Abstract

This datasheet on Liriomyza trifolii covers Identity, Overview, Distribution, Dispersal, Hosts/Species Affected, Diagnosis, Biology & Ecology, Natural Enemies, Impacts, Prevention/Control, Further Information.

Identity

Preferred Scientific Name

Liriomyza trifolii Burgess in Comstock, 1880

Preferred Common Name

American serpentine leafminer

Other Scientific Names

Agromyza phaseolunata Frost, 1943
Liriomyza alliivora Frick, 1955
Liriomyza alliovora Frick, 1955
Liriomyza phaseolunata (Frost, 1943)
Oscinis trifolii Burgess in Comstock, 1880

International Common Names

English: chrysanthemum leaf miner; serpentine leaf miner
Spanish: minador pequeño del frijol
French: mineuse du gerbera

Local Common Names

Germany: Floridaminierfliege
Russian Federation: American clover miner

EPPO code

LIRITR (Liriomyza trifolii)

Pictures

Adult male

Male and female L. trifolii are generally similar in appearance.

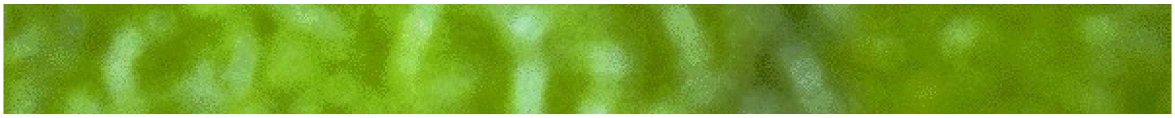
Feedback

Adult female

L. trifolii is very small: 1-1.3 mm body length, up to 1.7 mm in female with wings 1.3-1.7 mm.The scutellum is bright yellow; face, frons and third antennal segment bright yellow

Adult

Dorso-lateral view of adult L. trifolii (museum set specimen).



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Adult

Dacus bivittatus; Adult

Feedback

Leaf mine in chrysanthemum

Leaf mines usually long, linear, narrow and not greatly widening towards the end, greenish white. Frass deposited in black strips alternately at either side of the mine (like L. sativae), but becomes more granular

Taxonomic Tree

Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Subphylum: Uniramia
Class: Insecta
Order: Diptera
Family: Agromyzidae
Genus: Liriomyza
Species: Liriomyza trifolii

Notes on Taxonomy and Nomenclature

Liriomyza trifolii is one of the truly polyphagous agromyzids and has been recorded in 25 families (Spencer, 1990). It was first described as *Oscinis trifolii* (Burgess in Comstock, 1880) in the family Chloropidae from flies attacking the leaves of *Trifolium repens* (white clover) in Indiana, USA. Later, it was transferred to the family Agromyzidae in the genus *Agromyza* by Coquillet (1898), then to *Liriomyza* by de Meijere (1925). Spencer, 1973 synonymized *Liriomyza alliovora* Frick, 1955, breeding in Allium (onions) in Iowa, USA, and in Spencer, 1986, *Agromyza phaseolunata* Frost (1943, as *Liriomyza*) attacking *Phaseolus lunatus* (lima beans) in New Jersey, USA with *L. trifolii*.

Summary of Invasiveness

L. trifolii is a leaf-mining insect, commonly known as the serpentine leafminer. It is highly polyphagous and has been recorded from 25 families. As a major pest of ornamental and vegetable crops, including beans (phaseolus), *Capsicum*, carnations, celery, chrysanthemums

(Dendranthenum, the commercial 'Mum'), clover, *Cucumis, Gerbera, Gypsophila*, lettuces, lucerne, potatoes, *Senecio hybridus* and tomatoes it has had important biological and

Description

Descriptions of *L. trifolii* refer to fresh materials. Dry specimens may be distorted due to the manner in which they have been preserved. Also, the age of the specimen, when killed, will have some effect on its preservation characteristics.

For accurate identification, examination of the leaf mine and all stages of development are crucial.

Egg

L. trifolii eggs are 0.2-0.3 mm x 0.1-0.15 mm, off white and slightly translucent.

Larva

This is a legless maggot with no separate head capsule, transparent when newly hatched but colouring up to a yellow-orange in later instars and is up to 3 mm long. *L. trifolii* larvae and puparia have a pair of posterior spiracles terminating in three cone-like appendages. Spencer (1973) describes distinguishing features of the larvae. Petitt (1990) describes a method of identifying the different instars of the larvae of L. sativae, which can be adapted for use with the other Liriomyza species, including *L. trifolii*.

Puparium

This is oval and slightly flattened ventrally, 1.3-2.3 x 0.5-0.75 mm with variable colour, pale yellow-orange, darkening to golden-brown. The puparium has posterior spiracles on a pronounced conical projection, each with three distinct bulbs, two of which are elongate.

Pupariation occurs outside the leaf, in the soil beneath the plant.

huidobrensis, and L. sativae using allozyme variation patterns as revealed by gel electrophoresis.

Adult

L. trifolii is very small: 1-1.3 mm body length, up to 1.7 mm in female with wings 1.3-1.7 mm. The mesonotum is grey-black with a yellow blotch at the hind-corners. The scutellum is bright yellow; the face, frons and third antennal segment are bright yellow. Male and female *L. trifolii* are generally similar in appearance.

L. trifolii are not very active fliers, and in crops showing active mining, the flies may be seen walking rapidly over the leaves with only short jerky flights to adjacent leaves.

Head

The frons, which projects very slightly above the eye, is just less than 1.5 times the width of the eye (viewed from above). There are two equal ors and two ori (the lower one weaker). Orbital setulae are sparse and reclinate. The jowls are deep (almost 0.33 times the height of the eye at the rear); the cheeks form a distinct ring below the eye. The third antennal segment is small, round and noticeably pubescent, but not excessively so (vte and vti are both on a yellow ground).

Mesonotum

Acrostical bristles occur irregularly in 3-4 rows at the front, reducing to two rows behind. There is a conspicuous yellow patch at each hind-corner. The pleura are yellow; the meso- and sterno-pleura have variable black markings.

Wing

Length 1.3 -1.7 mm, discal cell small. The last section is M<(sub)3+4> from 3-4 times the length of the penultimate one.

Genitalia

The shape of the distiphallus is fairly distinctive but could be mis-identified for L. sativae. Identification using the male genitalia should only be undertaken by specialists.

Colour

The head (including the antenna and face) is bright yellow. The hind margin of the eye is largely yellow, vte and vti always on yellow ground.

The mesopleura is predominantly yellow, with a variable dark area, from a slim grey bar along the base to extensive darkening reaching higher up the front margin than the back margin. The sternopleura is largely filled by a black triangle, but always with bright yellow above.

The femora and coxa are bright yellow, with the tibia and tarsi darker; brownish-yellow on the fore-legs, brownish-black on the hind legs. The abdomen is largely black but the tergites are variably yellow, particularly at the sides. The squamae are yellowish, with a dark margin and fringe.

Although individual specimens may vary considerably in colour, the basic pattern is consistent.

List of Diseases and Disorders

No data to display for this datasheet

Distribution

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; Martinez and Etienne, 2002; EPPO, 2009). See also CABI/EPPO (1998, No. 96). *L. trifolii* is apparently unable to overwinter in

entry and spread in non-Mediterranean areas were found to be only partially effective, as interceptions are still being reported (EFSA, 2012).

The record for Argentina has been changed to 'Absent, unreliable record' as Martinez and Etienne (2002) and EPPO (2006) are based on Burgess (in Comstock, 1880 (1879)) and there have been no other reports of the pest in Argentina. *L. trifolii* is a quarantine pest for Argentina (SENASA, personal communication, 2008).

Distribution Table

The distribution in this summary table is based on all the information available to CABI. When several references are cited, they may give conflicting information on the status. When citing original literature, please check to ensure the correct reference is used. CABI makes every effort to ensure that these data are complete and up-to-date but cannot guarantee the accuracy of every record. If you have spotted something that needs updating, please contact us at compend@cabi.org. Please include reference to published literature. Data will be verified by CABI editors and published if there is sufficient evidence.

Last updated: 03 Apr 2024

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
Africa						
Benin	Present					CABI and EPPO (1997)
Côte d'Ivoire	Present					CABI and EPPO (1997)
Egypt	Present					CABI and EPPO (1997)
Ethiopia	Present					CABI and EPPO (1997)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
Guinea	Present					CABI and
Kenya	Present		Introduced	1976	Invasive	Spencer (1985)
Madagascar	Present					CABI and EPPO (1997)
Mauritius	Present					CABI and EPPO (1997)
Mayotte	Present					CABI and EPPO (1997)
Morocco	Present					EPPO (2023)
Nigeria	Present					CABI and EPPO (1997)
Réunion	Present					CABI and EPPO (1997)
Senegal	Present, Widespread					Deeming (1992)
South Africa	Present					Zengeya and Wilson (2021)
Sudan	Present			1985		CABI and EPPO (1997)
Tanzania	Present					Deeming (1992)
Tunisia	Present, Localized			1992		CABI and EPPO (1997)
Zambia	Present					CABI and EPPO (1997)
Zimbabwe	Present					CABI and EPPO (1997)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
Asia						

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
	Unconfirmed presence record(s)					(2023)
China	Present		Introduced	1988		Seebens et al. (2017)
- Anhui	Present					EPPO (2023)
- Fujian	Present					CABI and EPPO (1997)
- Gansu	Present					EPPO (2023)
- Guangdong	Present					Liu ChunYan et al. (2007)
- Guangxi	Present					EPPO (2023)
- Guizhou	Present					EPPO (2023)
- Hainan	Present					EPPO (2023)
- Hebei	Present					EPPO (2023)
- Henan	Present					EPPO (2023)
- Hubei	Present					EPPO (2023)
- Hunan	Present					EPPO (2023)
- Jiangsu	Present					Wang JianFu et al. (2010)
- Jiangxi	Present					EPPO (2023)
- Liaoning	Present					EPPO (2023)

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
- Shaanxi	Present					EPPO
- Shandong	Present					EPPO (2023)
- Shanghai	Present					EPPO (2023)
- Yunnan	Present					EPPO (2023)
- Zhejiang	Present					EPPO (2023)
India	Present					CABI and EPPO (1997)
- Andhra Pradesh	Present			1991		CABI and EPPO (1997)
- Delhi	Present					CABI and EPPO (1997)
- Gujarat	Present					CABI and EPPO (1997)
- Haryana	Present					EPPO (2023)
- Jammu and Kashmir	Present					Bhat et al. (2009)
- Karnataka	Present					CABI and EPPO (1997)
- Kerala	Present					EPPO (2023)
- Madhya Pradesh	Present					CABI and EPPO (1997)
- Maharashtra	Present					CABI and EPPO (1997)
- Nagaland	Present					EPPO (2023)
- Odisha	Present					CABI and EPPO

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
						(1997)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
						(1997)
- Tamil Nadu	Present					CABI and EPPO (1997)
- Telangana	Present					EPPO (2023)
- Tripura	Present					EPPO (2023)
- Uttar Pradesh	Present					EPPO (2023)
- West Bengal	Present					EPPO (2023)
Indonesia	Present					Baliadi and Tengkano (2010)
Iran	Present, Widespread					EPPO (2023)
Israel	Present, Widespread					Deeming (1992)
Japan	Present		Introduced	1990		Seebens et al. (2017)
- Honshu	Present					CABI and EPPO (1997)
- Kyushu	Present					CABI and EPPO (1997)
Jordan	Present					EPPO (2023)
Laos	Absent, Unconfirmed presence record(s)					EPPO (2023)
Lebanon	Present					CABI and EPPO (1997)

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
Malaysia	Absent ... record(s)					EPPO	
Maldives	Present					EPPO (2023)	
Oman	Present					EPPO (2023)	
Philippines	Present					CABI and EPPO (1997)	
Saudi Arabia	Present					EPPO (2023)	
South Korea	Present					CABI and EPPO (1997)	
Taiwan	Present, Few occurrences					CABI and EPPO (1997)	
Thailand	Absent, Unconfirmed presence record(s)					EPPO (2023)	
Turkey	Present, Localized			1985		Deeming (1992)	
United Arab Emirates	Present					EPPO (2023)	
Vietnam	Present, Localized					EPPO (2023)	
Yemen	Present					CABI and EPPO (1997)	
Europe							
Albania	Present		Introduced	1998		Seebens et al. (2017)	
Austria	Present, Localized					CABI and EPPO (1997)	Fi 1
Belgium	Present, Localized					CABI and EPPO	

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
						(1997)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
Bulgaria	Absent, Eradicated			1985		CABI and EPPO (1997)	
Croatia	Present, Localized					CABI and EPPO (1997)	
Cyprus	Present, Widespread			1988		CABI and EPPO (1997)	
Czechia	Absent, Eradicated			1981		CABI and EPPO (1997)	
Denmark	Absent, Intercepted only					IPPC (2013)	
Estonia	Absent, Confirmed absent by survey					EPPO (2023)	
Finland	Present, Few occurrences					CABI and EPPO (1997)	
France	Present, Widespread					CABI and EPPO (1997)	
Germany	Absent, Formerly present					CABI and EPPO (1997)	Fi 1
Greece	Present, Localized					EPPO (2023)	
- Crete	Present					EPPO (2023)	
Hungary	Absent, Eradicated			1986		CABI and EPPO (1997)	
Ireland	Absent, Eradicated					CABI and EPPO (1997)	

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
Italy	Present			1979		Süss
- Sardinia	Present					CABI and EPPO (1997)
- Sicily	Present		Introduced	1982		Seebens et al. (2017)
Lithuania	Absent, Confirmed absent by survey					EPPO (2023)
Malta	Present					CABI and EPPO (1997)
Moldova	Present					EPPO (2023)
Montenegro	Absent, Formerly present					EPPO (2023)
Netherlands	Present, Localized			1976		CABI and EPPO (1997)
Norway	Absent, Eradicated					CABI and EPPO (1997)
Poland	Absent, Formerly present			1980		CABI and EPPO (1997)
Portugal	Present, Localized					CABI and EPPO (1997)
Romania	Present, Few occurrences					CABI and EPPO (1997)
Russia	Present, Localized					EPPO (2023)
- Central Russia	Present, Localized					CABI and EPPO (1997)
- Southern Russia	Present, Few occurrences					CABI and EPPO

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
						(1997)	

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
Slovakia	Absent, Invalid presence record(s)					CABI and EPPO (1997)	
Slovenia	Absent, Eradicated					EPPO (2023)	
Spain	Present, Widespread					CABI and EPPO (1997)	
- Canary Islands	Present, Localized					CABI and EPPO (1997)	
Sweden	Absent, Eradicated			1980		CABI and EPPO (1997)	
Switzerland	Present, Few occurrences					CABI and EPPO (1997)	Fi 1
United Kingdom	Absent, Eradicated			1977		CABI and EPPO (1997)	
- England	Absent, Eradicated					EPPO (2023)	
North America							
Bahamas	Present					CABI and EPPO (1997)	
Barbados	Present					CABI and EPPO (1997)	
Bermuda	Present					CABI and EPPO (1997)	
British Virgin Islands	Present					EPPO (2023)	
Canada	Present, Localized					CABI and EPPO (1997)	

Feedback

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
- Alberta	Present					CABI and

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
- Nova Scotia	Present					CABI and EPPO (1997)
- Ontario	Present					CABI and EPPO (1997)
- Quebec	Present					CABI and EPPO (1997)
Costa Rica	Present					CABI and EPPO (1997)
Cuba	Present					CABI and EPPO (1997)
Dominican Republic	Present					CABI and EPPO (1997)
Guadeloupe	Present					CABI and EPPO (1997)
Guatemala	Present					CABI and EPPO (1997)
Martinique	Present, Widespread					CABI and EPPO (1997)
Mexico	Present					Martinez and Etienne (2002)
Puerto Rico	Present					EPPO (2023)
Saint Kitts and Nevis	Present, Localized					EPPO (2023)
Trinidad and Tobago	Present					CABI and EPPO (1997)
U.S. Virgin Islands	Present					EPPO

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Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
						(2023)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
						(1997)
- Arizona	Present					CABI and EPPO (1997)
- California	Present					CABI and EPPO (1997)
- Delaware	Present					CABI and EPPO (1997)
- District of Columbia	Present					CABI and EPPO (1997)
- Florida	Present					CABI and EPPO (1997)
- Hawaii	Present					CABI and EPPO (1997)
- Indiana	Present					CABI and EPPO (1997)
- Iowa	Present					CABI and EPPO (1997)
- Maryland	Present					CABI and EPPO (1997)
- Massachusetts	Present					CABI and EPPO (1997)
- Michigan	Present					CABI and EPPO (1997)
- Mississippi	Present					EPPO (2023)
- Nebraska	Present					Bueno et al. (2007)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
- Nevada	Present					EPPO
- New Jersey	Present					CABI and EPPO (1997)
- New Mexico	Present					CABI and EPPO (1997)
- New York	Present					EPPO (2023)
- North Carolina	Present					EPPO (2023)
- Ohio	Present					CABI and EPPO (1997)
- Pennsylvania	Present					CABI and EPPO (1997)
- South Carolina	Present					CABI and EPPO (1997)
- Texas	Present					CABI and EPPO (1997)
- Virginia	Present					EPPO (2023)
- Washington	Present					CABI and EPPO (1997)
- Wisconsin	Present					CABI and EPPO (1997)
Oceania						
American Samoa	Present					CABI and EPPO (1997)
Australia	Present, Localized					EPPO (2023)
- New South Wales	Absent, Intercepted only					CABI and EPPO (1997)

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference	
- Queensland	Present					EPPO	
- Victoria	Absent, Intercepted only					CABI and EPPO (1997)	
- Western Australia	Present, Localized					EPPO (2023)	
Federated States of Micronesia	Present					CABI and EPPO (1997)	
Fiji	Present					EPPO (2023)	
Guam	Present					CABI and EPPO (1997)	
Northern Mariana Islands	Present					CABI and EPPO (1997)	
Samoa	Present					CABI and EPPO (1997)	
Tonga	Present					CABI and EPPO (1997)	
South America							
Argentina	Absent, Unconfirmed presence record(s)					CABI (Undated)	O ci S p c 2
Brazil	Present					CABI and EPPO (1997)	
- Bahia	Present					EPPO (2023)	
- Espirito Santo	Present					EPPO (2023)	
- Minas Gerais	Present					CABI and EPPO (1997)	

Continent/Country/Region	Distribution	Last Reported	Origin	First Reported	Invasive	Reference
- Para	Present					EPPO
- Pernambuco	Present					CABI and EPPO (1997)
- Rio Grande do Norte	Present					Araujo et al. (2007)
- Sao Paulo	Present					CABI and EPPO (1997)
Chile	Present, Localized					EPPO (2023)
Colombia	Present					CABI and EPPO (1997)
Ecuador	Present					EPPO (2023)
French Guiana	Present					CABI and EPPO (1997)
Guyana	Present					CABI and EPPO (1997)
Peru	Present					CABI and EPPO (1997)
Venezuela	Present					CABI and EPPO (1997)

Risk of Introduction

L. trifolii is listed as an A2 quarantine pest by EPPO (OEPP/EPPO, 1984). It is one of the most important recent introductions to the EPPO region.

It is a major pest of a wide variety of ornamental or vegetable crops grown under glass (Lactuca, Dendranthema, Gypsophila, Dahlia) or as protected crops in the EPPO region. It could also cause damage to these crops grown in the open in the warmer parts of the EPPO region. It is widely distributed in the region and the success of eradication programmes which have been

Pathway Vectors

Pathway vector	Notes	Long distance	Local	References
Clothing, footwear and possessions (pathway vector)	Land/sea/air.	Yes		
Land vehicles (pathway vector)	Road transport/air.	Yes		

Plant Trade

Plant parts liable to carry the pest in trade/transport	Pest stages	Borne internally	Borne externally	Visibility of pest or symptoms
Leaves	arthropods/eggs arthropods/larvae	Yes		Pest or symptoms usually visible to the naked eye
Seedlings/Micropropagated plants	arthropods/eggs arthropods/larvae	Yes		Pest or symptoms usually visible to the naked eye

Plant parts not known to carry the pest in trade/transport
Bark
Bulbs/Tubers/Corms/Rhizomes
Flowers/Inflorescences/Cones/Calyx
Growing medium accompanying plants
Roots
Stems (above ground)/Shoots/Trunks/Branches
True seeds (inc. grain)
Wood

Hosts/Species Affected

The host range of *L. trifolii* includes over 400 species of plants in 28 families including both

species include: Apiaceae (*A. graveolens*); Asteraceae (*Aster* spp., *Chrysanthemum* spp., *Gerbera* spp., *Dahlia* spp., *Ixeris stolonifera*, *Lactuca sativa*, *Lactuca* spp., *Zinnia* spp.); Brassicaceae (*Brassica* spp.); Caryophyllaceae (*Gypsophila* spp.); Chenopodiaceae (*Spinacia oleracea*, *Beta vulgaris*); Cucurbitaceae (*Cucumis* spp., *Cucurbita* spp.); Fabaceae (*Glycine max*, *Medicago sativa*, *Phaseolus vulgaris*, *Pisum sativum*, *Pisum* spp., *Trifolium* spp., *Vicia faba*); Liliaceae (*A. cepa*, *Allium sativum*) and Solanaceae (*Capsicum annuum, Capsicum frutescens, Petunia* spp., *Solanum lycopersicum*, *Solanum* spp.) (EFSA, 2012).

It is now considered to be the most important pest of cowpea (*Vigna uniguilata*), towel gourd (*Luffa cylindrica*), cucumber (*Cucumis sativus*) and many other vegetable crops in southern China (Gao, 2014). In Europe, *L. trifolii* is a major pest of lettuce, beans, cucumber and celery, *Capsicum* sp., carnations, clover, *Gerbera* sp., *Gypsophila* sp., lucerne, Senecio hybridus, potatoes and tomatoes (EFSA, 2012). It is now a major pest of the Compositae worldwide, particularly chrysanthemums (including *Dendranthenum*, the commercial 'Mum') in North America, Colombia, and elsewhere. It also causes severe damage to different open field crops, such as chili peppers in Mexico.

Host Plants and Other Plants Affected

Host	Family	Host status	References
Type to search	Type to search	Type to search	Type to search
Abelmoschus esculentus (okra)	Malvaceae	Main	
Ageratum	Asteraceae	Main	
Allium	Liliaceae	Main	
Allium cepa (onion)	Liliaceae	Other	
Allium sativum (garlic)	Liliaceae	Main	

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Host	Family	Host status	References
Alstroemeria (Inca lily)	Alstroemeriaceae	Wild host	
Ambrosia (Ragweed)	Asteraceae	Wild host	
Antirrhinum (snapdragon)	Scrophulariaceae	Wild host	
Apium graveolens var. dulce (celery)	Apiaceae	Other	
Arachis	Fabaceae	Wild host	
Arachis hypogaea (groundnut)	Fabaceae	Main	
Artemisia (wormwoods)	Asteraceae	Wild host	
Aster	Asteraceae	Main	
Avena sativa (oats)	Poaceae	Wild host	
Baccharis	Asteraceae	Wild host	
Basella	Basellaceae	Wild host	
Bellis	Asteraceae	Other	
Beta vulgaris var. saccharifera (sugarbeet)	Chenopodiaceae	Main	
Bidens (Burmarigold)	Asteraceae	Main	
Brassica rapa cultivar group Mizuna	Brassicaceae	Main	
Brassica rapa subsp. chinensis (Chinese cabbage)	Brassicaceae	Main	
Callistephus	Asteraceae	Main	
Capsicum annuum (bell pepper)	Solanaceae	Main	
Carthamus	Asteraceae	Wild host	
Cassia (sennas)	Fabaceae	Other	
Centaurea (Knapweed)	Asteraceae	Other	
Cestrum (jessamine)	Solanaceae	Wild host	
Chenopodium (Goosefoot)	Chenopodiaceae	Other	

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Host	Family	Host status	References
Chrysanthemum indicum (chrysanthemum)	Asteraceae	Other	
Chrysanthemum morifolium (chrysanthemum (florists'))	Asteraceae	Main	
Citrullus	Cucurbitaceae	Other	
Citrullus lanatus (watermelon)	Cucurbitaceae	Other	
Coffea arabica (arabica coffee)	Rubiaceae	Other	
Coffea canephora (robusta coffee)	Rubiaceae	Other	
Crataegus (hawthorns)	Rosaceae	Wild host	
Crotalaria (rattlepods)	Fabaceae	Wild host	
Cucumis melo (melon)	Cucurbitaceae	Main	
Cucumis sativus (cucumber)	Cucurbitaceae	Main	Sappanukhro et al
Cucurbita maxima (giant pumpkin)	Cucurbitaceae	Other	
Cucurbita moschata (pumpkin)	Cucurbitaceae	Other	
Cucurbita pepo (marrow)	Cucurbitaceae	Main	
Cucurbitaceae (cucurbits)	Cucurbitaceae	Main	
Dahlia	Asteraceae	Main	
Daucus carota (carrot)	Apiaceae	Other	
Dianthus (carnation)	Caryophyllaceae	Main	
Erigeron (Fleabane)	Asteraceae	Other	
Eupatorium	Asteraceae	Wild host	
Gaillardia	Asteraceae	Main	
Gazania (treasure-flower)	Asteraceae	Other	
Gerbera (Barbeton daisy)	Asteraceae	Main	

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Host	Family	Host status	References
Glycine	Fabaceae	Other	
Glycine max (soyabean)	Fabaceae	Main	
Gossypium (cotton)	Malvaceae	Main	
Gypsophila (baby's breath)	Caryophyllaceae	Main	
Helianthus (sunflower)	Asteraceae	Main	
Hordeum (barleys)	Poaceae	Other	
Ipomoea (morning glory)	Convolvulaceae	Wild host	
Lactuca sativa (lettuce)	Asteraceae	Main	
Lagenaria siceraria (bottle gourd)	Cucurbitaceae	Other	
Lathyrus (Vetchling)	Fabaceae	Main	
Linaria (Toadflax)	Scrophulariaceae	Other	
Luffa acutangula (angled luffa)	Cucurbitaceae	Other	
Luffa aegyptiaca (loofah)	Cucurbitaceae	Other	
Lycopersicon	Solanaceae	Main	
Macrotyloma	Fabaceae	Other	
Malva (mallow)	Malvaceae	Wild host	
Medicago (medic)	Fabaceae	Other	
Medicago sativa (lucerne)	Fabaceae	Main	
Melilotus (melilots)	Fabaceae	Wild host	
Mollucella		Wild host	
Ocimum	Lamiaceae	Wild host	
Phaseolus (beans)	Fabaceae	Main	
Phaseolus lunatus (lima bean)	Fabaceae	Main	
Phaseolus vulgaris (common bean)	Fabaceae	Main	

Feedback

Host	Family	Host status	References

Host	Family	Host status	References
Physalis (Groundcherry)	Solanaceae	Wild host	
Pisum sativum (pea)	Fabaceae	Main	
Polyphagous (polyphagous)		Main	
Primula (Primrose)	Primulaceae	Other	
Ricinus	Euphorbiaceae	Wild host	
Ricinus communis (castor bean)	Euphorbiaceae	Other	Suganthy (2007)
Salvia (sage)	Lamiaceae	Main	
Senecio (Groundsel)	Asteraceae	Main	
Solanum lycopersicum (tomato)	Solanaceae	Main	Shakti et al. (2013) Abe and Kawahara
Solanum melongena (aubergine)	Solanaceae	Main	
Solanum tuberosum (potato)	Solanaceae	Main	
Sonchus (Sowthistle)	Asteraceae	Wild host	
Spinacia oleracea (spinach)	Chenopodiaceae	Main	
Tagetes (marigold)	Asteraceae	Main	
Taraxacum (dandelion)	Asteraceae	Wild host	
Tithonia	Asteraceae	Wild host	
Tragopogon (goat's-beard)	Asteraceae	Wild host	
Tribulus (caltrop)	Zygophyllaceae	Wild host	
Trifolium (clovers)	Fabaceae	Main	
Trifolium repens (white clover)	Fabaceae	Main	
Trigonella	Fabaceae	Wild host	
Tropaeolum	Tropaeolaceae	Main	
Typha (reedmace)	Typhaceae	Wild host	

Host	Family	Host status	References
Vicia (vetch)	Fabaceae	Main	
Vicia faba (faba bean)	Fabaceae	Other	
Vigna unguiculata (cowpea)	Fabaceae	Main	Zhang et al. (2017)
Vigna unguiculata subsp. sesquipedalis (asparagus bean)	Fabaceae	Unknown	Sappanukhro et al
Xanthium (Cocklebur)	Asteraceae	Other	
Zinnia	Asteraceae	Main	

Feedback

Growth Stages

Flowering stage

Fruiting stage

Seedling stage

Vegetative growing stage

Symptoms

L. trifolii feeding punctures appear as white speckles between 0.13 and 0.15 mm in diameter. Oviposition punctures are usually smaller (0.05 mm) and are more uniformly round.

L. trifolii leaf mines can vary in form with the host plant, but when adequate leaf area is available they are usually long, linear, narrow and not greatly widening towards the end. They are usually greenish white.

In very small leaves the limited area for feeding results in the formation of a secondary blotch at the end of the mine, before pupariation. In Kenya, Spencer (1985) notes the growth of many *L. trifolii* from mines which began with a conspicuous spiral. This is not a characteristic

The frass is distinctive in being deposited in black strips alternately at either side of the mine (like *L. sativae*), but becomes more granular towards the end of the mine (unlike *L. sativae*) (Spencer, 1973).

Fungal destruction of the leaf may also occur as a result of infection introduced by *L. trifolii* from other sources during breeding activity. Wilt may occur, especially in seedlings.

List of Symptoms/Signs

Symptom or sign	Life stages	Sign or diagnosis
Plants/Leaves/abnormal colours		
Plants/Leaves/abnormal forms		
Plants/Leaves/abnormal leaf fall		
Plants/Leaves/external feeding		
Plants/Leaves/internal feeding		
Plants/Leaves/necrotic areas		
Plants/Leaves/wilting		

Similarities to Other Species/Conditions

Liriomyza species, in general, may be recognized by their black (sometimes brilliantly black) and yellow colouring. Particularly, the scutellum is usually yellow and distinctive.

Several pests in this genus are similar and may be mistaken for each other on quick examination. These are *L. sativae* (shining black mesonotum without yellow at the hindquarters, vte always and vti usually on black ground, origins probably in South America); *L.*

huidobrensis (which has a larger discal cell, origins in South America); *L. trifolii* (origins probably Caribbean/Florida); *L. brassicae* (origins probably South America/Caribbean); *L. bryoniae* (origins

The spread of *Liriomyza* species through international commerce and the similarities between the seven species means that identification of individual infestations must be confirmed by specialists (Spencer, 1973).

Habitat

L. trifolii'sdevelopment is strictly connected with temperature. Consequently, at a uniform temperature of 28°C one generation cycle can be accomplished in 14-15 days, but at lower temperatures the time taken is progressively longer. At 16°C puparial diapause begins and winter generations of puparia will remain in the soil until warmer conditions occur again. The adult can survive temperatures down to about 12°C but does not appear to feed or lay eggs.

In heated glasshouses where suitable hosts may be grown throughout the year, the breeding and development of *L. trifolii* will be virtually continuous. In cool glasshouses generation rates will be different throughout the seasons, with fairly rapid development during the summer and puparia remaining undeveloped in the soil during the coldest periods.

In the moderate and variable temperatures of open-field cultivation there will be only a few (perhaps three) generations produced throughout the growing season because of the longer time required to complete each cycle (Süss et al., 1984).

Environments

Habitat	Presence	Status
Terrestrial		

Biology and Ecology

Egg

temperature. Harris and Tate (1933) give 4-7 days at 24°C. Many eggs may be laid on a single leaf.

Larva

The duration of larval development also depends on temperature and probably host plant. Several generations can occur during the year, breeding only being restricted by the temperature and the availability of fresh plant growth in suitable hosts (Spencer, 1973).

Puparium

L. trifolii pupariation occurs outside the leaf, in the soil beneath the plant. Puparial development will vary according to season and temperature. Adult emergence occurs 7-14 days after pupariation at temperatures between 20 and 30°C (Leibee, 1982). Wolfenbarger (1947) gives 24-28 days for the complete cycle, in Florida during December-January (winter period).

Adult

Peak emergence of adult *L. trifolii* occurs before midday (McGregor, 1914). Males usually emerge before females. Mating takes place from 24 hours after emergence and a single mating is sufficient to fertilize all a female's eggs.

Female *L. trifolii* flies puncture the leaves of the host plants causing wounds which serve as sites for feeding or oviposition. Feeding punctures cause the destruction of a large number of cells and are clearly visible to the naked eye. About 15% of oviposition punctures made by *L. trifolii* contain viable eggs (Parrella et al., 1981). Male *L. trifolii* are unable to puncture the leaves but have been observed feeding at punctures made by females. Both male and female *L. trifolii* feed on dilute honey (in the laboratory) and take nectar from flowers (OEPP/EPPO, 1990).

In the southern USA, the *L. trifolii* life cycle is probably continuous throughout the year. There is a noticeable first generation which reaches a peak in April (Spencer, 1973). In southern Florida, *L. trifolii* has two or three generations followed by a number of incomplete, overlapping generations (Spencer, 1973).

On celery *L. trifolii* completes its life cycle (oviposition to adult emergence) in 12 days at 35°C, 26 days at 20°C, and 54 days at 15°C (Leibee, 1982). On chrysanthemums the life-cycle is completed in 24 days at 20°C but on Vigna sinensis and Phaseolus lunatus it takes only 20 days at this temperature (Poe, 1981).

Adults of *L. trifolii* live between 15 and 30 days. On average, females live longer than males.

Both male and female *L. trifolii* may act as vectors for disease by transference during feeding or egg laying, but are not inherent carriers of disease.

Natural enemy of

Species	Stages attacked	Countries where known to occur	References
Ambrosia artemisiifolia	Stems Leaves		
Erechtites hieraciifolius			Darbyshire et al. (2012)
Luffa aegyptiaca			
Tridax procumbens	Plants|Leaves		Stegmaier (1966)
Tropaeolum majus	Plants|Leaves		

Notes on Natural Enemies

Numerous parasitic wasps (Hymenoptera) occurring naturally, may be used for control of *L. trifolii*. These wasps are difficult to isolate or identify and local agricultural advisory services

artificial introduction.

There has been considerable work on natural enemies in relation to biological control introduction programmes. Waterhouse and Norris (1987) give a detailed list of the natural enemies of *Liriomyza* spp. and a summary of the results of the biological control introductions against *L. trifolii*.

Foliar applications of the entomophagous nematode, *Steinernema carpocapsae*, significantly reduced adult development of *L. trifolii* (Harris et al., 1990).

Natural enemies

Natural enemy	Type	Life stages	Specificity
Type to search	Type to search	Type to search	Type to search
Bacillus thuringiensis kurstaki	Pathogen		
Beauveria bassiana (white muscardine fungus)	Pathogen		
Chrysocharis ainsliei	Parasite		
Chrysocharis caribea	Parasite	Larvae	
Chrysocharis clarkae	Parasite		
Chrysocharis giraulti	Parasite		
Chrysocharis melaensis	Parasite		
Chrysocharis oscinidis	Parasite	Larvae	
Chrysocharis pentheus	Parasite		
Chrysocharis punctiventris	Parasite		

Natural enemy	Type	Life stages	Specificity

Natural enemy	Type	Life stages	Specificity
Chrysonotomyia punctiventris	Parasite	Larvae	
Cirrospilus vittatus	Parasite		
Cirrospilus vittatus	Parasite		
Closterocerus purpureus	Parasite	Larvae	
Closterocerus trifasciatus	Parasite	Larvae	
Closterocerus utahensis	Parasite		
Cothonaspis pacifica	Parasite		
Dacnusa sibirica	Parasite		
Diaulinopsis callichroma	Parasite		
Dicyphus tamaninii	Predator		
Diglyphus begini	Parasite	Larvae	
Diglyphus chabrias	Parasite		
Diglyphus intermedius	Parasite	Larvae	
Diglyphus isaea	Parasite	Larvae	
Diglyphus minoeus	Parasite		
Diglyphus pulchripes	Parasite		
Epiclerus nomocerus	Parasite		
Eucoilidea fetura	Parasite		
Eucoilidea guamensis	Parasite		
Eucoilidea micromorpha	Parasite		

Feedback

Natural enemy	Type	Life stages	Specificity
Ganaspidium utilis	Parasite	Larvae	
Gnaptodon pumilio	Parasite		
Halticoptera	Parasite		
Halticoptera circulus	Parasite	Larvae	
Hemiptarsenus semialbiclavus	Parasite		
Hemiptarsenus varicornis	Parasite	Larvae	
Hemiptarsenus zilahisebessi	Parasite		
Metarhizium anisopliae (green muscardine fungus)	Pathogen		
Neochrysocharis formosa	Parasite	Larvae	
Neochrysocharis okazakii	Parasite		
Neochrysocharis punctiventris	Parasite		
Nordlanderia plowa			
Oenonogastra microrhopalae	Parasite		
Opius bruneipes	Parasite		
Opius dimidiatus	Parasite	Larvae	
Opius dissitus	Parasite	Larvae	
Opius montanus	Parasite		
Opius pallipes	Parasite		
Orius dissitus	Predator		

Natural enemy	Type	Life stages	Specificity

Natural enemy	Type	Life stages	Specificity
Paecilomyces fumosoroseus	Pathogen		
Pediobius acantha	Parasite		
Pseudopezomachus masii	Parasite		
Rhizarcha lestes	Parasite		
Steinernema carpocapsae	Parasite	Eggs	
Steinernema feltiae	Parasite		
Zagrammosoma	Parasite		

Impact

L. trifolii is an economically important key pest of both ornamental crops (Bogran, 2006) and vegetables (Cheri, 2012).

In Kenya, chrysanthemums were grown commercially before 1976, but *L. trifolii* was thought to have been introduced in contaminated cuttings from Florida (USA) in 1976, at a large propagating nursery at Masongaleni. By 1979 the nursery was closed, but the establishment of the pest in local wild hosts, and the dissemination of cuttings from the nursery to other parts of the country as well as abroad, has added *L. trifolii* to the other pests of East Africa. It has caused considerable crop losses and loss of overseas markets due to quarantine requirements (IPPC Secretariat, 2005).

Vegetable losses in the USA are also considerable. For example, losses for celery were estimated at US$ 9 million in 1980 (Spencer, 1982). It was noted, however, that damage to celery during the first 2 months of the 3-month growing season was insignificant and largely cosmetic, whereas considerable yield loss resulted from pest presence during the final month (Foster et al., 1988). 1.5 million larval mines per hectare were recorded from onions in Iowa

(Harris et al., 1933).

of the plants is often greatly reduced as the chlorophyll-containing cells are destroyed. Severely infested leaves may fall, exposing plant stems to wind action, and flower buds and developing fruit to scald (Musgrave et al., 1975). The presence of unsightly larval mines and adult punctures caused by L. trifolii in the leaf palisade of ornamental plants, such as chrysanthemums, can further reduce plant value (Smith et al., 1962; Musgrave et al., 1975). In young plants and seedlings, *L. trifolii* mining may cause considerable delay in plant development, even leading to plant loss. The level of damage depends on many factors, including climate suitability, host resistance, crop distribution, growing conditions, control methods in place and the degree of infestation (EFSA, 2012).

L. trifolii is also known to be a vector of plant viruses (Zitter et al., 1980).

Detection and Inspection

L. trifolii are small black and yellow flies which may be detected flying closely around host plants or moving erratically and rapidly upon the leaf surfaces. Inspection of the leaf surface will reveal punctures of the epidermis and the obvious greenish-white mines with linear grains of frass along their length. For accurate identification, examination of the leaf mine and all stages of development are crucial.

L. trifolii larvae will be found feeding at the end of the mine, or the mine will end with a small convex slit in the epidermis where the larva has left the mine to pupariate on the ground. Sometimes the puparium may be found adhering to the leaf surface, although in most cases the fully-fed larva will have found its way to the ground beneath the plant to pupariate. This is especially true in hot, dry conditions where the larva/puparia would quickly desiccate if exposed on the leaf surface. Empty puparial cases are split at the anterior end, but the head capsule is not usually separated from the rest of the case.

Mined leaves should be collected into polythene bags and transferred to a press as soon as possible. Leaves containing larvae intended for breeding should be collected into individual

blowing into them before sealing the end. Blowing up the bag by mouth and sealing it adds valuable carbon dioxide to the moist air mix. Constant attention is required to ensure that puparia are transferred to individual tubes until the fly emerges. If the plant material begins rotting, good material with feeding larvae must be removed to more sanitary conditions.

When puparia are observed they can be very carefully removed to tubes containing a layer of fine sand, or a small strip of blotting paper or filter paper. This should be kept damp (never wet) until the adult emerges.

On emergence, the fly should be kept for at least 24 hours to harden up. Do not allow condensation to come into contact with the fly, or it will stick to the water film and be damaged.

Field collection of the adult *L. trifolii* is done by netting. The use of sticky traps, especially yellow ones, placed near host plants is a very effective method of collection and estimation of infestation.

If the puparial stage is collected from the soil, care must be taken not to damage the puparial skin or death will almost certainly follow. The pupae should be stored in glass tubes on a layer of clean sand or, better still, thick filter paper. The tube must have high humidity, but be free of condensation.

When the fly emerges, it must be allowed to harden for 24 hours before killing for identification purposes. Ensure that the tube has no condensation present.

Newly emerged adult *L. trifolii* are generally softer than specimens aged for several days and may crinkle as drying proceeds, especially the head. The ptilinal sac may still protrude from the suture between the frons and face obliterating some important characteristics. Adults should be dried slowly in the dark in a sealed receptacle over blotting paper. If preserving wet is

90% alcohol after 2 days.

Prevention and Control

Due to the variable regulations around (de)registration of pesticides, your national list of registered pesticides or relevant authority should be consulted to determine which products are legally allowed for use in your country when considering chemical control. Pesticides should always be used in a lawful manner, consistent with the product's label.

Feedback

Physical Control

The use of glue traps can be effective for assessing the presence of adult *L. trifolii*, gauging the best time to apply control measures on a population, and as a direct method of pest suppression (Valenzuela, 2010). Yellow sticky traps (YSTs) attracted significantly more adult *L. trifolii* than blue, purple or white traps; the average percentage of damaged leaves and damage severity (number of mines per leaf) were significantly lower in fields with YSTs after 50 days (Arida et al., 2013).

Chemical Control

L. trifolii has developed resistance to most commonly used insecticides that were recommended for its control before 1990 (Parella et al., 1984; Nuessly and Webb, 2013), including carbamates, organophosphates, pyrethroids, avermectins, spinosyns and moulting disruptors, such as cyromazina (Hernandez, 2009). However, its susceptibility to insecticides varies widely between agricultural regions and populations. In Florida, USA, the lifetime of an insecticide’s effectiveness is often only two to four years, and is then usually followed by a strong resistance in treated populations (Reitz et al., 2013; Capinera, 2014).

The insecticides (active ingredients) abamectin, acephate, acephate + fenpropathrin, acetamiprid, bifenazate + abamectin, bifenthrin, carbaryl, chlorpyrifos, clothianidin, cyantraniliprole, cyromazine, deltamethrin, diazinon, diflubenzuron, dimethoate, dinotefuran, emamectin benzoate, fenpropathrin, fenoxycarb, gamma-cyhalothrin, imidacloprid,

novaluron, naled, permethrin, phosmet, rynaxypyr (chlorantraniliprole), spinetoram, spinosad, thiamethoxam, thiamethoxam + chlorantraniliprole, and the natural insecticides azadirachtin, extract of *Chenopodium ambrosioides*, *Isaria fumosorosea* Apopka strain 97, mineral oils, potassium salts of fatty acids and pyrethrins have been cited for the control or suppression of immature or adult *L. trifolii* in agricultural and ornamental crops (Price and Nagle, 2012; Webb et al., 2012; Webb and Stansly, 2012; Misra, 2013; Nuessly and Webb, 2013; Webb, 2013).

For the control of *L. trifolii,* effective insecticides with different modes of action (and with different site of action) should be rotated during the growing season (IRAC, 2014).

Biological Control

Natural enemies periodically suppress leaf-miner populations (Spencer, 1972). Parasitoids, and to a lesser extent to nematodes, bacteria and fungi, are used for biological control of leafminers (Cikman y Comelkcloglu, 2006; Sher et al. 2000; Abd El-Salam et al., 2012; Capinera, 2014). Although several predatory species have been found feeding on *Liriomyza*, predators are not considered to be important as biological control agents (Liu et al., 2009; Capinera 2011, 2014). There are several successful cases of classical biological control with parasitoids to different species of leaf miners, both in open fields and greenhouses (Abd-Rabou, 2006; Salvo y Valladares, 2007; Liu et al., 2011;).

There has been considerable work on natural enemies in relation to biological control introduction programmes. Waterhouse and Norris (1987) gave a detailed list of the natural enemies of *Liriomyza* spp. and a summary of the results of the biological control introductions against *L. trifolii*. In Hawaii, several parasitoids were already present as immigrant species, presumably accidentally introduced with their hosts. More of these parasitoids were introduced from the USA, to broaden the genetic base, as well as *Chrysonotomyia punctiventris* and *Ganaspidium hunteri*, and have proved a substantial control, at least on water melons when natural enemies are not eliminated by pesticide sprays (Johnson, 1987). Subsequently, introductions of species established in Hawaii were made in Pohnpei (Mariana Islands) and *G. utilis* and *C. oscinidis* became established and are credited with achieving substantial control

Tonga where control is reported as complete (Johnson, 1993). Earlier unsuccessful introductions were made in the Caribbean islands (Cock, 1985) and a biological control programme has been carried out in Senegal: the results of this require re-assessment but it is unlikely that any beneficial results were obtained (Neuenschwander et al., 1987).

Foliar applications of the entomophagous nematode *Steinernema carpocapsae* significantly reduced adult development of *L. trifolii* (Harris et al., 1990).

Extensive global research has reported more than 150 species of parasitoids associated with *Liriomyza* sp. (Liu et al. 2011). For *L. trifolii,*Hernandez et al. (2010) listed 20 genera of parasitoids in various chili crops during autumn 2007 and spring 2008 in Weslaco, Texas, USA: *Neochrysocharis formosa*, *Closterocerus cinctippenis* Ashmead, *Diglyphus isaea*, *Cirrospilus variegatus* Masi, *Asecodes* spp., *Pnigalio* spp., *Zogrammosoma* spp., *Chrysocharis* spp. (Eulophidae); *Opius dissitus* Muesebeck, *O. dimidiatus* (Ashmead), *O.* nr. *brownsvillensis* Fischer, *O. thoracosema* Fischer, *O. bruneipes* Gahan, *O.* spp. (Braconidae); *Ganaspidium pusillae* Weld, *G. nigrimanus* (=*utilis*) (Kieffer), *Disorygma pacifica* (Yoshimoto), *Agrostocynips robusta* (Ashmead) (Figitidae) and *Halticoptera* nr. *circulus* Walker (Pteromalidae). *N. formosa* was the most common, comprising 60% of the natural enemies.

In Tamaulipas, Mexico, Arcos-Cavazos et al. (2011) found six larval parasitoid hymenopterid natural enemies: *Opius* sp., *Chysocharis* sp., *Diglyphus* sp. (Eulophidae), *Gronotoma* sp. (Hymenoptera: Figitidae), and two unidentified species. Of these, *Chrysocharis* was the primary regulator of *L. trifolii* populations, with an average of 79.5% larval parasitism of *L. trifolii* and in some samples of 100%. Fadl and El-Khawas (2009) found five species of hymenopterid parasitoids of *L. trifolii* on tomato in Qalyubia, Egypt, during two growing crop seasons: *Cirrospilus* sp., *Diglyphus crassinervis*, *D. isaea*, *Chrysocharis* sp. and *Neochrysocharis.Neochrysocharis* had the highest recorded total numbers.

Currently, mass rearing of leaf miner parasitoids for augmentative biological control includes the simultaneous use of three trophic levels: host plant, phytophagous insects and parasitoids,

Mondaca and Valenzuela-Escoboza, 2013).

The impact of insecticides on parasitoids of leaf miners is complex and further studies are needed to determine which insecticides are least damaging to natural enemies of *L. trifolii* (Hernandez 2009). Field studies suggested that cyromazine has the least impact on parasitoid populations, followed by abamectin and spinosyns, which in turn were not as detrimental as carbamates, organophosphate or pyrethroids (Reitz et al., 2013). Nuessly and Webb (2013) reported that the use of selective insecticides, such as spinosad and emamectin benzoate, for armyworm and cabbage looper control also provided some control of *L. trifolii* populations, as well as being gentle to most beneficial insects. Novaluron had the least impact on adult parasitoids in laboratory bioassays compared to other treatments (abamectin, spinetoram, lambda-cyhalothrin) (Hernandez, 2009). The insecticide lambda-cyhalothrin showed negative effects only for the parasitoid *Ganaspidium nigrimanus* (in topical application assays), but residual tests had negative effects on *G. nigrimanus* and on *Neochrysocharis formosa*. Abamectin showed no ill effects on *N. formosa* or *G. nigrimanus* in topical bioassays. In contrast, spinetoram showed negative effects on *N. formosa* and *G. nigrimanus* in all bioassays in the laboratory.

It is possible to increase the action of leafminer natural enemies through habitat management (Musundire et al., 2012). Weed patches near crops may be important as possible reservoirs of parasitoids (Altieri and Nichols, 2009). For this reason, there have been suggestions of increasing weed diversity or improving the availability of pollen and nectar for natural enemies in agroecosystems affected by *L. trifolii* (Altieri et al., 2005; Altieri and Nichols, 2009). The combined use of cultural practices and low- or reduced-impact insecticides on non-target species might favour populations of parasites (Cortez-Mondaca and Valenzuela-Escoboza, 2013; Reitz et al., 2013).

Cultural Control

In chrysanthemum cuttings, *L. trifolii* survived cold storage at 1.7°C for at least 10 days. Newly laid eggs of *L. trifolii* in chrysanthemums survived for up to 3 weeks in cold storage at 0°C

should be maintained under normal glasshouse conditions for 3-4 days after lifting to allow eggs to hatch. Subsequent storage of plants at 0°C for 1-2 weeks should then kill the larvae.

Gamma irradiation of eggs and first larval stages at doses of 40-50 Gy provided effective control (Süss et al., 1986; Yathom et al., 1991). The release of sterile *L. trifolii* males significantly reduced the number of offspring (Kaspy and Parrella, 2006). When the release of sterile males was combined with a release of the parasitoid *Diglyphus isaia,* the damage caused by *L. trifolii* and the size of the adult population were significantly reduced.

It is important to destroy and bury the remains of broadleaf weeds and senescent cultures as they can harbor reproductive leaf miners (Capinera, 2011; University of California, 2012).

Yildrim and Unay (2011) noted that foliar fertilizers of fulvic acid and calcium nitrate combinations in tomato had a negative effect on *L. trifolii* population. Mortezaiefard et al. (2012) found that foliar applications of potassium silicate reduced *L. trifolii* populations on *Gerbera jamesonii*.

Host Plants

Lei et al. (2008) found that *L. trifolii* were found more often and made more feeding punctures on non-Bt transgenic cotton plants than on Bt cotton plants. Females oviposited more eggs on non-Bt cotton plants, but larval and puparial survival did not differ between Bt and non-Bt plants.

Sahu et al. (2006) reported that the leaf area of the lower leaves of the tomato plants was positively correlated with the percentage of leaves affected by *L. trifolii*, indicating that *L. trifolii* infestation increases with increasing leaf surface area. Thus, genotypes with narrow leaves would be less preferred by the species. Studies with similar purposes have been made ??in the castor oil plant *Ricinus communis* and cowpea *Vigna unguiculata*, among others (Eid, 2008; Hedge et al., 2009).

The nitrogen content in the leaves of a host plant of *L. trifolii* is an important component that influences in the susceptibility to attack (Altieri et al., 2005). Potassium and phosphorus reduce

Lenteren, 1986; Facknath & Lalljee, 2005).

Integrated Pest Management

The selection, integration and implementation of different control tactics of the leafminer, based on the conservation of biological control, is sufficient for adequate management of *L. trifolii* (Liu et al., 2009, 2011; Cortez-Mondaca and Valenzuela-Escoboza, 2013). One of the most important steps is the use of selective or specific biorational insecticides, such as botanical extracts, soaps, minerals, entomopathogenic insecticides and growth regulators (Hernandez, 2009; Hernández 2011; Liu et al., 2009, 2011; Yildirim and Baspinar 2012). It is also important to apply insecticides so that they cause the least impact to natural enemies; for instance, some systemic insecticides can be applied in the seed or irrigation system (Cikman and Comelkcloglu, 2006; Nath and Singh, 2006; Kumar, 2010; El-Wakeil et al., 2013).

Regulatory Control

To avoid the introduction of *L. trifolii* (and other leaf miner species *L. huidobrensis*, *L. sativae* and *Amauromyza maculosa* [*Nemorimyza maculosa*]), EPPO recommends that propagating material (except seeds) of *Capsicum*, carnations, celery, chrysanthemums, *Cucumis*, *Gerbera*, *Gypsophila*, lettuces, *Senecio hybridus* and tomatoes from countries where *L. trifolii* occurs must have been inspected at least every month during the previous 3 months and found free from the pests (EOPP/EPPO, 1990).

Regulations could be tightened in the EU by including additional commodities under regulatory control, clearly prescribing the inspection procedures and the appropriate treatments to be used, and combining these with other measures, such as screening (EFSA, 2012). The application of protected zones to areas where *L. trifolii* is not yet present could help prevent further spread of the pest.

A phytosanitary certificate should be required for cut flowers and for vegetables with leaves.

Links to Websites

GISD/IASPMR: Invasive Alien Species Pathway Management Resource and DAISIE European Invasive Alien Species Gateway	https://doi.org/10.5061/dryad.m93f6	Data source for updated system data added to species habitat list.
Global register of Introduced and Invasive species (GRIIS)	http://griis.org/	Data source for updated system data added to species habitat list.

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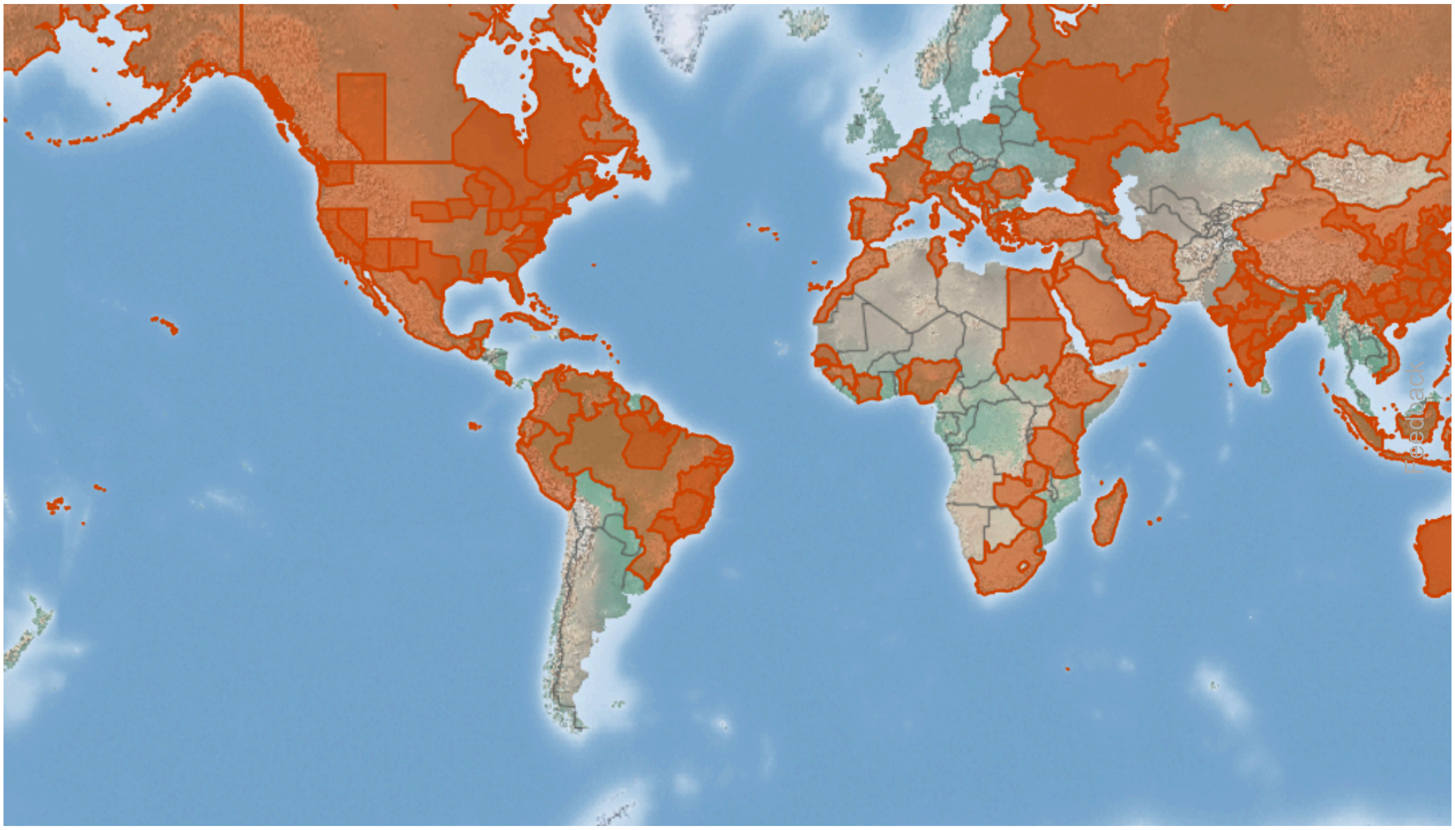

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Abd-Rabou S, 2006. Biological control of the leafminer, Liriomyza trifolii by introduction, releasing, evaluation of the parasitoids Diglyphus isaea and Dacnusa sibirica on vegetables crops in greenhouses in Egypt. Archives of Phytopathology and Plant Protection, 39(6):439-443.

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