Image 1. Serpentine leafminer (*Liriomyza huidobrensis*) fly. Image courtesy of Ausveg.

Greenlife Industry Australia

Serpentine Leafminer

(*Liriomyza huidobrensis*)

Management Plan 2021

Developed for the Australian Nursery Industry

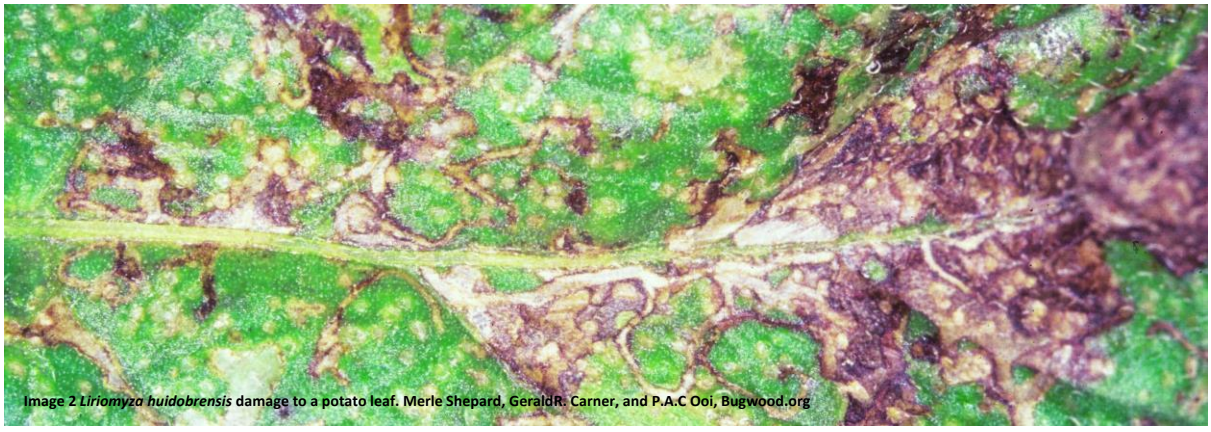

Image 2 *Liriomyza huidobrensis* damage to a potato leaf. Merle Shepard, GeraldR. Carner, and P.A.C Ooi, Bugwood.org

Acknowledgements:

This Serpentine Leafminer (*Liriomyza huidobrensis*) Management Plan has been developed by Greenlife Industry Australia (Emma De Landre – Plant Protection Officer) for the Australian Nursery Industry.

Version 1 July 2021.

Photographs have been sourced from Ausveg, Bugwood, New South Wales Department of Primary Industries (NSW DPI), Biosecurity QLD, Joe Wessels and Dept. of Agriculture and Fisheries QLD.

Various sources have contributed to the contents of this plan including:

- Threat Specific Contingency Plan – Serpentine leafminer *(Liriomyza huidobrensis)* Plant Health Australia and Nursery Garden Industry Australia, 2009.
- Final Report MT16004; RD&E Program for Control, Eradication and Preparedness for Vegetable Leafminer by Cesar Australia, the University of Melbourne, Northern Australia Quarantine Strategy, Plant Health Australia and AUSVEG - Horticulture Innovation Australia.
- Management of leafmining flies in vegetable and nursery crops in Australia – Ausveg
- Information provided by Dr Elia Pirtle (Cesar), Zarmeen Hassan (Ausveg), Madeline Quirk (Ausveg) and Shannon Mulholland (NSW DPI).
- Primefact PUB20/934 Plant Biosecurity and Product Integrity – NSW DPI.
- Primefact – Reporting and Testing for Serpentine Leafminer.
- The Australian Plant Production Standard, Greenlife Industry Australia.
- Greenlife Industry Australia (GIA) Biosecurity Advice; 5/11/2020 and 19/11/2020, GIA National Biosecurity Manager John McDonald.

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Hort Innovation Strategic levy investment | NURSERY FUND

This project has been funded by Hort Innovation using the nursery research and development levy and funds from the Australian Government. For more information on the fund and strategic levy investment visit horticulture.com.au

Table of Contents

1. Introduction

Serpentine leafminer (*Liriomyza huidobrensis*), also called Pea leafminer, can cause damage to a wide range of edible and ornamental crops impacting production nurseries growing seedlings and potted colour for supply into food production and amenity horticulture markets. Serpentine leafminer looks very similar to other species of leafminer and requires a laboratory analysis for accurate diagnosis. An integrated pest management (IPM) approach is recommended as leafminers can carry and develop insecticide resistance; IPM should include crop monitoring, testing, pesticide rotation and beneficial insect friendly treatment options. Fortunately, contingency plans that were developed anticipating the arrival of exotic leafminers into Australia have provided valuable information that is being used to assist with the management of this pest. This includes a list of host species affected by Serpentine leafminer in other countries before its arrival into Australia.

In October 2020 Serpentine leafminer was detected in Australia at a vegetable farm in Western Sydney, New South Wales (NSW). The detection was managed under the Emergency Plant Pest Response Deed (EPPRD) with a comprehensive surveillance program carried out by the New South Wales Department of Primary Industries (NSW DPI) and Local Land Services (LLS) to determine the technical feasibility of eradication. By December 2020, a total of 37 properties in NSW and farms in South East Queensland (QLD) were confirmed to be infested. Detections in rural NSW were linked to the main outbreak in the Sydney basin. Affected businesses included vegetable farms, production nurseries and flower importers. Host crops most affected were beans, lettuce, spinach, chillies, and cucurbits however it is important to note that a at least thirty-eight host plant species in Australia have returned positive results including Petunias and Snapdragons which are common ornamentals in production horticulture.

In December 2020 it was deemed not technically feasible to eradicate Serpentine leafminer in Australia by the Consultative Committee on Emergency Plant Pests (CCEPP) and a transition to management was implemented. Western Australia (WA) is the only jurisdiction to impose restrictions on the movement of host plants into that state. Growers in all states and territories are required to observe their General Biosecurity Duty and ensure crops are free of Serpentine leafminer. Serpentine leafminer remains a notifiable pest and suspected infestations should be reported within 24-48hrs via the **Exotic Plant Pest Hotline: 1800 084 881.**

The development of this industry specific **Serpentine Leafminer Management Plan**, by Greenlife Industry Australia, is intended as a guide for nursery growers in production and retail environments. As a professional and responsible industry, it is appropriate that all growers, greenlife markets and retailers apply the relevant strategies to manage Serpentine leafminer as described in this plan.

GIA have provided a range of resources for businesses affected by Serpentine leafminer. Further research is underway courtesy of Hort Innovation and delivery partners including Cesar and Ausveg. NSW DPI will also be undertaking further surveillance to assist with management of this pest.

Note: State/territory laws and requirements including interstate movement protocols over-ride this Industry Serpentine Leafminer Management Plan.

Greenlife Industry Australia, Serpentine Leafminer National Management Plan – 2021

2. Seperpentine Leafminer (*Liriomyza huidobrensis*)

Image 3. Central Science Laboratory, Harpenden, British Crown, Bugwood.org

Image 4 Larvae/pupae. Merle Shepard and Gerald R. Carner, Bugwood.org

(a) Description

Serpentine leafminers are flies in the genus Liriomyza and can be confused with other species within the genera. Fly larvae feed internally on plant tissue, particularly the leaf, creating the classic mining trails that are associated with infestation. Larvae then pupate in the substrate beneath the plants and hatch out as flies which then lay eggs on surrounding host plants perpetuating the reproductive cycle and increasing damage. Damaged plants commonly have reduced yield and in some cases are destroyed completely. The pest is known to carry and develop insecticide resistance making it difficult to control. It has a wide host range which includes common vegetable and ornamental nursery crops. Please refer to *Appendix 1* for a detailed host list. **Image 4 Larvae/pupae Merle Shepard and Gerald R. Carner Bugwood.org Image**

(b) Distribution

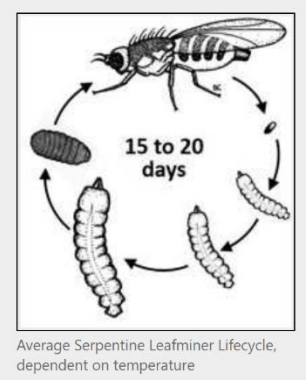
Liriomyza huidobrensis - Serpentine leafminer is widely distributed across the America's, Asia, Africa, Middle East and Europe and was first identified in Australia within New South Wales in October 2020, then Queensland in November 2020. Serpentine leafminer can fly short distances and be dispersed by the wind. Other ways in which it can spread that pose a greater risk are by movement of eggs, larvae or pupa in nursery stock, cut flowers, herbs or vegetables transported by people.

Table 1. Confirmed Host Families and Host Plants of Serpentine Leafminer in NSW from testing between Oct -Dec 2020.
Note: Snapdragon (Family Plantaginaceae) is not listed in Appendix 1 – Table 2

Host Family	Host Plant	Host Family	Host Plant	Host Family	Host Plant
Amaranthaceae	Silverbeet	Brassicaceae	Bok Choy	Fabaceae	Snow Pea
Amaranthaceae	Spinach	Brassicaceae	Broccoli	Fabaceae	Bean
Allium	Shallots	Brassicaceae	Choi sum	Fabaceae	Flat Bean
Apiaceae	Celery	Brassicaceae	Cabbage	Fabaceae	Runner Bean
Apiaceae	Celeriac	Brassicaceae	Chinese Lettuce	Fabaceae	Clover
Apiaceae	Parsley	Brassicaceae	Pak Choy	Lamiaceae	Basil
Asteraceae	Lettuce	Brassicaceae	Pak sum	Lamiaceae	Thai Basil
Asteraceae	Fleabane	Brassicaceae	Kohlrabi	Plantaginaceae	Snapdragon
Asteraceae	Sowthistle	Brassicaceae	Beetroot	Solanaceae	Eggplant
Asteraceae	Chicory	Cucurbitaceae	Zucchini	Solanaceae	Chilli
Asteraceae	Thistle	Cucurbitaceae	Cucumber	Solanaceae	Petunia
Brassicaceae	Broccoli	Cucurbitaceae	Pumpkin	Solanaceae	Tomato

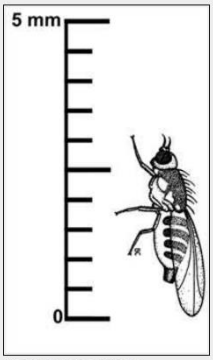
(c) Life Cycle

Serpentine leafminer (*Liriomyza huidobrensis)* completes its lifecycle in several stages from egg to larvae, to pupae, to its adult fly form. A female inserts an egg just under the surface of the leaf of a host plant. The egg hatches in 2-5 days. The larvae then begin to feed within the leaf creating tunnels or mines that get larger as the larvae mature. After passing through three larval stages in 4-7 days the larva leaves the plant to form a puparium in the soil underneath the host plant. Pupariation is adversely affected by high humidity or drought. After 7-14 days an adult emerges and begins to reproduce. Temperature affects the timing of lifecycle completion which varies between 13-26 days.



Average Serpentine Leafminer Lifecycle, dependent on temperature


Serpentine leafminer *(L. huidobrensis)* larva and pupa. Photo courtesy of Biosecurity Queensland



Size of Serpentine leafminer

Signs and symptoms

Adult flies are small (1.3-2.3 mm long with a wing length of 1.5-2.2 mm wide, a shiny black mesonotum and yellow markings on the head (Images 1, 3&7). Female flies use their ovipositor to puncture the leaves of the host plants causing wounds which serve as sites for feeding (by both male and female flies) or oviposition. Feeding punctures of Serpentine leafminer are rounded, usually about 0.2 mm in diameter, and appear as white speckles on the upper leaf surface.

Several generations may be produced during the year, with eggs being laid just beneath the surface of the leaf. On hatching, the larvae "mine" the leaf, hence the name leafminer. Leaf mines are the most obvious symptom and are pale coloured with black and brown areas. Mines can be linear or serpentine and increase in width along their length as the larvae matures. The mines are easily visible and when the larvae are in large numbers this feeding damage can cause substantial economic losses in food production. Ornamental crops can become unsaleable due to their appearance.


Image 8. Leaf mines on Tomato
Images: Shannon Mulholland, NSW DPI


9. Leaf mines on Cucumber


10. Leaf mines and feeding damage on squash

In summary, damage to the plant is caused in several ways: (i) by the stippling that results from punctures made by females from feeding on sap and laying eggs; (ii) by the internal mining by the larvae; (iii) by allowing pathogenic fungi to enter the leaf through the feeding punctures; and (iv) mechanical transmission of plant viruses. This damage results in a reduction of photosynthesis in the plant. Extensive mining also causes premature leaf drop, which can result in sun scalding of fruit or reduced tuber filling of potatoes which again may result in economic loss.

3. Monitoring, Inspection and Sampling Process.

Production nurseries should establish crop monitoring, inspection and sampling processes to reduce the risk of crop damage from Serpentine leafminer and reduce the spread of this pest. For example

* Identify across your cropping system susceptible host species and aggregate as much as possible within common growing areas allowing efficient resource allocation when managing Serpentine leafminer. Refer to Appendix 1 for a full host list of vegetable, herb and ornamental host plants.

* Crop monitoring – regular structured process to determine pest presence/absence and/or location and density of Serpentine leafminer, see BioSecure HACCP manual for crop monitoring procedure and recording templates here: https://nurseryproductionfms.com.au/)

* Put in place a yellow sticky trap program across the susceptible host range(s) and regularly inspect traps for presence/absence of Serpentine leafminer, see BioSecure HACCP manual for sticky trap procedure and recording templates here: https://nurseryproductionfms.com.au/)

* Weeds are a common host of Serpentine leafminer therefore ensure an effective and constant weed management program is in place and monitor crop(s) and surrounding areas, to limit the reproduction and reinfestation opportunities in treated/managed crops, see BioSecure HACCP manual for site surveillance procedure and recording templates here: https://nurseryproductionfms.com.au/)

* Use a robust pest identification resource to make sure that the correct identification is being made when crop monitoring or inspecting sticky traps (Pest ID Tool here: https://pestid.com.au/)

* Where there is evidence of ovipositing and leaf mines in significant quantities on known host plants a sample should be prepared and sent for laboratory analysis to confirm the species. It is not possible to distinguish one species of leafminer from another by looking at the mines. Adult flies are also difficult to identify given that there are several species of endemic, native and exotic leafminers that all look very similar. Please refer to the link below for detailed instructions.

Report suspected infestations via the **Exotic Plant Pest Hotline: 1800 084 881.**

For further information refer to: Primefact – Reporting and Testing for Serpentine Leafminer: https://www.dpi.nsw.gov.au/__data/assets/pdf_file/0003/1274574/Primefact-SLM-sample-submission.pdf

4. On site Biosecurity Actions

(a). General Biosecurity Duty/Obligation

In December 2020, after extensive surveillance, authorities deemed Serpentine leafminer (SLM) not technically feasible to eradicate and the emergency response then transitioned to management. Growers are required to adhere to their General Biosecurity Duty/Obligation. Put simply this involves acting to prevent further spread of SLM, eliminating heavy infestations of SLM and minimising the impact of SLM in plant production systems.

The General Biosecurity Duty/Obligation is a legislative mechanism due to the risk of an adverse effect on the economy, environment and the community that arises from the presence or spread of unwanted plant pests. This duty is described in detail in Part 3 of the NSW Biosecurity ACT (2015)/ Chapter 2 Part 1 QLD Biosecurity Act 2014 and may be met by implementing processes and procedures to reduce infestations of SLM. Technical downloads related to biosecurity and best management practice guidelines are industry specific and available at: Australian Plant Production Standard (APPS) | Australian Plant Production Standard (APPS). Industry standards such as NIASA Production Nursery and BioSecure HACCP programs can also be useful tools to put systems in place to improve pest and disease management.

(b) Integrated Pest Management

A site-specific Integrated Pest Management (IPM) plan should include options for cultural, biological and appropriate chemical control. Excessive use of non-selective chemical control is not recommended as this insect can develop resistance and naturally occurring beneficial parasitoids have been proven to be an effective suppressant. An IPM approach should include:

- Inspection of incoming stock – all plants should be inspected for pest and disease symptoms before entering the nursery
- Training – educate staff in the identification of plant pests and provide reference material that is easily accessible e.g., Pest ID Tool (https://pestid.com.au/).
- Access restrictions – limit visitor and staff access into production areas
- Crop Monitoring – complete regularly at least weekly, more frequently if problems arise.
- Stocktake – group host plants together where practical so that if treatment is required it can be carried out efficiently
- Remove – weed hosts of the leafminer and all waste plant material from growing areas
- Despatch – inspect stock for signs of pest and disease prior to despatch.

Image 11. Potential natural enemy – Parasitoid wasp, *Eupelmidae sp*. Credit Joe Wes

(c) Infested Crop Management

To manage a confirmed infestation of Serpentine Leafminer follow these steps:

- Spray infested plants with a registered insecticide and/or using an approved minor use permit
- Treat adjacent host plant material with a registered insecticide and/or using an approved minor use permit
- Bury affected plants, adult leafminers have difficulty emerging from pupae buried deeply in soil or where deep burial is not possible dispose of to landfill ensuring material is enclosed in bags/containers
- Monitor remaining crops closely and complete a preventative treatment cycle before despatch
- Raising the temperature in empty, enclosed production areas after cleaning and treatment can be an effective way of destroying any remaining pests. Preferably above 32 degrees Celsius.

5. Insecticide Treatment

Select the appropriate insecticides for a rotation program considering least impact on beneficials, workers and the environment. Follow the **Minor Use Permit (MUP)** directions on application rate and on the number of applications per treatment cycle. Once the 'treatment cycle' is completed the next treatment must be with the second active ingredient in the rotation program and so on. Note, if the product label states 'three sprays 7 days apart' that constitutes the 'treatment cycle' which must be completely applied before moving to the next active ingredient in the rotation plan. Please find the **PER88977** here: https://nurseryproductionfms.com.au/minor-use-permits-mups-for-pesticides/

Table 3. Minor Use Permit PER88977 Active Ingredients

Active/mode of action	Trade names examples	Active/mode of action	Trade names examples
Abamectin - (Group 6 Insecticide)	SORCERER; VERTIMEC INSECTICIDE	Chlorantraniliprole + thiamethoxam - (Group 28 + 4A)	DURIVO INSECTICIDE
Azadirachtin - (Group UN Insecticide)	AZAMAX INSECTICIDE	Cyantraniliprole - (Group 28 Insecticide)	BENEVIA INSECTICIDE
Cyromazine - (Group 17 Insecticide)	DIPTEX 150 WP IGR	Indoxacarb - (Group 22A Insecticide)	AVATAR INSECTICIDE
Emamectin - (Group 6 Insecticide)	PROCLAIM OPTI INSECTICIDE	Spinetoram - (Group 5 Insecticide)	SUCCESS NEO INSECTICIDE

Table 4. Examples of Serpentine leafminer Pesticide Rotation Programs

	Pesticide Rotation #1	Pesticide Rotation #2	Pesticide Rotation #3
Example #1	Abamectin - (Group 6 Insecticide) + Azadirachin (1ml/L)	Chlorantraniliprole + thiamethoxam - (Group 28 + 4A) + Azadirachin (1ml/L)	Spinetoram - (Group 5 Insecticide) + Azadirachin (1ml/L)
Example #2	Emamectin - (Group 6 Insecticide) + Azadirachin (1ml/L)	Cyromazine - (Group 17 Insecticide) + Azadirachin (1ml/L)	Indoxacarb - (Group 22A Insecticide) + Azadirachin (1ml/L)
Example #3	Cyantraniliprole - (Group 28 Insecticide) + Azadirachin (1ml/L)	Abamectin - (Group 6 Insecticide) + Azadirachin (1ml/L)	Spinetoram - (Group 5 Insecticide) + Azadirachin (1ml/L)

NOTE: Test all insecticides and combinations on a crop sample before applying to the total crop(s) to avoid phytotoxicity.

6. Insecticide Application

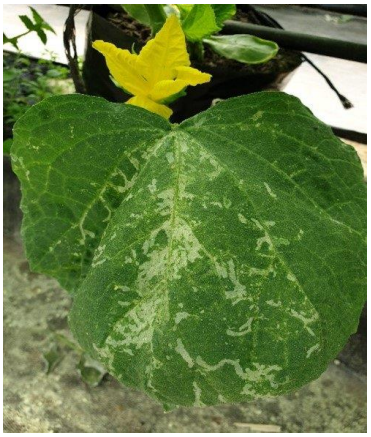
Applying insecticides requires the appropriate application equipment, nozzle type and size in line with industry best practice and regulatory requirements. Ensure that the relevant staff have:

- Completed the necessary training i.e. AusChem, ChemCert or Smarttrain certification
- Read instructions on the product label ensuring application rates are as per the MUP
- MUP is available on site to confirm correct application rates
- Safety Data Sheets (SDS) are current and available on site
- Personal protective equipment is used and meets the requirements of the SDS
- Environmental considerations are adhered to i.e., if the product is toxic to fish take all reasonable measures not to contaminate waterways when cleaning equipment
- Insecticide is not out of date or past its used by date
- An applicable insecticide rotation program has been selected
- Equipment has been calibrated ensuring that the nozzle type and size are appropriate for insecticide application and excess quantities of diluted product are not prepared
- Sprayer has not been used for herbicide previously. Even if it has been cleaned thoroughly insecticides can 'strip' residual herbicide from plastic containers
- Signage is in place to notify staff not to enter the treatment area
- Re-entry periods are followed as per the product label/MUP
- Overhead irrigation is scheduled to allow sufficient contact time for the product to be effective, refer to the product label e.g., rainfastness

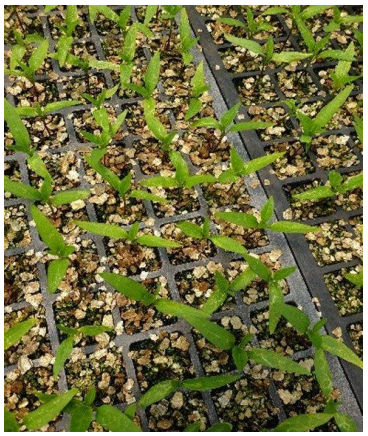
Check weather conditions before spraying to minimise drift and observe the ideal temperature for application, for example – early afternoon or evening when temperatures are cooler, and evaporation is less likely to occur.

7. Serpentine Leaf Miner Identification Images

12. Mine damage on squash, Shannon Mulholland. NSW DPI



13. Mine damage on cucumber, Shannon Mulholland. NSW DPI



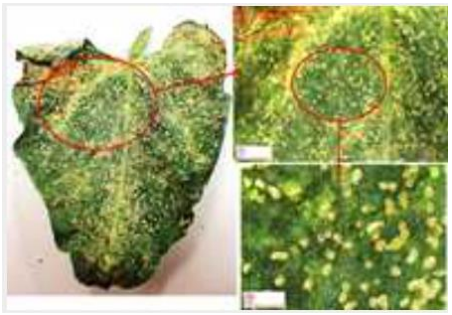
14. Mine damage on Chilli seedlings, Shannon Mulholland. NSW DPI

15. Leafminer on Coral lettuce, Shannon Mulholland. NSW DPI

16. Mines on Cos lettuce, Shannon Mulholland. NSW DPI

17. Leaf mines celery, John Duff. QDAF

18. Image of mines on green bean leaf, John Duff. QDAF



19. Bean leaf infested with Serpentine Leafminer, note the feeding and oviposition holes, Biosecurity Queensland

20. Pupa exposed ventral surface

21. Larva exposed from mine ventral surface

8. Links to other resources:

Greenlife Industry Australia - Australian Plant Production Standard (APPS) | Pests, Diseases & Weeds

Plant Health Australia Fact sheets and Contingency Plan - Pea Leafminer (Liriomyza huidobrensis)

NSW Department of Primary Industries -Serpentine leafminer

Ausveg - https://ausveg.com.au/biosecurity-agrichemical/biosecurity/mt16004/

Department of Agriculture - Leaf miner - Department of Agriculture

Cesar Australia Lifecycle Prediction Tool (enter as Pea leafminer) - DARABUG2

Appendix 1 Hosts of Serpentine Leafminer (*Liriomyza huidobrensis*) - Source: Final Report MT16004

Table 2 - Commercial, ornamental and non-cultivated plants for which comprehensive evidence of lifecycle completion in the field has been provided within the scientific literature.

Host Type	Common Name/s	Scientific name	Variety	Family	Records with Comprehensive Evidence	All Other records (Partial and Unverified Records)
Commercial		*Beta sp.*		Amaranthaceae		Collins (1996)
Commercial	Beet; Chard; Betroot	*Beta vulgaris*		Amaranthaceae	Nakamura et al. (2013);Rauf et al. (2000);Scheffer et al. (2001);Takano et al. (2008)	Andersen et al. (2008); Echevarria et al.(1994); He et al. (2002); (Koch and Waterhouse 2000); Korytkowski (2014);Korytkowski (1982); Ripa et al. (1995);Saunders et al. (1998); Spencer (1973);Weintraub et al. (2017); Wijesekara(2010); Kox et al. (2005)
Commercial	Swiss Chard; Common Beet	*Beta vulgaris*	cicla	Amaranthaceae	Hammad and Nemer (2000); Mujica and (2000); Mujica and Kroschel (2011); Salvo and Valladares (2002)	He et al. (2001); He et al. (2002); Salvo and Valladares (1997); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al.-2011
Commercial	Beetroot	*Beta vulgaris*	rapacea	Amaranthaceae	Salvo and Valladares (2002)	Valladares (1984); Valladares et al.(1996); Valladares et al. (1999);Valladares et al. (2011)
Commercial		*Beta vulgaris*	rubra	Amaranthaceae		Shiao and Wu (2000)
Commercial	Beetroot	*Beta vulgaris*	saccharifera	Amaranthaceae		Hidalgo and Carballo (1991)
Commercial	Beetroot	*Beta vulgaris*	vulgaris	Amaranthaceae	Mujica and Kroschel (2011)	
Commercial	Spinach; Silverbeet	*Spinacia oleracea*		Amaranthaceae	Foba et al. (2015); Mujica and Kroschel (2011); Nakamura et al. (2013); Rauf et al. (2000)	Andersen et al. (2008); Bahlai et al.(2006); He et al. (2001); (Koch andWaterhouse 2000); Korytkowski (1982);Martin et al. (2005); Spencer (1973);Valladares et al. (1996); Kox et al. (2005)
Commercial	Leek; Leeks	*Allium ampeloprasum*		Amaryllidaceae	Rauf et al. (2000)	Hincapie et al. (1993)
Commercial	Onion; Shallot; Multiplier onion	*Allium sepa*		Amaryllidaceae	Foba et al. (2015); Rauf et al (2000)	Andersen et al. (2002); Andersen et al. (2008); He et al. (2001); Hidalgo and Carballo (1991); Hincapie et al. (1993); Korytkowski (2014); Korytkowski (1982); Kuhnke et al. (1998); Martin et al. (2005); Pang et al. (2006); Rauf et al. (2000); Spencer (1973); Ueno (2006); Verjel-Manzano and Mejia-Florez (2000); Weintraub et al. (2017); (Koch and Waterhouse 2000)
Commercial	Scallion	*Allium sepa*	aggregatum	Amaryllidaceae	Mujica and Kroschel (2011)	Korytkowski (1982)

Host Type	Common Name/s	Scientific name	Variety	Family	Records with Comprehensive Evidence	All Other records (Partial and Unverified Records)
Commercial		*Allium sepa*	cepa	Amaryllidaceae		Scheffer et al. (2006)
Commercial	Japanese Bunching Onion; Scallion; Welsh Onion	*Allium fistulosum*		Amaryllidaceae	Rauf et al. (2000)	He et al. (2001); Hidalgo and Carballo (1991); Pang et al. (2006); Shepard et al. (1998); Shiao and Wu (2000); Ueno (2006); Wei et al. (2000)
Commercial	Garlic	*Allium sativum*		Amaryllidaceae	Rauf et al. (2000)	He et al. (2001); Hincapie et al. (1993); Pang et al. (2006); Saunders et al. (1998); Silva (1993); Wei et al. (2000)
Commercial		*Allium sp.*		Amaryllidaceae	Scheffer et al. (2001)	Bahlai et al. (2006); de Clercq and
Commercial	Celery	*Apium graveolens*		Apiaceae	Larrain and Munoz (1997); Rauf et al. (2000); Sivapragasam and Syed (1999)	Casteels (1992); He et al. (2001); He et al. (2002); Hidalgo and Carballo (1991); (Koch and Waterhouse 2000); Korytkowski (2014); Korytkowski (1982); Kuhnke et al. (1998); Martin et al. (2005); Pang et al. (2006); Romero- Zuniga et al. (1991); Shepard et al. (1998); Spencer (1973); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Wei et al. (2000); Weintraub (1999); Weintraub et al. (2017)
Commercial	Celery	*Apium graveolens*	dulce	Apiaceae	Mujica and Kroschel (2011)	He et al. (2001); Korytkowski (2014); Scheffer et al. (2006)
Commercial		*Apium sp.*		Apiaceae		Collins (1996)
Commercial	Carrot	*Daucus carota*		Apiaceae	Rauf et al. (2000)	Korytkowski (2014); Korytkowski (1982); Shepard et al. (1998)
Commercial		*Daucus carota*	sativa	Apiaceae		Korytkowski (2014)
Commercial	Carrot	*Daucus carota*	sativus	Apiaceae		Scheffer et al. (2006)
Commercial	Lettuce; Garden Letuce	*Lactuca sativa*		Asteraceae	Masetti et al. (2006);Mujica and Kroschel (2011); Rauf et al. (2000); Takano et al. (2008)	Andersen et al. (2002); Andersen et al. (2008); Bahlai et al. (2006); de Clercq and Casteels (1992); Echevarria et al. (1994); Godinho and Mexia (2000); He et al. (2002); Hincapie et al. (1993); (Koch and Waterhouse 2000); Korytkowski (2014); Korytkowski (1982); Kuhnke et al. (1998); Martin et al. (2005); Olivera and Bordat (1996); Weintraub et al. (2017); Parish et al. (2017); Salvo and Valladares (1997); Spencer (1973); Takano et al. (2008); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Weintraub et al. (2017)

Host Type	Common Name/s	Scientific name	Variety	Family	Records with Comprehensive Evidence	All Other records (Partial and Unverified Records)
Commercial		*Lactuca sativa*	asparagina	Asteraceae		Wei et al. (2000)
Commercial		*Lactuca sativa*	capitata	Asteraceae		Scheffer et al. (2006); Wei et al. (2000)
Commercial		*Lactuca sativa*	intybeca	Asteraceae		Shiao and Wu (2000)
Commercial	Indian Nightshade	*Basella alba*		Basellaceae	Rauf et al. (2000)	He et al. (2001)
Commercial	Chinese cabbage; cabbage; Petsai; Common Yellow Mustard	*Brassica campestris*		Brassicaceae	Rauf et al. (2000); Sivapragasam et al. (1999); Sivapragasam and Syed (1999)	Hidalgo and Carballo (1991); Pang et al. (2006); Romero-Zuniga et al. (1991)
Commercial		*Brassica campestris*	pekinensis	Brassicaceae	Mujica and Kroschel - 2011	He et al. (2001)
Commercial	Turnip	*Brassica campestris*	rapa	Brassicaceae	Mujica and Kroschel - 2011	Hincapie et al. (1993)
Commercial	Pak-choi cabbage; Petsai	*Brassica chinensis*		Brassicaceae	Rauf et al. (2000); Sivapragasam et al. (1999)	Andersen et al. (2008); Shepard et al.
Commercial	Leaf mustard; Mustard greens; Radish; Chinese mustard; Indian mustard; Mustard	*Brassica juncea*		Brassicaceae	Rauf et al. (2000); Scheffer et al. (2001)	Andersen et al. (2008); Bahlai et al. (2006); He et al. (2001); Scheffer et al. (2006); Silva (1993); Wei et al. (2000)
Commercial	Gai lan; Cabbage; Broccoli; Caisin; Cabbage; Cauliflower; Field cabbage	*Brassica oleracea*		Brassicaceae	Rauf et al. (2000); Scheffer et al. (2001)	Bahlai et al. (2006); Echevarria et al. (1994); Korytkowski (2014); Korytkowski (1982); Pang et al. (2006); Saunders et al. (1998); Shepard et al. (1998)
Commercial	Kale	*Brassica oleracea*	acephala	Brassicaceae	Foba et al. (2015)	He et al. (2001)
Commercial	Cauliflower	*Brassica oleracea*	botrytis	Brassicaceae		He et al. (2001); Korytkowski (2014)
Commercial	Cabbage	*Brassica oleracea*	capitata	Brassicaceae	Mujica and Kroschel 2011	He et al. (2001); Hincapie et al. (1993);Scheffer et al. (2006); Weintraub et al.(2017)
Commercial		*Brassica oleracea*	caulorapa	Brassicaceae		He et al. (2001)
Commercial		*Brassica oleracea*	geminifera	Brassicaceae		Weintraub et al. (2017)
Commercial	Broccoli	*Brassica oleracea*	italica	Brassicaceae		He et al. (2001); Scheffer et al. (2006); Shepard et al. (1998); Weintraub et al. (2017)

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Commercial	Turnip; Rinsho; Chinese cabbage; Bokchoy	*Brassica rapa*		Brassicaceae	Rauf et al. (2000); Takano et al. (2008)	
Commercial	Pak choi; Pechay; Chinese Cabbage	*Brassica rapa*	Chinensis	Brassicaceae	Takano et al. (2008)	Andersen et al. (2008)
Commercial		*Brassica rapa*	cultivar Ciaxin	Brassicaceae		CABI (2019)
Commercial		*Brassica sp.*		Brassicaceae		Hincapie et al. (1993)
Commercial	Watercress	*Nasturtium officinale*		Brassicaceae	Rauf et al. (2000)	He et al. (2001); Weintraub et al. (2017)
Commercial		*Nasturtium sp.*		Brassicaceae		Valladares (1984)
Commercial	Radish; Chinese radish (Daikon); Wild radish; Garden radish; White radish	*Raphanus sativus*		Brassicaceae	Mujica and Kroschel (2011); Rauf et al. (2000)	He et al. (2001); Collins (1996); Echevarria et al. (1994); Shepard et al. (1998); Weintraub et al. (2017)
Commercial		*Raphanus sativus*	sativus	Brassicaceae		Scheffer et al. (2006)
Commercial	Sweet Potato	*Ipomoea*		Convolvulaceae	Rauf et al. (2000)	Shepard et al. (1998)
Commercial	Watermelon	*batatas*		Cucurbitaceae	Foba et al. (2015)	(Koch and Waterhouse 2000); Ripa et al. (1995)
Commercial	Cucumber	*Cucumis sativus*		Cucurbitaceae	Hammad and Nemer (2000); Masetti et al. (2006); Mujica and Kroschel (2011); Nakamura et al. (2013); Rauf et al. (2000)	Andersen et al. (2002); Weintraub et al. (2017); Hincapie et al. (1993); Kuhnke et al. (1998); Martin et al. (2005); Weintraub et al. (2017); Parish et al. (2017); Ripa et al. (1995); Shiao and Wu (2000); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Yabas et al. (1995)
Commercial		*Cucumis sp.*		Cucurbitaceae		(Koch and Waterhouse 2000)
Commercial	Pumpkin; Winter squash; Squash	*Cucurbita maxima*		Cucurbitaceae	Foba et al. (2015); Mujica and Kroschel (2011)	Korytkowski (2014); Korytkowski (1982); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011)
Commercial	Courgette	*Cucurbita maxima*	zapallito	Cucurbitaceae	Salvo and Valladares (2002)	Salvo and Valladares (1997); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011)
Commercial		*Cucurbita moschata*	medullosa	Cucurbitaceae		Pang et al. (2006)

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Commercial	Butternutsquash;Pumpkin;Crooknecksquash	*Cucurbita moschata*		Cucurbitaceae	Foba et al. (2015)	Pang et al. (2006); Valladares et al.(1996); Valladares et al. (1999);Valladares et al. (2011)
Commercial		*Cucurbita moschata*	medullosa	Cucurbitaceae		Pang et al. (2006)
Commercial	Courgette; Zucchini; Pumpkin	*Cucurbita pepo*		Cucurbitaceae	Foba et al. (2015); Mujica and Kroschel (2011); Scheffer et al. (2001)	He et al. (2001); Korytkowski (1982); Olivera and Bordat (1996); Pang et al. (2006); Spencer (1973)
Commercial		*Cucurbita pepo*	pepo	Cucurbitaceae		Scheffer et al. (2006)
Commercial	Squash	*Cucurbita sp.*		Cucurbitaceae		Korytkowski (2014); Salvo and Valladares (1997); Valladares (1984); Valladares et al. (1996)
Commercial	Bitter Gourd; Balsam Pear	*Momordica charantia*		Cucurbitaceae	Foba et al. (2015)	Pang et al. (2006)
Commercial	Swartz Chayote	*Sechium edule*		Cucurbitaceae	Rauf et al. (2000)	He et al. (2001)
Commercial	Chickpea	*Cicer arietinum*		Fabaceae	Avalos et al. (2013)	
Commercial	Soy Bean; Soya Bean	*Glycine max*		Fabaceae	Rauf et al. (2000)	He et al. (2001); Parish et al. (2017); Valladares (1984); Valladares et al. (1999)
Commercial	Sweet Dolichos;Field bean	*Lablab purpureus*		Fabaceae	Foba et al. (2015)	
Commercial	Alfalfa; Lucerne	*Medicago sativa*		Fabaceae	Mujica and Kroschel (2011)	Echevarria et al. (1994); Gloria and Salas (1976); (Koch and Waterhouse 2000); Korytkowski (2014); Valladares (1984); Valladares et al. (1999); Valladares et al. (2011)
Commercial	Sieva; Lima bean; Lima bean	*Phaseolus lunatus*		Fabaceae	Sivapragasam et al. (1999)	
Commercial	Beans; Grean beans; Pole beans	*Phaseolus sp*		Fabaceae		Scheffer et al. (2006)
Commercial	Green Pea	*Phaseolus vulgaris*	vulgaris	Fabaceae	Mujica and Kroschel (2011)	
Commercial		*Pisum sativum*	macrocarpenser	Fabaceae		He et al. (2001)
Commercial	Snow Pea	*Pisum sp.*		Fabaceae		Collins (1996); Scheffer et al. (2006); Shepard et al. (1998)

Host Type	Common Name/s	Scientific name	Variety	Family	Records with Comprehensive Evidence	All Other records (Partial and Unverified Records)
Commercial	Green bean;French bean;Kidney bean;Bean; Commonbean; Snap bean	*Phaseolusvulgaris*		Fabaceae	Foba et al. (2015); Larrainand Munoz (1997);Mujica and Kroschel(2011); Rauf et al. (2000);de Souza (1986);Hammad and Nemer(2000); Salvo andValladares (2002)	Andersen et al. (2002); Andersen et al.(2008); Masetti et al. (2006); Olivera andBordat (1996); Pang et al. (2006); Parish Macdonald et al. (2003); Musundire etal. (2012); Okoth et al. (2014); Salvo andValladares (1997); Shepard et al. (1998);Shiao and Wu (2000); Spencer (1973);Takano et al. (2008); Valladares et al.(1996); Valladares et al. (1999);Valladares et al. (2011); Weintraub et al.(2017); Yabas et al. (1995)et al. (2017); Saunders et al. (1998);Verjel-Manzano and Mejia-Florez(2000); Echevarria et al. (1994); Godinhoand Mexia (2000); Weintraub et al.(2017); He et al. (2001); He et al. (2002);Hidalgo and Carballo (1991); Hincapieet al. (1993); Iwasaki (2004b);Korytkowski (2014); Korytkowski (1982);
Commercial	Garden pea; Pea; Snow pea; Sugar snap	*Pisum sativum*		Fabaceae	Sivapragasam et al. (1999); Foba et al. (2015); Larrain and Munoz (1997); Mujica and Kroschel (2011); Rauf et al. (2000); Scheffer et al. (2001); Sivapragasam and Syed (1999)	Andersen et al. (2002); Andersen et al. (2008); Bahlai et al. (2006); He et al. (2001); (Koch and Waterhouse 2000); Korytkowski (2014); Korytkowski (1982); Martin et al. (2005); Musundire et al. (2012); Okoth et al. (2014); Pang et al. (2006); Ripa et al. (1995); Salvo and Valladares (1997); Saunders et al. (1998); Silva (1993); Spencer (1973); Takano et al. (2008); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Wei et al. (2000); Weintraub et al. (2017); Yabas et al. (1995); Kox et al. (2005)
Commercial	Broad bean;Faba bean; Favabean	*Vicia faba*		Fabaceae	Mujica and Kroschel(2011); Rauf et al. (2000);Salvo and Valladares(2002); Scheffer et al.(2001)	Blanchard (1938); Collins (1996);Echevarria et al. (1994); Gallegos 2000;Weintraub et al. (2017); He et al. (2001);Salvo and Valladares (1997); Saunderset al. (1998); Silva (1993); Takano et al.(2008); Valladares (1984); Valladares etal. (1996); Valladares et al. (1999);Valladares et al. (2011); Wei et al.(2000); Yabas et al. (1995)He et al. (2002); (Koch and Waterhouse2000); Korytkowski (1982); Musundire etal. 2011; Musundire et al. (2012);Noujeim et al. 2013; Okoth et al. (2014);
Commercial		*Vicia sp.*		Fabaceae		Spencer (1973)

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Commercial	Red bean; Black eyed pea; Cowpea	*Vigna sinensis*		Fabaceae	Rauf et al. (2000)	He et al. (2001); Shepard et al. (1998); Wei et al. (2000)
Commercial	Walp Cowpea; Yard-long bean; Long bean; Snakebean; Cowpea	*Vigna unguiculata*		Fabaceae	Foba et al. (2015); Rauf et al. (2000)	Hincapie et al. (1993)
Commercial		*Vigna unguiculata*	unguiculata	Fabaceae		Takano et al. (2008)
Commercial	Basil; Sweet basil; Thai basil	*Ocimum basilicum*		Lamiaceae	Mujica and Kroschel (2011); Rauf et al. (2000)	
Commercial	Okra	*Abelmoschus esculentus*		Malvaceae	Foba et al. (2015)	
Commercial	Pepper; Sweet pepper; Green pepper; Chili; Capsicum	*Capsicum annuum*		Solanaceae	Sivapragasam et al. (1999); Mujica and Kroschel (2011); Rauf et al. (2000); Sivapragasam and Syed (1999)	Calabretta et al. 1995; (Koch and Waterhouse 2000); Pang et al. (2006); Salvo and Valladares (1997); Saunders et al. (1998); Shepard et al. (1998); Shiao and Wu (2000); Spencer (1973); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Weintraub et al. (2017)
	Yellow Chilli	*Capsicum baccatum*		Solanaceae	Mujica and Kroschel (2011)	
	Sweet pepper; Pepper; Chilli	*Capsicum sp.*		Solanaceae	Foba et al. (2015)	Romero-Zuniga et al. (1991)
	Tomato	*Lycopersiconesculentum*		Solanaceae	Mujica and Kroschel(2011); Rauf et al. (2000);Sivapragasam et al.(1999); Sivapragasam andSyed (1999)	Korytkowski (2014); Kox et al. (2005); Heet al. (2001); (Koch and Waterhouse2000); Okoth et al. (2014); Olivera andBordat (1996); Osorio et al. 1983; Salvoand Valladares (1997); Shepard et al.(1998); Spencer (1973); Valladares(1984); Valladares et al. (1996);Valladares et al. (1999); Valladares et al.(2011); Collins (1996);
	Tomato	*Lycopersicon esculentum*	esculentum	Solanaceae		Scheffer et al. (2006)
		Solanum sp.		Solanaceae	Scheffer et al. (2001)	Andrade et al. (1989)

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	Tomato	*Solanum lycopersicum*		Solanaceae	Foba et al. (2015)	Andersen et al. (2008); Andersen et al. (2002); de Clercq and Casteels (1992); Godinho and Mexia (2000); Hanafi (2005); Hidalgo and Carballo (1991); Korytkowski (1982); Macdonald et al. (2003); Moura et al. (2014); Musundire et al. (2012); Weintraub et al. (2017); Pang et al. (2006); Parish et al. (2017); Saunders et al. (1998); Weintraub et al.2017
Commercial	Brinjal eggplant Eggplant; common eggplant; Pickling eggplant	*Solanum melongen*		Solanaceae	Foba et al. (2015); Rauf et al (2000)	He et al. (2001); Korytkowski (1982); Salvo and Valladares (1997); Saunders et al. (1998); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011)
Commercial	Potato	*Solanum tuberosum*		Solanaceae	de Souza (1986); Foba et al. (2015); Larrain and Munoz (1997); Mujica and Kroschel (2011); Nino et al. (2009); Rauf et al. (2000); Salvo and Valladares (2002); Scheffer et al. (2001); Sivapragasam and Syed (1999)	Andersen et al. (2002); Andersen et al. (2008); Bahlai et al. (2006); Gallegos 2000; He et al. (2001); Hidalgo and Carballo (1991); Iwasaki (2004a); (Koch and Waterhouse 2000); Korytkowski (2014); Korytkowski (1982); Macdonald et al. (2003); Maharjan et al. 2014; Martin et al. (2005); Romero-Zuniga et al. (1991); Salvo and Valladares (1997); Saunders et al. (1998); Shepard et al. (1998); Spencer (1973); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011); Wijesekara (2010); Yabas et al. (1995)
Ornamental	pot Marigold	*Calendula officinalis*		Asteraceae	Salvo and Valladares	He et al. (2001); Korytkowski (1982); Salvo and Valladares (1997); Valladares (1984); Valladares et al. (1996); Valladares et al. (1999); Valladares et al. (2011)
Ornamental		*Calendula sp.*		Asteraceae		Weintraub et al. (2017)
Ornamental	Chinese Aster	*Callistephus chinensis*		Asteraceae	Salvo and Valladares	de Clercq and Casteels (1992); Salvo and Valladares (1997); Valladares et al. (1999); Valladares et al. (2011); Wei et al. (2000); Valladares et al. (1996)

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Ornamental	Garland chrysanthemum	*Chrysanthemum coronarium*		Asteraceae		Wei et al. (2000)
Ornamental	Garland chrysanthemum	*Chrysanthemum coronarium*	coronarium	Asteraceae	Tran (2009)	
Ornamental	Garland chrysanthemum; Chrysanthemum	*Chrysanthemum sp.*		Asteraceae	Scheffer et al. (2001)	Collins (1996); Hincapie et al. (1993); Pang et al. (2006); Salvo and Valladares (1997); Scheffer et al. (2006); Weintraub et al. (2017); Anderson et al. (2008)
Ornamental	Chrysanthemum	*Chrysanthemum sp.*		Asteraceae	Rauf et al. (2000)	
Ornamental	Dahlia	*Dahlia sp.*		Asteraceae	Rauf et al. (2000)	Collins (1996); Weintraub et al. (2017)
Ornamental	Gerbera; Barberton daisy; Transvaal daisy	*Gerbera jamesonii*		Asteraceae	Rauf et al. (2000)	Wei et al. (2000)
Ornamental		*Gerbera sp.*		Asteraceae		Weintraub et al. (2017)
Ornamental	Marigold; Aztec marigold	*Tagetes erecta*		Asteraceae	Mujica and Kroschel (2011)	Wei et al. (2000)
Ornamental		*Tagetes erecta*	hybrids	Asteraceae		de Clercq and Casteels (1992)
Ornamental	Marigold	*Tagetes sp.*		Asteraceae		Weintraub et al. (2017); Salvo and Valladares (1997); Valladares (1984); Valladares et al. (1996)
Ornamental		*Eustoma sp.*		Gentianaceae	Nakamura et al. (2013)	Weintraub et al. (2017)
Ornamental	`Swai tanah'	*Nasturtium indicum*		Tropaeolaceae	Rauf et al. (2000)	
Ornamental	Garden Nasturtium	*Tropaeolum majus*		Tropaeolaceae	Salvo and Valladares (2002)	He et al. (2001); Salvo and Valladares (1997); Silva (1993); Valladares (1984)
Ornamental	Nasturtium	*Tropaeolum sp.*		Tropaeolaceae	Spencer (1983)	
Non-cultivated	Amaranth; Bayam	*Amaranthus sp.**		Amaranthaceae	Rauf et al. (2000); Sivapragasam et al. (1999)	Hidalgo and Carballo (1991); Romero-Zuniga et al. (1991); Shepard et al. (1998); Valladares et al. (1999); Valladares et al. (2011); Weintraub et al.2017
Non-cultivated	Goosefoot; Lamb's quarters; Fat hen	*Chenopodium album**		Amaranthaceae	Salvo and Valladares (2002)	He et al. (2001); Silva (1993)
Non-cultivated	Amaranth	*Deeringia amaranthoides**		Amaranthaceae	Rauf et al. (2000)	
Non-cultivated	Penniwort	*Hydrocotyle sp.**		Araliaceae	Salvo and Valladares (2002)	Salvo and Valladares (1997)

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Non-cultivated	Chick weed; Goatweed	*Ageratum conyzoides**		Asteraceae	Rauf et al. (2000)	
Non-cultivated	Commonburdock	*Arctium minus**		Asteraceae	Salvo and Valladares(2002)	Salvo and Valladares (1997); Valladareset al. (1999); Valladares et al. (2011)
Non-cultivated	Sow thistle	*Emilia sonchifolia**		Asteraceae	Rauf et al. (2000) Scheffer et al. (2001)	Hincapie et al. (1993); Scheffer et al. (2006)
Non-cultivated	American burnweed; Pilewort; Fireweed	*Erechtites hieracifolia* (currently under quarantine in Australia (CABI 2019))*		Asteraceae	Rauf et al. (2000)	Romero-Zuniga et al. (1991)
Non-cultivated	Indian lettuce	*Lactuca indica*		Asteraceae	Rauf et al. (2000) Sivapragasam et al. (1999)	
Non-cultivated	Cinderella weed; Nodeweed	*Synedrella nodiflora**		Asteraceae	Rauf et al. (2000)	
Non-cultivated	Wild cucumber	*Melothria indica*		Cucurbitaceae	Rauf et al. (2000)	
Non-cultivated	Cutleaf ground cherry; Mullaca; Wild gooseberry	*Physalis angulata**		Solanaceae	Rauf et al. (2000)	Hidalgo and Carballo (1991)
Non-cultivated	American black nightshade	*Solanum americanum*		Solanaceae	Rauf et al. (2000)	

Notes