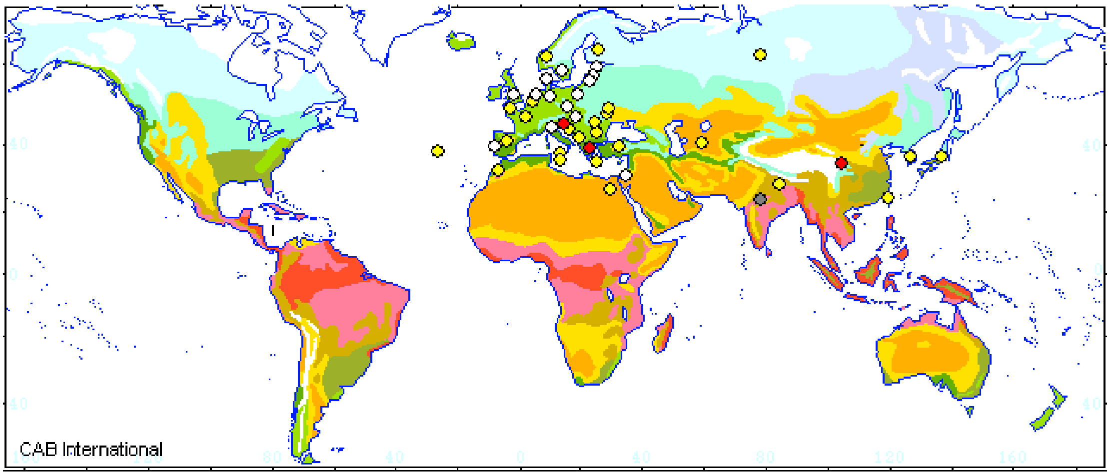
| | | |
|---|---|---|
| **Asia** | | |
| China | | present, no further details |
| | Fujian | present, no further details |
| | Taiwan | present, few occurrences |
| India | | present, no further details |
| | Andhra Pradesh | present, no further details |
| | Delhi | present, no further details |
| | Gujarat | present, no further details |
| | Haryana | present, no further details |
| | Indian Punjab | present, no further details |
| | Karnataka | present, no further details |
| | Kerala | present, no further details |
| | Madhya Pradesh | present, no further details |
| | Maharashtra | present, no further details |
| | Orissa | present, no further details |
| | Tamil Nadu | present, no further details |
| | Uttar Pradesh | present, no further details |
| | West Bengal | present, no further details |
| Israel | | widespread |
| Japan | | present, no further details |
| | Honshu | present, no further details |
| | Kyushu | present, no further details |
| Jordan | | present, no further details |
| Korea, Republic of | | present, no further details |
| Lebanon | | present, no further details |
| Oman | | present, no further details |
| Philippines | | present, no further details |
| Saudi Arabia | | present, no further details |
| Thailand | | present, no further details |
| Turkey | | restricted distribution |
| Yemen | | present, no further details |
| **Europe** | | |
| Austria | | restricted distribution |
| Belgium | | restricted distribution |
| Bulgaria | | eradicated |
| Croatia | | restricted distribution |
| Cyprus | | widespread |
| Czech Republic | | eradicated |
| Denmark | | eradicated |
| Estonia | | absent, never occurred |
| Finland | | eradicated |
| France | | widespread |
| | France [mainland] | widespread |
| Germany | | absent, formerly present |
| Greece | | restricted distribution |
| | Greece [mainland] | restricted distribution |
| Hungary | | eradicated |
| Ireland | | eradicated |
| Italy | | widespread |
| | Italy [mainland] | widespread |
| | Sardinia | present, no further details |
| | Sicily | present, no further details |
| Malta | | present, no further details |
| Netherlands | | restricted distribution |
| Norway | | present, few occurrences |
| Poland | | absent, formerly present |
| Portugal | | restricted distribution |
| | Portugal [mainland] | restricted distribution |
| Romania | | present, no further details |
| Russian Federation | | restricted distribution |
| | Central Russia | restricted distribution |
| | Southern Russia | present, few occurrences |
| Serbia and Montenegro | | restricted distribution |
| Slovakia | | absent, invalid record |
| Slovenia | | restricted distribution |
| Spain | | widespread |
| | Canary Islands | restricted distribution |
| | Spain [mainland] | widespread |
| Sweden | | eradicated |
| Switzerland | | present, few occurrences |
| United Kingdom | | eradicated |
| | England and Wales | eradicated |
| **Africa** | | |
| Benin | | present, no further details |
| Côte d'Ivoire | | present, no further details |
| Egypt | | present, no further details |
| Ethiopia | | present, no further details |
| Guinea | | present, no further details |
| Kenya | | present, no further details |
| Madagascar | | present, no further details |
| Mauritius | | present, no further details |
| Mayotte | | present, no further details |
| Nigeria | | present, no further details |
| Réunion | | present, no further details |
| Senegal | | widespread |
| South Africa | | present, few occurrences |
| Sudan | | present, no further details |
| Tanzania | | present, no further details |
| Tunisia | | restricted distribution |
| Zambia | | present, no further details |
| Zimbabwe | | present, no further details |
| **North America** | | |
| Bermuda | | present, no further details |
| Canada | | restricted distribution |
| | Alberta | present, no further details |
| | Nova Scotia | present, no further details |
| | Ontario | present, no further details |
| | Quebec | present, no further details |
| Mexico | | present, no further details |
| USA | | restricted distribution |
| | Arizona | present, no further details |
| | California | present, no further details |
| | Delaware | present, no further details |
| | District of Columbia | present, no further details |
| | Florida | present, no further details |
| | Hawaii | present, no further details |
| | Indiana | present, no further details |
| | Iowa | present, no further details |
| | Maryland | present, no further details |
| | Massachusetts | present, no further details |
| | Michigan | present, no further details |
| | New Jersey | present, no further details |
| | New Mexico | present, no further details |
| | Ohio | present, no further details |
| | Pennsylvania | present, no further details |
| | South Carolina | present, no further details |
| | Texas | present, no further details |
| | Washington | present, no further details |
| | Wisconsin | present, no further details |
| **Central America** | | |
| Bahamas | | present, no further details |
| Barbados | | present, no further details |
| British Virgin Islands | | present, no further details |
| Costa Rica | | present, no further details |
| Cuba | | present, no further details |
| Dominican Republic | | present, no further details |
| Guadeloupe | | present, no further details |
| Guatemala | | present, no further details |
| Martinique | | widespread |
| Netherlands Antilles | | restricted distribution |
| Puerto Rico | | present, no further details |
| Trinidad and Tobago | | present, no further details |
| United States Virgin Islands | | present, no further details |

| South America | |
|---|---|
| Argentina | present, no further details |
| Brazil | present, no further details |
| Minas Gerais | present, no further details |
| Pernambuco | present, no further details |
| Sao Paulo | present, no further details |
| Colombia | present, no further details |
| Ecuador | present, no further details |
| French Guiana | present, no further details |
| Guyana | present, no further details |
| Peru | present, no further details |
| Venezuela | present, no further details |

| Oceania | |
|---|---|
| American Samoa | present, no further details |
| Australia | absent, intercepted only |
| New South Wales | absent, intercepted only |
| Victoria | absent, intercepted only |
| Federated states of Micronesia | present, no further details |
| Guam | present, no further details |
| Northern Mariana Islands | present, no further details |
| Samoa | present, no further details |
| Tonga | present, no further details |

**_Liriomyza bryoniae_ (tomato leafminer)**
**Distribution map - 2006**





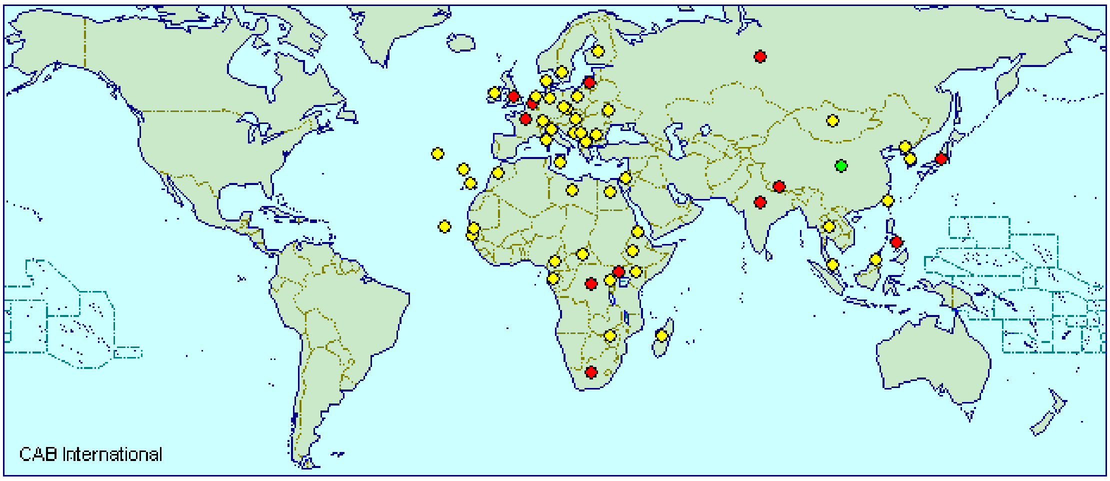

Note in the CABI Crop Protection Compendium: "*L. bryoniae* probably originates from southern Europe, but has now spread to many parts of Europe and the Mediterranean where crops are grown under glass. The insect is also present in the Far East (Japan and Taiwan) and Africa (Egypt, Morocco)."

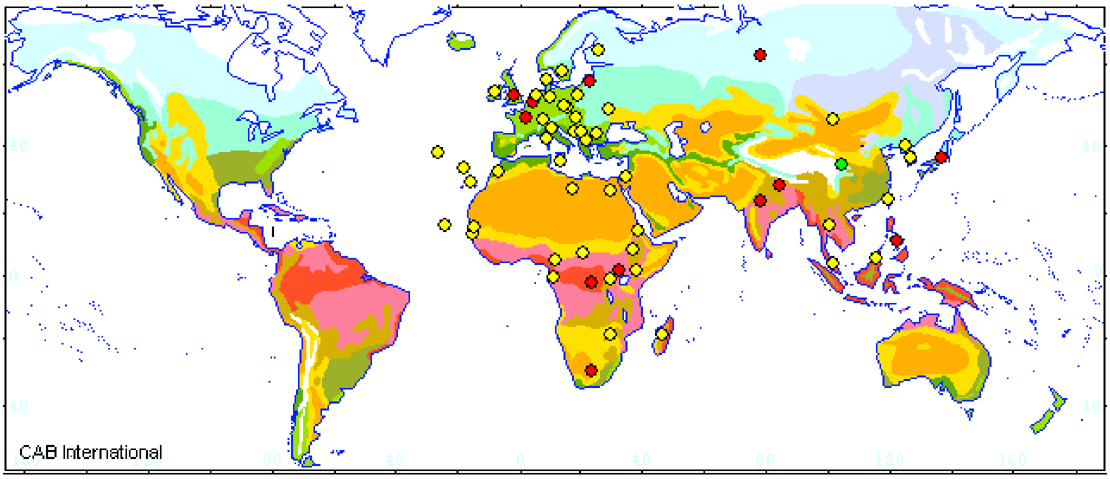
"An isolated report of *L. bryoniae* as a glasshouse pest in Massachusetts, USA, was made but there are no subsequent records for this pest in the USA. It has also been reported from Malta and Nepal. The distribution map includes a record from India based on undated specimens of *L. bryoniae* from the collection of the National History Museum (London, UK). See the Crop Protection Compendium for references and more detailed information."

## *Liriomyza bryoniae* (tomato leaf miner)
## Distribution list

| | |
|---|---|
| **Asia** | |
| China | widespread |
| Anhui | restricted distribution |
| Fujian | restricted distribution |
| Guangdong | restricted distribution |
| Guangxi | restricted distribution |
| Guizhou | present, no further details |
| Hainan | restricted distribution |
| Hebei | present, no further details |
| Henan | restricted distribution |
| Hubei | restricted distribution |
| Hunan | restricted distribution |
| Jiangsu | restricted distribution |
| Jiangxi | restricted distribution |
| Sichuan | restricted distribution |
| Taiwan | present, no further details |
| Yunnan | restricted distribution |
| Zhejiang | restricted distribution |
| India | present, few occurrences |
| Maharashtra | present, no further details |
| Israel | restricted distribution |
| Japan | present, no further details |
| Korea, Republic of | present, no further details |
| Nepal | present, no further details |
| Turkey | present, no further details |
| Turkmenistan | present, no further details |
| **Europe** | |
| Albania | present, no further details |
| Belgium | present, no further details |
| Bulgaria | present, no further details |
| Croatia | present, no further details |
| Czech Republic | restricted distribution |
| Denmark | restricted distribution |
| Estonia | restricted distribution |
| Finland | present, no further details |
| France | present, no further details |
| France [mainland] | present, no further details |
| Germany | restricted distribution |
| Greece | widespread |
| Crete | present, no further details |
| Greece [mainland] | widespread |
| Hungary | restricted distribution |
| Italy | restricted distribution |
| Sicily | present, no further details |
| Latvia | restricted distribution |
| Lithuania | restricted distribution |
| Malta | present, no further details |
| Moldova | present, no further details |
| Netherlands | restricted distribution |
| Norway | present, no further details |
| Poland | restricted distribution |
| Portugal | restricted distribution |
| Azores | present, no further details |
| Romania | present, no further details |
| Russian Federation | present, no further details |
| Central Russia | present, no further details |
| Southern Russia | present, no further details |
| Western Siberia | present, no further details |
| Slovenia | widespread |
| Spain | present, no further details |
| Canary Islands | absent, invalid record |
| Spain [mainland] | present, no further details |
| Sweden | restricted distribution |
| Ukraine | present, no further details |
| United Kingdom | restricted distribution |
| Channel Islands | present, no further details |
| England and Wales | restricted distribution |
| **Africa** | |
| Egypt | present, no further details |
| Morocco | present, no further details |
| **North America** | |
| USA | absent, invalid record |
| Massachusetts | absent, invalid record |

## *Chromatomyia horticola* (pea leaf miner)
## Distribution map





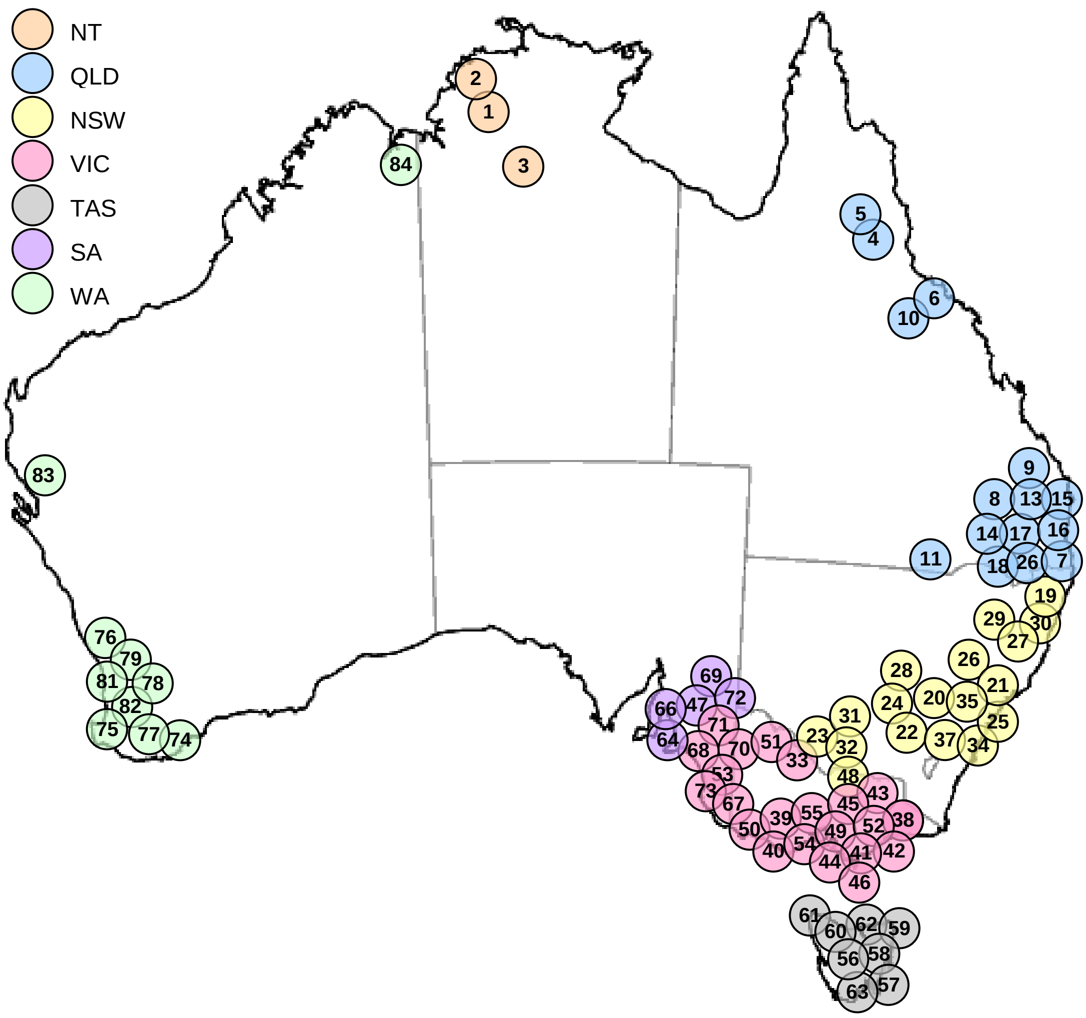

Note in the CABI Crop Protection Compendium: “In addition to the countries marked on the distribution map, *C. horticola* has also been recorded in Kuwait and in Kyushu, Japan (D.J. Henshaw, c/o IIE, London, UK, personal communication, 1996). It must be assumed that all countries in Europe and all states in India and China have populations of *C. horticola*. For the rest of the world, with the exception of the Americas and Australasia, omissions from the distribution map must be assumed to be due to lack of recording, not the absence of the pest.”

## *Chromatomyia horticola* (pea leaf miner)
## Distribution list

| | |
|---|---|
| **Asia** | |
| China | |
| Fujian | widespread |
| Gansu | widespread |
| Guangdong | widespread |
| Guangxi | widespread |
| Hainan | widespread |
| Hebei | widespread |
| Hubei | widespread |
| Jiangxi | widespread |
| Liaoning | present, no further details |
| Nei Menggu | widespread |
| Shaanxi | widespread |
| Shanxi | widespread |
| Taiwan | present, no further details |
| Xinjiang | widespread |
| Xizhang | widespread |
| India | widespread |
| Chandigarh | widespread |
| Israel | present, no further details |
| Japan | widespread |
| Honshu | widespread |
| Korea, DPR | present, no further details |
| Korea, Republic of | present, no further details |
| Malaysia | present, no further details |
| Peninsular Malaysia | present, no further details |
| Sabah | present, no further details |
| Mongolia | present, no further details |
| Nepal | widespread |
| Philippines | widespread |
| Thailand | present, no further details |
| **Europe** | |
| Belgium | widespread |
| Bosnia and Herzegovina | present, no further details |
| Bulgaria | present, no further details |
| Czech Republic | present, no further details |
| Czechoslovakia (former -) | present, no further details |
| Denmark | present, no further details |
| Faroe Islands | present, no further details |
| Finland | present, no further details |
| Former Yugoslavia | present, no further details |
| France | widespread |
| Corsica | present, no further details |
| Germany | present, no further details |
| Hungary | present, no further details |
| Ireland | present, no further details |
| Italy | present, no further details |
| Lithuania | widespread |
| Macedonia | present, no further details |
| Malta | present, no further details |
| Netherlands | present, no further details |
| Poland | present, no further details |
| Portugal | present, no further details |
| Azores | present, no further details |
| Madeira | present, no further details |
| Russian Federation | widespread |
| Serbia and Montenegro | present, no further details |
| Spain | present, no further details |
| Canary Islands | present, no further details |
| Sweden | present, no further details |
| Switzerland | present, no further details |
| Ukraine | present, no further details |
| United Kingdom | widespread |
| **Africa** | |
| Cameroon | present, no further details |
| Cape Verde | present, no further details |
| Central African Republic | present, no further details |
| Congo Democratic Republic | widespread |
| Egypt | present, no further details |
| Eritrea | present, no further details |
| Ethiopia | present, no further details |
| Gabon | present, no further details |
| Gambia | present, no further details |
| Kenya | present, no further details |
| Libya | present, no further details |
| Madagascar | present, no further details |
| Morocco | present, no further details |
| Rwanda | present, no further details |
| Senegal | present, no further details |
| South Africa | widespread |
| Uganda | widespread |
| Zimbabwe | present, no further details |

## Appendix 8. Vegetable production regions in Australia

Main vegetable production regions in Australia (HAL, 2004). Refer to tables below to identify the name of the numbered regions, the main vegetable crop species grown in each region (2006), and which crops could be potential major (●) and minor (○) hosts of exotic miners if they were to establish in the growing region. Colours identify states or territories. Sources of information are HAL (2004) for production regions and CAB International (2007) for leafminer hosts.

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Horticulture Australia Limited (HAL). 2004. The Australian Horticulture Statistics Handbook 2004. Horticulture Australia Limited. <http://www.horticulture.com.au/>

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| NT | 1 | Batchelor | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| NT | 2 | Darwin | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| NT | 2 | Darwin | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| NT | 2 | Darwin | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NT | 2 | Darwin | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| NT | 2 | Darwin | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| NT | 2 | Darwin | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| NT | 3 | Katherine | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| NT | 3 | Katherine | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| NT | 3 | Katherine | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NT | 3 | Katherine | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| NT | 3 | Katherine | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 4 | Atherton | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 4 | Atherton | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 5 | Atherton Tablelands | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 5 | Atherton Tablelands | Potatoes | Solanaceae | ● | ● | ● | | |
| QLD | 6 | Bowen | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| QLD | 6 | Bowen | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 6 | Bowen | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 6 | Bowen | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 6 | Bowen | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| QLD | 6 | Bowen | Sweet corn | Graminae | | | | | |
| QLD | 6 | Bowen | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 6 | Bowen | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 7 | Brisbane | Spinach | Chenopodiaceae | ● | ○ | ● | ○ | ● |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| QLD | 7 | Brisbane | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| QLD | 8 | Brunett | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 9 | Bundaberg | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| QLD | 9 | Bundaberg | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 9 | Bundaberg | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 9 | Bundaberg | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 9 | Bundaberg | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| QLD | 9 | Bundaberg | Sweet corn | Graminae | | | | | |
| QLD | 9 | Bundaberg | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 9 | Bundaberg | Potatoes | Solanaceae | ● | ● | ● | | |
| QLD | 9 | Bundaberg | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 10 | Burdekin | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 10 | Burdekin | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| QLD | 10 | Burdekin | Sweet corn | Graminae | | | | | |
| QLD | 10 | Burdekin | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 11 | Darling Downs | Broccoli | Brassicaceae | | | ● | | ● |
| QLD | 11 | Darling Downs | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 11 | Darling Downs | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| QLD | 12 | Fassifern Valley | Beetroot | Chenopodiaceae | ● | ○ | ● | | ● |
| QLD | 12 | Fassifern Valley | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 12 | Fassifern Valley | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 13 | Gympie | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| QLD | 13 | Gympie | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| QLD | 13 | Gympie | Sweet corn | Graminae | | | | | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| QLD | 13 | Gympie | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 14 | Lockyer Valley | Garlic | Alliaceae | ● | ● | ● | | ● |
| QLD | 14 | Lockyer Valley | Onions | Alliaceae | ○ | ● | ● | | ● |
| QLD | 14 | Lockyer Valley | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| QLD | 14 | Lockyer Valley | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| QLD | 14 | Lockyer Valley | Broccoli | Brassicaceae | | | ● | | ● |
| QLD | 14 | Lockyer Valley | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| QLD | 14 | Lockyer Valley | Cauliflower | Brassicaceae | | | ● | | ● |
| QLD | 14 | Lockyer Valley | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| QLD | 14 | Lockyer Valley | Beetroot | Chenopodiaceae | ● | ○ | ● | | ● |
| QLD | 14 | Lockyer Valley | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| QLD | 14 | Lockyer Valley | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 14 | Lockyer Valley | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| QLD | 14 | Lockyer Valley | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 14 | Lockyer Valley | Potatoes | Solanaceae | ● | ● | ● | | |
| QLD | 14 | Lockyer Valley | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 14 | Lockyer Valley | Carrots | Umbelliferae | ○ | | ● | | ● |
| QLD | 14 | Lockyer Valley | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| QLD | 15 | North Moreton | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| QLD | 16 | Redlands | Leeks | Alliaceae | ● | ● | ● | | ● |
| QLD | 16 | Redlands | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| QLD | 16 | Redlands | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| QLD | 16 | Redlands | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| QLD | 16 | Redlands | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 17 | South East Queensland | Sweet corn | Graminae | | | | | |
| QLD | 18 | Stanthorpe | Leeks | Alliaceae | ● | ● | ● | | ● |
| QLD | 18 | Stanthorpe | Broccoli | Brassicaceae | | | ● | | ● |
| QLD | 18 | Stanthorpe | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| QLD | 18 | Stanthorpe | Cauliflower | Brassicaceae | | | ● | | ● |
| QLD | 18 | Stanthorpe | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| QLD | 18 | Stanthorpe | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| QLD | 18 | Stanthorpe | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| QLD | 18 | Stanthorpe | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| QLD | 18 | Stanthorpe | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| NSW | 19 | Far North Coast | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 20 | Bathurst | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| NSW | 20 | Bathurst | Broccoli | Brassicaceae | | | ● | | ● |
| NSW | 20 | Bathurst | Cauliflower | Brassicaceae | | | ● | | ● |
| NSW | 20 | Bathurst | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 20 | Bathurst | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 21 | Central Coast | Carrots | Umbelliferae | ○ | | ● | | ● |
| NSW | 22 | Crockwell | Potatoes | Solanaceae | ● | ● | ● | | |
| NSW | 23 | Finley | Sweet corn | Graminae | | | | | |
| NSW | 24 | Forbes | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 24 | Forbes | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 25 | Gosford | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| NSW | 26 | Hunter Valley | Cabbages | Brassicaceae | ● | | ● | ● | ● |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| NSW | 26 | Hunter Valley | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| NSW | 26 | Hunter Valley | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NSW | 26 | Hunter Valley | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 26 | Hunter Valley | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 26 | Hunter Valley | Sweet corn | Graminae | | | | | |
| NSW | 26 | Hunter Valley | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 26 | Hunter Valley | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| NSW | 27 | Mid North Coast | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| NSW | 28 | Narromine | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 29 | New England | Potatoes | Solanaceae | ● | ● | ● | | |
| NSW | 30 | North Coast | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| NSW | 30 | North Coast | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NSW | 31 | Riverina | Garlic | Alliaceae | ● | ● | ● | | ● |
| NSW | 31 | Riverina | Onions | Alliaceae | ○ | ● | ● | | ● |
| NSW | 31 | Riverina | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| NSW | 31 | Riverina | Broccoli | Brassicaceae | | | ● | | ● |
| NSW | 31 | Riverina | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| NSW | 31 | Riverina | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| NSW | 31 | Riverina | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NSW | 31 | Riverina | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 31 | Riverina | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 31 | Riverina | Sweet corn | Graminae | | | | | |
| NSW | 31 | Riverina | Capsicum | Solanaceae | ● | ○ | ● | ○ | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| NSW | 31 | Riverina | Potatoes | Solanaceae | ● | ● | ● | | |
| NSW | 31 | Riverina | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 31 | Riverina | Carrots | Umbelliferae | ○ | | ● | | ● |
| NSW | 32 | Riverina (seed prod. only) | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| NSW | 34 | Sydney | Spinach | Chenopodiaceae | ● | ○ | ● | ○ | ● |
| NSW | 35 | Sydney Basin | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| NSW | 35 | Sydney Basin | Broccoli | Brassicaceae | | | ● | | ● |
| NSW | 35 | Sydney Basin | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| NSW | 35 | Sydney Basin | Cauliflower | Brassicaceae | | | ● | | ● |
| NSW | 35 | Sydney Basin | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| NSW | 35 | Sydney Basin | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| NSW | 35 | Sydney Basin | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 35 | Sydney Basin | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| NSW | 35 | Sydney Basin | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| NSW | 35 | Sydney Basin | Sweet corn | Graminae | | | | | |
| NSW | 35 | Sydney Basin | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 35 | Sydney Basin | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| NSW | 35 | Sydney Basin | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| NSW | 35 | Sydney Basin | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| NSW | 36 | Tumut | Sweet corn | Graminae | | | | | |
| NSW | 37 | Windsor | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| VIC | 33 | Robinvale | Carrots | Umbelliferae | ○ | | ● | | ● |
| VIC | 38 | Bairnsdale | Broccoli | Brassicaceae | | | ● | | ● |
| VIC | 39 | Ballarat | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| VIC | 39 | Ballarat | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 39 | Ballarat | Potatoes | Solanaceae | ● | ● | ● | | |
| VIC | 40 | Colac | Potatoes | Solanaceae | ● | ● | ● | | |
| VIC | 41 | East & South Gippsland | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| VIC | 42 | Gippsland | Onions | Alliaceae | ○ | ● | ● | | ● |
| VIC | 43 | Goulburn Valley | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| VIC | 44 | Melbourne | Spinach | Chenopodiaceae | ● | ○ | ● | ○ | ● |
| VIC | 44 | Melbourne | Carrots | Umbelliferae | ○ | | ● | | ● |
| VIC | 45 | Melbourne Metro Area | Leeks | Alliaceae | ● | ● | ● | | ● |
| VIC | 45 | Melbourne Metro Area | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| VIC | 45 | Melbourne Metro Area | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| VIC | 45 | Melbourne Metro Area | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| VIC | 45 | Melbourne Metro Area | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| VIC | 45 | Melbourne Metro Area | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 45 | Melbourne Metro Area | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 45 | Melbourne Metro Area | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| VIC | 46 | Mornington Peninsula | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| VIC | 48 | Northern Victoria | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| VIC | 49 | Outer Melbourne | Potatoes | Solanaceae | ● | ● | ● | | |
| VIC | 49 | Outer Melbourne | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| VIC | 50 | Portland | Potatoes | Solanaceae | ● | ● | ● | | |
| VIC | 51 | Sunraysia | Garlic | Alliaceae | ● | ● | ● | | ● |
| VIC | 51 | Sunraysia | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| VIC | 51 | Sunraysia | Cabbages | Brassicaceae | ● | | ● | ● | ● |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| VIC | 51 | Sunraysia | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| VIC | 51 | Sunraysia | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| VIC | 51 | Sunraysia | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| VIC | 51 | Sunraysia | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 51 | Sunraysia | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 51 | Sunraysia | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| VIC | 51 | Sunraysia | Sweet corn | Graminae | | | | | |
| VIC | 51 | Sunraysia | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| VIC | 51 | Sunraysia | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| VIC | 52 | Warragul | Potatoes | Solanaceae | ● | ● | ● | | |
| VIC | 53 | Warrnambool | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 53 | Warrnambool | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| VIC | 54 | Werribee | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| VIC | 54 | Werribee | Broccoli | Brassicaceae | | | ● | | ● |
| VIC | 54 | Werribee | Cauliflower | Brassicaceae | | | ● | | ● |
| VIC | 55 | Western Districts | Onions | Alliaceae | ○ | ● | ● | | ● |
| TAS | 56 | Devonport | Broccoli | Brassicaceae | | | ● | | ● |
| TAS | 56 | Devonport | Carrots | Umbelliferae | ○ | | ● | | ● |
| TAS | 57 | Hobart | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| TAS | 58 | Launceston | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| TAS | 59 | North East TAS | Sweet corn | Graminae | | | | | |
| TAS | 60 | North West Coast | Onions | Alliaceae | ○ | ● | ● | | ● |
| TAS | 61 | North West TAS | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| TAS | 61 | North West TAS | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| TAS | 61 | North West TAS | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| TAS | 61 | North West TAS | Sweet corn | Graminae | | | | | |
| TAS | 61 | North West TAS | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| TAS | 62 | Northern Tasmania | Potatoes | Solanaceae | ● | ● | ● | | |
| TAS | 63 | South TAS | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| SA | 47 | North Adelaide Plains | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| SA | 47 | North Adelaide Plains | Broccoli | Brassicaceae | | | ● | | ● |
| SA | 47 | North Adelaide Plains | Cauliflower | Brassicaceae | | | ● | | ● |
| SA | 47 | North Adelaide Plains | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| SA | 47 | North Adelaide Plains | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| SA | 64 | Adelaide | Onions | Alliaceae | ○ | ● | ● | | ● |
| SA | 64 | Adelaide | Spinach | Chenopodiaceae | ● | ○ | ● | ○ | ● |
| SA | 64 | Adelaide | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| SA | 65 | Adelaide Hills | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| SA | 65 | Adelaide Hills | Broccoli | Brassicaceae | | | ● | | ● |
| SA | 65 | Adelaide Hills | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| SA | 65 | Adelaide Hills | Sweet corn | Graminae | | | | | |
| SA | 65 | Adelaide Hills | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| SA | 66 | Adelaide Plains | Garlic | Alliaceae | ● | ● | ● | | ● |
| SA | 66 | Adelaide Plains | Leeks | Alliaceae | ● | ● | ● | | ● |
| SA | 66 | Adelaide Plains | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| SA | 66 | Adelaide Plains | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| SA | 66 | Adelaide Plains | Cauliflower | Brassicaceae | | | ● | | ● |
| SA | 66 | Adelaide Plains | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| SA | 66 | Adelaide Plains | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| SA | 66 | Adelaide Plains | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| SA | 66 | Adelaide Plains | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| SA | 66 | Adelaide Plains | Carrots | Umbelliferae | ○ | | ● | | ● |
| SA | 66 | Adelaide Plains | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| SA | 67 | Mt. Gambier | Potatoes | Solanaceae | ● | ● | ● | | |
| SA | 68 | Murray Bridge | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| SA | 69 | North Adelaide Hills | Potatoes | Solanaceae | ● | ● | ● | | |
| SA | 70 | Pinnaroo | Potatoes | Solanaceae | ● | ● | ● | | |
| SA | 71 | River Murray | Onions | Alliaceae | ○ | ● | ● | | ● |
| SA | 72 | Riverland | Garlic | Alliaceae | ● | ● | ● | | ● |
| SA | 72 | Riverland | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| SA | 72 | Riverland | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| SA | 72 | Riverland | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| SA | 72 | Riverland | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| SA | 72 | Riverland | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| SA | 72 | Riverland | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| SA | 72 | Riverland | Sweet corn | Graminae | | | | | |
| SA | 72 | Riverland | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| SA | 72 | Riverland | Potatoes | Solanaceae | ● | ● | ● | | |
| SA | 72 | Riverland | Carrots | Umbelliferae | ○ | | ● | | ● |
| SA | 73 | South East | Onions | Alliaceae | ○ | ● | ● | | ● |
| WA | 74 | Albany | Potatoes | Solanaceae | ● | ● | ● | | |
| WA | 75 | Bunbury | Sweet corn | Graminae | | | | | |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| WA | 76 | Gingin | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| WA | 76 | Gingin | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 76 | Gingin | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 76 | Gingin | Carrots | Umbelliferae | ○ | | ● | | ● |
| WA | 77 | Manjimup | Onions | Alliaceae | ○ | ● | ● | | ● |
| WA | 77 | Manjimup | Broccoli | Brassicaceae | | | ● | | ● |
| WA | 77 | Manjimup | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| WA | 77 | Manjimup | Cauliflower | Brassicaceae | | | ● | | ● |
| WA | 77 | Manjimup | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| WA | 77 | Manjimup | Potatoes | Solanaceae | ● | ● | ● | | |
| WA | 77 | Manjimup | Carrots | Umbelliferae | ○ | | ● | | ● |
| WA | 78 | Perth | Onions | Alliaceae | ○ | ● | ● | | ● |
| WA | 78 | Perth | Lettuce | Asteraceae | ● | ● | ● | ● | ● |
| WA | 78 | Perth | Cauliflower | Brassicaceae | | | ● | | ● |
| WA | 78 | Perth | Potatoes | Solanaceae | ● | ● | ● | | |
| WA | 78 | Perth | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| WA | 78 | Perth | Cut Flowers | Various families | ● | ● | ● | ● | ○ |
| WA | 79 | Perth Metro | Carrots | Umbelliferae | ○ | | ● | | ● |
| WA | 80 | Perth Metro Area | Broccoli | Brassicaceae | | | ● | | ● |
| WA | 80 | Perth Metro Area | Chinese Cabbage | Brassicaceae | ● | | ● | | ● |
| WA | 80 | Perth Metro Area | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| WA | 80 | Perth Metro Area | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 80 | Perth Metro Area | Beans | Fabaceae | ● | ● | ● | ○ | ● |

Vegetable production regions and grown crops that overseas are known hosts of exotic leafminers (continued)

| State / Territory | Region number | Region name | Host crop | Host family | *L. trifolii* | *L. huidobrensis* | *L. sativae* | *L. bryoniae* | *C. horticola* |
|---|---|---|---|---|---|---|---|---|---|
| WA | 80 | Perth Metro Area | Celery | Umbelliferae | ○ | ● | ● | ○ | ● |
| WA | 81 | Perth Metro Outer Areas | Garlic | Alliaceae | ● | ● | ● | | ● |
| WA | 81 | Perth Metro Outer Areas | Leeks | Alliaceae | ● | ● | ● | | ● |
| WA | 81 | Perth Metro Outer Areas | Spring Onions | Alliaceae | ○ | ● | ● | | ● |
| WA | 81 | Perth Metro Outer Areas | Cabbages | Brassicaceae | ● | | ● | ● | ● |
| WA | 81 | Perth Metro Outer Areas | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 81 | Perth Metro Outer Areas | Sweet corn | Graminae | | | | | |
| WA | 81 | Perth Metro Outer Areas | Capsicum | Solanaceae | ● | ○ | ● | ○ | |
| WA | 82 | Waroona | Pumpkin | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 82 | Waroona | Zucchini | Cucurbitaceae | ● | ● | ● | ● | ● |
| WA | 83 | Carnarvon | Cucumbers | Cucurbitaceae | ● | ○ | ● | ● | |
| WA | 83 | Carnarvon | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |
| WA | 83 | Carnarvon | Beans | Fabaceae | ● | ● | ● | ○ | ● |
| WA | 83 | Carnarvon | Tomatoes | Solanaceae | ● | ○ | ● | ○ | |
| WA | 84 | Kununurra | Melons | Cucurbitaceae | ● | ○ | ● | ● | ● |

## Appendix 9. Awareness material

PHA has leafminer factsheets for some of the exotic *Liriomyza* species which are included in the Awareness Material section of the National Industry Biosecurity Plans developed for Vegetables, Onions, and Potatoes. *L. sativae* Fact sheet is included in the National Onion Industry Biosecurity Plan <http://www.planthealthaustralia.com.au/UserFiles/File/Industry%20Biosecurity%20-%20Vegetable/070403%20Section%205%20Fact%20sheet%20-%20L%20sativae.pdf>

Species information factsheets for all the species in the exotic group can be located in the Lucid key server *Polyphagous Agromyzid Leafminers* (Malipatil and Ridland, 2008).

## References

Malipatil, M. and P. Ridland. 2008. Polyphagous Agromyzid leafminers. Department of Primary Industries, Victoria, Australia. <http://keys.lucidcentral.org/keys/v3/leafminers/index.htm>

Ridland P., M. Malipatil, and Plant Health Australia. 2008. Industry Biosecurity Plan for the Grains Industry- Threat Specific Contingency Plan: American serpentine leafminer, *Liriomyza trifolii*, bundled with *L. cicerina*, *L. huidobrensis*, *L. sativae*, *L. bryoniae* and *Chromatomyia horticola*. Plant Health Australia, Canberra, ACT, Australia.