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Agromyzidae (Insecta: Diptera) species as an important agricultural pest

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Abstract

The Agromyzidae family represent a very particular group of phytophagous insects because of their habit. The larvae of this group of insects, when feeding on the plant, build galleries in the leaf parenchyma that also provide them with shelter. Although most representatives of this group of insects are leaf miners (around 75%), there are agromyzid larvae that can feed on roots, stems, pods and inflorescences of herbaceous plants, and trunks and branches of trees. The aim of this manuscript was to carry out an inventory of the Agromyzidae Family (Insecta: Diptera) related to its biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology and taxonomic and conceptual aspects of the Family, Subfamilies and Species. To this end, a bibliographic survey of Agromyzidae was carried out in the years 1937 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events, Doctoral Thesis and Master's Dissertation were considered. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science and ERIC.

Keywords: Agromyzid larvae; Phytophagous insects; *Liriomyza*; Trees; Herbaceous plants

1 Introduction

Figure 1A Specimen of the Family Agromyzidae; (Source: https://bugtracks.wordpress.com/tag/agromyzidae/page/2/)

Flies of the Agromyzidae family represent a very particular group of phytophagous insects because of their habit. The larvae of this group of insects, when feeding on the plant, build galleries in the leaf parenchyma that also provide them with shelter. Although most representatives of this group of insects are leaf miners (around 75%), there are agromyzid larvae that can feed on roots, stems, pods and inflorescences of herbaceous plants, and trunks and branches of trees.

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Mining flies of the genus *Liriomyza* are considered the most economically important of the group (Figures 1A and 1B) [1,2,3].

1.1 Description

Its adult females measure 1.5 mm in wingspan. They are generally dark in color, with yellowish side spots, including on the scutellum (back of the chest). Its body is covered with dark bristles. Males are smaller and darker. In potato plants, in the leaves, the females with their ovipositor cause feeding bites, on both pages, and oviposition bites only on the lower page (Figure 1C) [4,5,6].

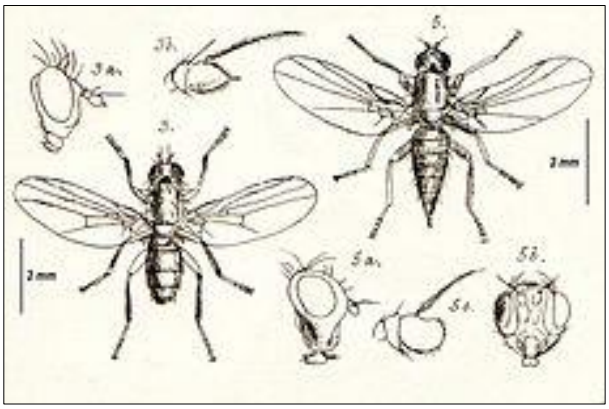

Figure 1B *Cerodontha denticornis* (Panzer, 1806), 3rd side head, 3b antenna, and figure 5 *Phytomyza affinis* Fallen, 1823, 5th side head, 5b face, 5c antenna; (Source: https://en.wikipedia.org/wiki/Agromyzidae)

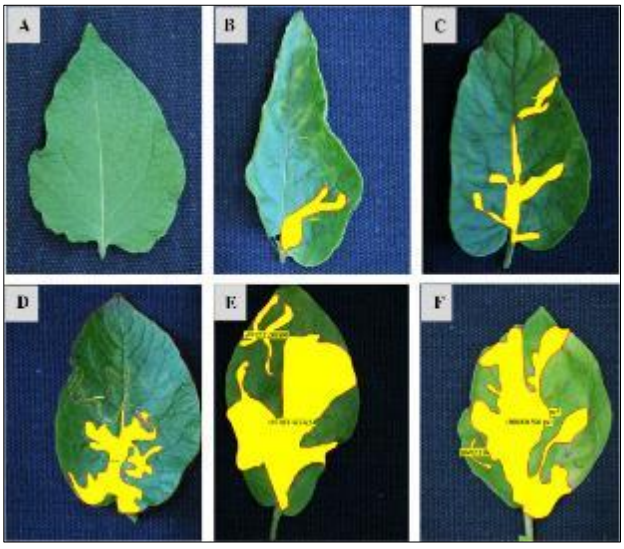

Figure 1C The damage is caused by their larvae that mine the leaves of the plants as they feed mines that are necrotic areas, that is, dead, without photosynthesizing activity; (Source: https://www.semanticscholar.org/paper/Effect-of-Liriomyza-huidobrensis-(Diptera%3A-density-Kwon-Kim/5842700fc2d26f337de55f910fc44cee28fc1f86/figure/2)

A great diversity of cultures, mainly of oleraceous and ornamental plants, is associated with the occurrence of these dipterans, in field and protected crops. Spontaneous plants are also common hosts for these pest insects. The three main species of economic importance *Liriomyza trifolii* (Burgess 1880), *Liriomyza sativae* Blanchard, 1938 and *Liriomyza huidobrensis* Blanchard, 1926, are native to the American continent and have a history of rapid dissemination and occupation of different environments and are currently present in different parts of the world (Figures 2, 3, 4, 5 and 6) [4,5,6].

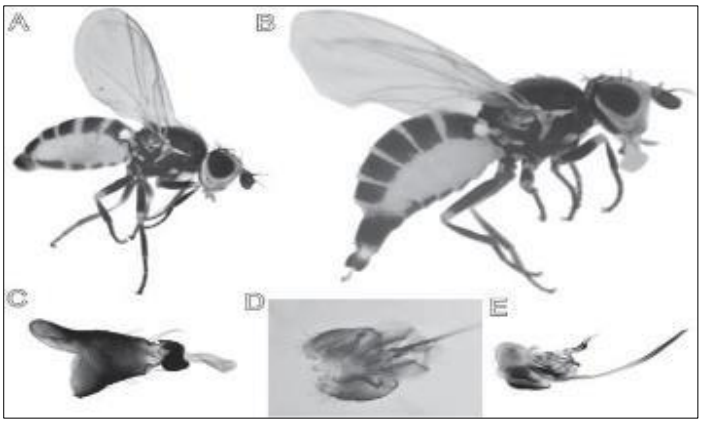

Figure 2 Agromyzidae: lateral view of adult's male (A) and female (B), female ovipositor sheath (C), male genitalia ventrally (D), and laterally (E); (Source: a-entomologist/volume-101/issue-3/024.101.0333/First-Report-of-Phytomyza-orobanchia-Diptera--Agromyzidae-from-Poland/10.1653/024.101.0333.full)

Figure 3 *Liriomyza trifolii* **(Burgess 1880)**; (Source: https://keys.lucidcentral.org/keys/v3/leafminers/key/Polyphagous%20Agromyzid%20Leafminers/Media/Html/Liriomyza_trifolii.htm)

Figure 4 *Liriomyza sativae* Blanchard, 1938; (Source:

https://www.insectimages.org/browse/detail.cfm?imgnum=5458912)

Figure 5 *Liriomyza huidobrensis* Blanchard, 1926; (Source: https://www.biolib.cz/en/taxon/id119251/)

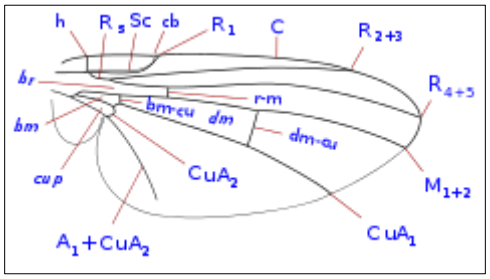

Figure 6 Wing vein 6 is present, falling short of the wing margin (Agromyzidae); (Source: https://www.wikiwand.com/en/Agromyzidae)

1.2 Geographical distribution

Agromyzids are distributed all over the world, from North Greenland to Patagonia and in the sub-Antarctic islands of South New Zealand. Miner flies of the genus *Liriomyza* are widely distributed in the New and Old World; however, they are more common in temperate areas, with few species in the tropics. Of the five species considered polyphagous, *Liriomyza bryoniae* (Kaltenbach, 1858) and *Liriomyza strigata* (Meigen, 1830) are native to Europe and *Liriomyza trifolii* (Burgess & Comstock 1880), *Liriomyza sativae* Blanchard, 1938 and *Liriomyza huidobrensis* Blanchard 1926 are native to the Americas. Currently, the last three species mentioned have caused concern because of the high level of polyphagy and the increase in their occurrence in new geographic areas [7,8].

1.3 Damage

Numerous cultivated plant species and even some weeds, of herbaceous size, all over the world, including Brazil, have their leaves mined by larvae of several species of tiny flies belonging to the order Diptera and family Agromyzidae. This complex of fly species, very similar to each other, is scientifically called *Liriomyza* spp. They are commonly called leafminers, leafminers, leafminers, larvae-miners (Figure 7) [9,10].

Figure 7 *Liriomyza* spp.; (Source: https://cipotato.org/riskatlasforafrica/liriomyza-trifolii/)

Specifically in the potato crop, *Solanum tuberosum* L., the species that attacks it is *L. huidobrensis*, discussed below. As with all species of miners, *L. huidobrensis* also presents a complete development cycle, passing through the egg, larva, pupa and adult stages (Figure 8).

Figure 8 Morphological features of *Melanagromyza sojae* (Zehntner, 1900): A) Female adult; B) Egg laying; C) Larva; D) Anterior spiracles of larva; E) Pupa; F -G) Posterior spiracles of pupa; H) Wing and detail of insertion of subcostal vein (photos by L. Vitorio); (Source: https://www.researchgate.net/figure/Morphological-features-of-Melanagromyza-sojae-A-Female-adult-B-Egg-laying-C-Larva_fig2_332118344)

1.4 The biological cycle

The biological cycle of the insect is very variable, depending on the climate, usually around 21 to 28 days. Under favorable climatic conditions its cycle is reduced, and its population can evolve rapidly in a short period of time, giving many generations per year. The biological cycle for *L. huidobrensis*, around 15 days, with the following duration of each phase: egg – 2 days; larva 4.2 days and pupa – 9 days. Adults are dispersed by the wind over great distances, being carried from one crop to another(s) (Figure 9) [11,12,13,14].

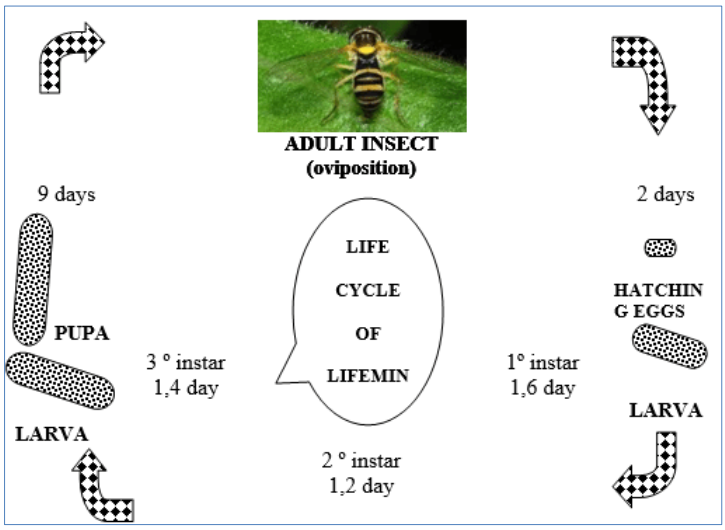

Figure 9 Life cycle of *Liriomyza huidobrensis* Blanchard 1926 (Diptera: Agromyzidae) in the potato crop; (Source: Adapted from Nakano (1993)

1.5 Damage

The main damage resulting from the *Liriomyza* spp. it results from larval feeding, which reduces the plant's green area and, consequently, its photosynthetic capacity. A severe attack early in the plant's development can cause its death. Aesthetic damage is also important when the leaf is the product to be marketed, and can be caused by mines formed by larvae, oviposition points or punctures in the feeding of females. These openings can also serve as an entry point for pathogens (Figure 10) [15,16,17].

Figure 10 Larva of *Liriomyza asclepiadis* Spencer, 1969 on leaf of *Asclepias; (*Source: https://en.wikipedia.org/wiki/Agromyzidae)

1.6 Control

Their host plants, in southern Minas Gerais, for example, are potatoes, common bean and some weeds associated with them in crops, such as black-and-white (Solanaceae). The leaf miner occurs in potato plantations in the south of Minas, where it has been studied throughout the year, mainly in those with the cultivars Achat, Bintje and Atlantic, implanted in the winter planting, carried out from the end of March to June /July, requiring chemical control (Figure 11) [17,18,19].

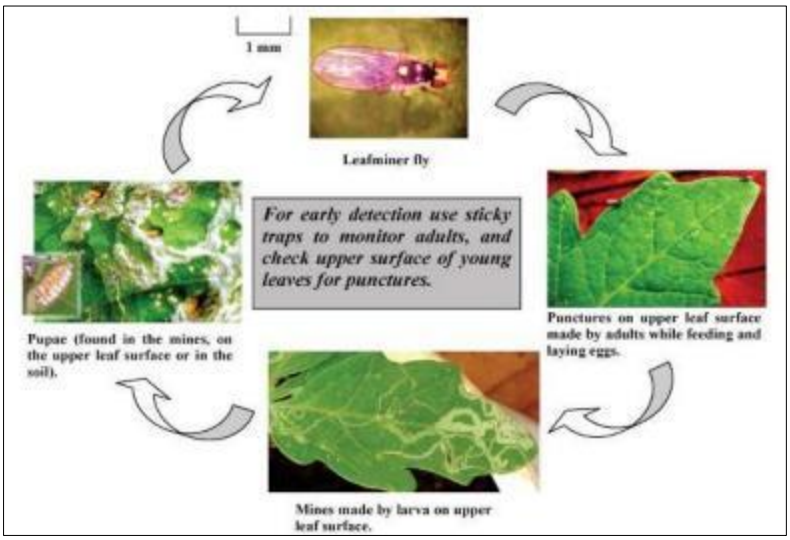

Figure 11 Adult American serpentine leafminer. Prospects of fungal endophytes in the control of *Liriomyza leafminer* (Blanchard 1938) flies (Diptera: Agromyzidae) in common bean; (Source: Photograph by Lyle J. Buss, University of Florida)

In that region, as the miner has started its infestation in the field later, from 40-45 days after planting, in the lower leaves, initially, with maximum infestation peak at approximately 75 days after planting, no large amounts are expected. Damage to the productivity of tubers. However, in an experiment installed in the same region in 1997, under an atypical, hot, and dry winter, plants from plots treated with insecticides showed, on average, an increase of 14% in commercial tuber production compared to plants that did not receive the control.

1.7 Management

This increase in production, converted into money, was higher than the cost of controlling the insect at the time, hence it was economically viable. On the other hand, if the miner infests earlier in the field, for example, as early as 25 days after planting, as occurs in some potato producing regions in the state of São Paulo, with an infestation peak 60 days after planting, they may losses occur, since as a consequence of the presence of mines in the leaves caused by the insect's larvae, there will be a reduction in the crop cycle within the period of greatest weight gain and in the transversal diameter of the tubers, resulting in small tubers, of low commercial value in the market, about 30 to 40% of the market price of the special potato (Figure 12) [18,19, 20 21,22].

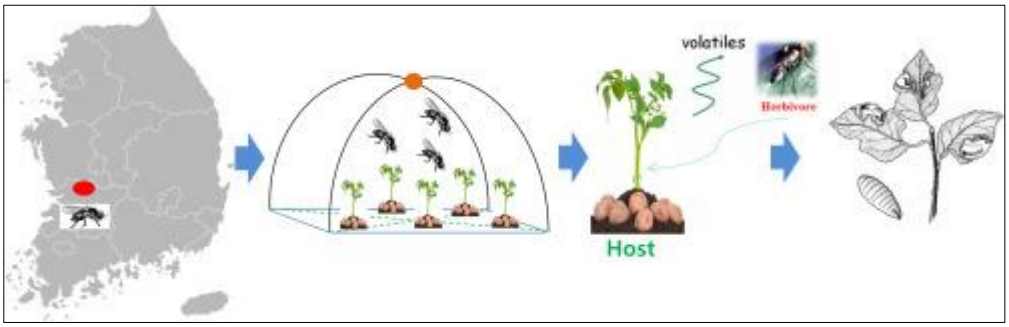

Figure 12 Different potato (*Solanum tuberosum* L.) cultivars mediated life-history variables of the potato leafminer, *Liriomyza* (Korean); (Source: https://www.sciencedirect.com/science/article/abs/pii/S1226861516302758)

1.8 Taxonomic

Agromyzidae Fallen 1810, ENG: Leafmining flies Diversity: 27 genera, ~2.850 species (Containing group: Diptera: Cyclorrhapha: Opomyzoidea).

1.8.1 Subfamily: Agromyzinae and Phytomyzinae

Several species, including those of the *Agromyza* and *Liriomyza* genera, can produce stimulation with part of the first segment of their abdomen and femur.

1.8.2 Taxonomy for Agromyzidae

Agromyzidae has 4 sub-category (s)

Calycomyza: this category has 1 species, *Japanagromyza*: this category has 1 species, *Liriomyza*: this category has 1 species, *Phytomyza:* this category has 1 species. The Agromyzidae are called the leaf-miner or leaf-mining flies and not without reason, although a substantial fraction of the species feed as larvae on other parts of living plants. While Agromyzidae is traditionally placed in the superfamily Opomyzoidea, its exact relationships with other Acalyptrate Diptera are poorly understood.

Two subfamilies are recognized within the leaf-mining flies: Agromyzinae and Phytomyzinae. Both are now recognized as natural groups. Unfortunately, the genera are not as well defined: at least *Ophiomyia, Phytoliriomyza* and *Aulagromyza* are paraphyletic in DNA sequence analyzes (Figure 13) [23,24,25].

1.8.3 Liriomyza sativae

leaf miner Leaf miner fly, leaf miner larva *Liriomyza sativae* Blanchard, 1938.

Crops Affected: Potato, Eggplant, Watermelon, Melon, Pepper, Tomato.

These are insects whose larvae cause damage to potato, eggplant, pea, onion, watermelon, melon, pepper and tomato crops.

Damage: The larvae open mines inside the leaf parenchyma, feed on the tissues and partially or totally destroy the leaf, causing its drying. In certain cases, when the attack is very intense, they can harm the development of the culture.

Control: Spraying with pyrethroid insecticides or application of crop-specific granulated systemic insecticides, registered for crops, is recommended [25].

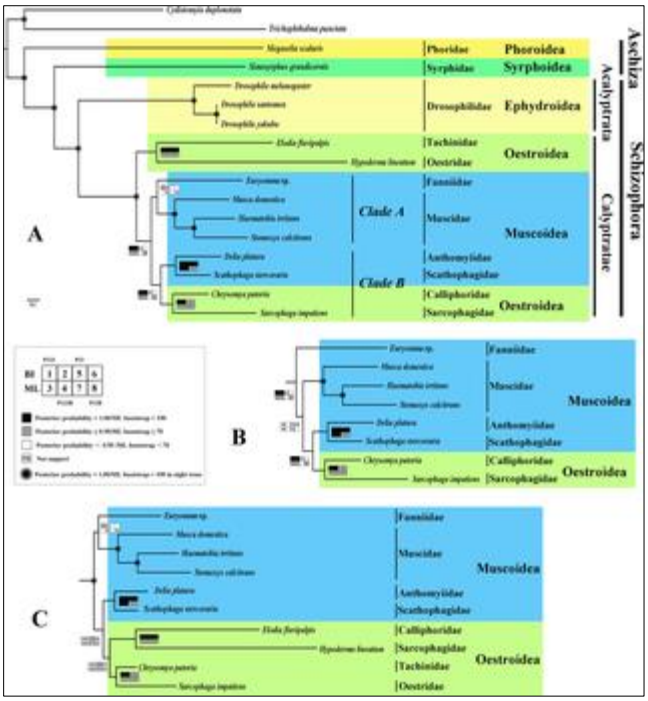

Figure 13 Phylogenetic tree based on mt genome data Cladogram of resulting relationships from Bayesian analyzes with datasets and ML analyzes with datasets, with *Cydistomyia Duplonotata* (Ricardo, 1914) (Nemestrinidae) and *Trichophthalma punctata* (Macquart, 1846) (Tabanidae) as outgroups. A. The Bayesian tree and RNA datasets as well as the ML tree and datasets. B. Part of the Bayesian tree dataset as well as the ML tree C. Part of the Bayesian tree of PCG12 dataset; (Source: https://doi.org/10.1371/journal.pone.0134170.g004)

Objective

The objective of this work is to research the biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology, of the Agromyzidae family (Insecta: Diptera).

2 Methods

The Agromyzidae Family (Insecta: Diptera) related to its biogeography, bioecology, habitat, geographic distribution, taxonomy, life cycle, phenology and taxonomic and conceptual aspects of the Family, Subfamilies and Species. To this end, a bibliographic survey of Agromyzidae was carried out in the years 1937 to 2021. Only complete articles published in scientific journals and expanded abstracts presented at national and international scientific events, Doctoral Thesis and Master's Dissertation were considered. Data were also obtained from platforms such as: Academia.edu, Frontiers, Qeios, Pubmed, Biological Abstract, Publons, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science and ERIC.

2.1 Study 1

The aim of this manuscript is the biology, ecology, biological cycle of the species *Liriomyza huidobrensis* Blanchard, 1926.

An exotic fly species, the serpentine leafminer, *L. huidobrensis*, has been detected infesting field vegetables in western Sydney. The serpentine leafminer is a pest with a wide host range, spanning vegetable, potato, nursery and broadacre cropping plant species. While a biosecurity response is currently underway at the time of writing this article, here we investigate the potential impact from a grain's perspective should this species establish in Australia. Life cycle and

feeding symptoms the serpentine leafminer belongs to a family of leaf-mining flies called 'Agromyzidae', which tunnel through internal plant tissue as larvae.

The serpentine leafminer fly lifecycle has four stages:

Adults' flies are small (1 – 2.5 mm in length) and black with yellow spots on the head and thorax. They feed on plants and lay microscope, translucent eggs inside plant tissue.

The eggs hatch and larvae tunnel through plant tissue feeding. The larvae are legless about 3.5 mm long when mature found feeding inside the leaf. They change from creamy-white to pale yellow-orange as they grow through three instars. Once they approach maturity, the larvae cut a slit in the plant and drop to the ground to pupate. The pupae oval segmented and slightly flattened, dark brown to black between 1.6 mm and 3.3 mm in length.

Adult flies emerge from pupae and mate. While adult feeding does create stippling symptoms and can expose plant to secondary infection, most damage occurs from larvae feeding and creating thick white trails called leaf mines. Leaf mines can reduce the photosynthetic ability of the plant and reduce the growth and development of seedlings and young plants. In severe cases, the miner feeding can lead to plant death. Mining is usually restricted to the leaves; however, add vegetable pods can display symptoms.

Figure 14 Serpentine leaf miner *Liriomyza huidobrensis* Blanchard, 1926 (Diptera: Agromyzidae) larvae damage (left) is not distinguishable by eye from native and established species in Australia (up and down); (Source: Photo by National Plant Protection Organization, the Netherlands, Bugwood.org, CC BY-NC 3.0 US)

Figure 15 Serpentine *Liriomyza huidobrensis* Blanchard, 1926 (Diptera: Agromyzidae) leaf miner (*L. huidobrensis*) Diptera: Agromyzidae) larvae damage is not distinguishable by eye from native and established species in Australia; (Source: Photo by Elia Pirtle, Cesar Australia)

Australia is already home to several native and introduced leafminer flies. Species that can occur within cultivated grains and pulses include the cabbage leafminer, *Liriomyza brassicae* (Riley, 1885) (Diptera: Agromyzidae), which attacks a wide range of brassica crops and can occasionally be found within canola, *Ceradontha* (Diptera: Agromyzidae) species leafminer which attack grasses and are occasionally found in cultivated grains such as wheat and barley, and the rice

leafminer *Hydrellia* spp. (Diptera: Agromyzidae) which can occasionally be found within rice. None are considered problematic pests (Figures 14, 15 and 16) [26].

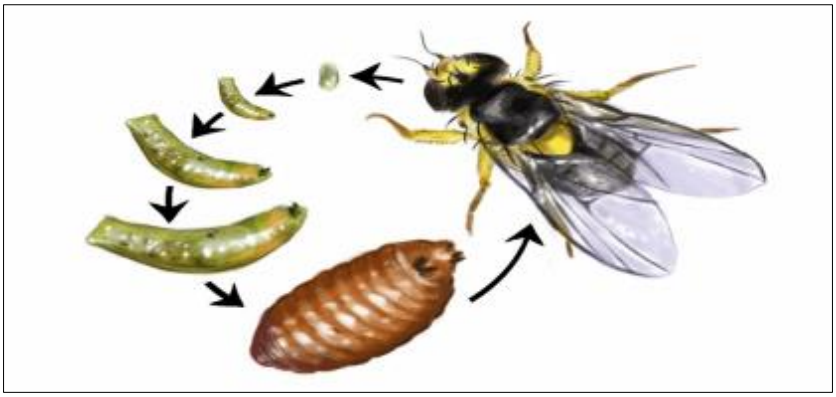

Figure 16 The serpentine *Liriomyza huidobrensis* Blanchard, 1926 (Diptera: Agromyzidae) leafminer life cycle has four life stages: egg, larva, pupa, and adult; (Source: Illustration by Elia Pirtle, Cesar Australia)

2.2 Study 2

The aim of this is the bioecology of the species *Liriomyza trifolii* (Burgess 1880)

Adult - The small fly, about 2.5 mm long, is dark gray with yellow markings.

Egg - The tiny, whitish egg is deposited in the leaf.

Larva - The legless, whitish to yellow larva grows to about 2 mm long, with a darker head and a mouth hook structure that is retractable into the body.

Pupa - The pupa, formed within the old skin of the last larva (puparium), is yellowish brown (Figure 17) [27].

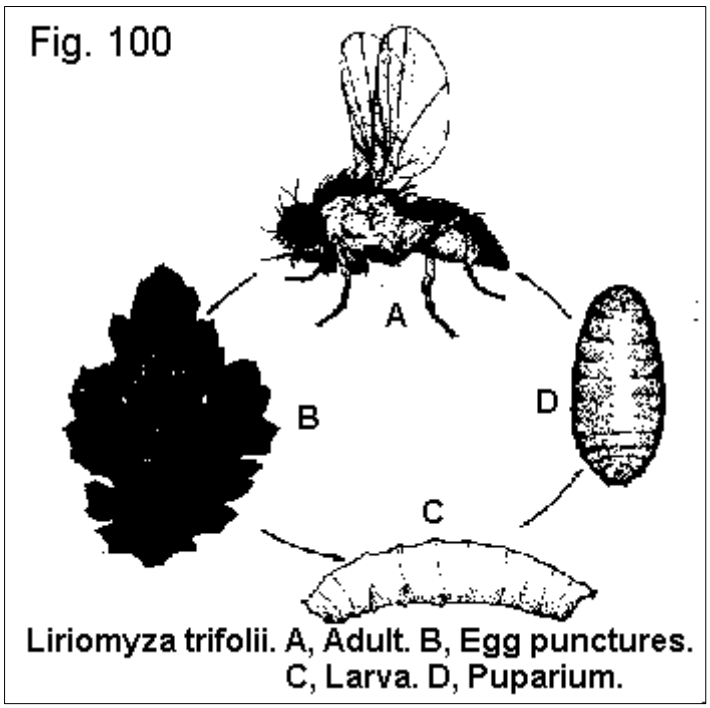

Figure 17 *Liriomyza trifolii* (Burgess, 1880), no common name, Agromyzidae, Diptera A, Adult. B, Egg punctures. C, Larva. D, Puparium; (Source: Elia Pirtle, Cesar Australia)

Distribution - Presently, *L. trifoli* occurs primarily in Florida and California, and is rarely found in greenhouses along the eastern United States to Maryland. It is also found in Central America.

Host Plants – *L. trifolii* (Burgess 1880) has been found on many plants. Some of the hosts are aster, dahlia, marigold, chrysanthemum, sunflower, zinnia, baby's breath, mistflower, petunia, daisy, eggplant, celery, carrot, potato, beans, garden pieces, cantaloupe, lettuce, cucumber, and garden onion.

Damage - Large populations of these flies destroy leaves and seriously retard growth of young plants. The presence of the larval mines reduces the commercial value of ornamental plants and cut flowers.

Life History – *L. trifolii* is one of a few leafmining flies that are truly polyphagous. It feeds on many economically important plants and can be destructive leaf miner of chrysanthemums, gerbera daisies, tomatoes, celery, and other vegetables.

Liriomyza trifolii breeds throughout the year in southern Florida, but it has only 3 to 4 complete generations in its more northerly range. The first generation appears in April, and the egg stage last only 2 days. In the leaves, the larvae form linear mines, if space is available, confining phrases to the sides in regular, alternate strips. If leaves are very small, the larvae form blotch mines. There are three larval stages each requiring 7 to 8 days to develop. Pupation occurs within the leaf and lasts 7 to 11 days, depending upon the time of the year. Adults live 3 or4 weeks. Partial generations occur in the winter when the reproductive activities of the insects decrease. The flies can be found in greenhouses year-round [27].

2.3 Study 3

The miner fly, *Liriomyza sativae* (Blanchard, 1938) (Diptera: Agromyzidae) causes serious damage in tomato crops. When L. sativae larvae develop on the leaves of tomato plants, they cause up to 65% reduction in photosynthesis. Another consequence is the entry of opportunistic pathogens in tomato crops, through feeding punctures performed by females. It stands out as an important pest for the tomato crop, as it causes a reduction in productivity and harms producers (Figure 18) [28].

2.3.1 Hosts

There are well over 20 hosts in the Cucurbitaccae, Fabaceae, Solanaceae and Brassicaceae families recorded for this insect. In Hawaii it is considered a serious pest of beans, broccoli, cauliflower, celery, Chinese cabbage, Chinese wax gourd, cucumber, edible gourds, eggplant, green beans, hyotan, lettuce, luffa, onion, passion fruit, peppers, pumpkin, squash, togan, tomatoes, watermelon, yardlong beans and zucchini.

2.4 Distribution

Native to the Americas, this insect is widespread over North, South, and Central America. In the Pacific it is present in Tahiti, Guam, New Caledonia, American and Western Samoa, Vanuatu, and Hawaii. It is present on all major islands in Hawaii.

2.5 Damage

Larvae produce continuous mines in leaves and young tender stems. Mines are linear and irregular, whitish or greenish in color, with conspicuous black thread-like strips of frass at alternate sides of the channel. Individual mines are of little significance; however, entire leaves may be mined when larval populations are large. In large numbers the feeding damage can severely weaken or even destroy both mature and young plants. Heavily damaged plants appear as if they have been scorched by fire. Infested leaves are more susceptible to wind damage and possibly plant pathogen infection (Figure 18) [28].

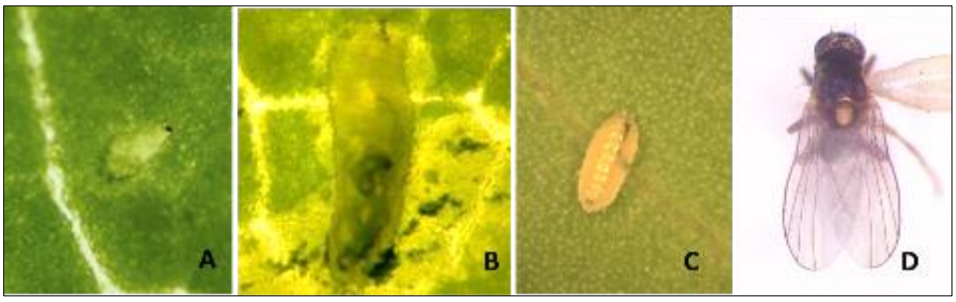

Figure 18 Egg Eggs are off-white, slightly translucent, and about 0.2–0.3 x 0.10–0.15 mm in size (Photo 2A). Larva is headless maggot up to 3 mm in length when fully grown. First instar larvae are colorless on hatching, turning pale yellow orange. Later in stars are yellow orange (Photo 2B). Larvae (and pupae) have a pair of posterior spiracles shaped like a triple cone. Each posterior spiracle opens by three pores, one pore located toward the apex of each cone. Pupa The pupa is oval, slightly flattened ventrally, 1.3–2.3 x 0.5–0.75 mm, with variable color, pale yellow orange often darkening to golden brown (Photo 2C). Adult Adults are very small (1.3–2.3 mm in body length, up to 1.7 mm in female with wing length), grayish-black, compact-bodied. Females are slightly larger than males. The mesonotum is shiny black to the edge of a bright-yellow scutellum; the face, frons, and third antennal segment are bright yellow (Photo 2D); (Source: hrome-
extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=http%3A%2F%2Fnkxms1019hx1xmtstxk3k9sko.wpengine.netdna-cdn.com%2Friskatlasforafrica%2Fwp)

2.6 Study 4

The objective of this work was to evaluate the parasitoids of *Liriomyza huidobrensis* Blanchard, 1926 (Diptera-Agromyzidae).

From puparia collected in the plots where the treatments were applied, there was the emergence of 1,173 individuals of *L. huidobrensis* and 610 parasitoids, which represented a total parasitism rate of 34.21%. Among the parasitoids, there was a predominance of *Chrysocharis bedius* (Walker, 1842) (Hym.: Eulophidae), in 59.34% of the parasitized puparia. Still, there was the emergence of *Opius* sp. (Hym.: Braconidae, Opiinae), Eucoilinae (Hym.: Figitidae) and parasitoids of the order Diptera, corresponding to 38.69%, 1.64% and 0.33% of the total parasitoids, respectively.

Zaeucoila unicarinata Ashmead, 1903 (Hym.: Cynipidae) and the others belonging to the subfamilies Entedontinae (Eulophidae) and Braconinae (Braconidae) (Figure 19) [29].

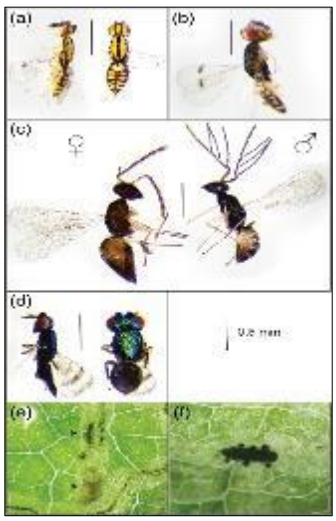

Figure 19 Adult stage and immature stages of parasitoid wasps (Hymenoptera: Eulophidae) reared from *Liriomyza sativae* (Blanchard, 1938)on Thursday Island, Australia, in order of frequency of collection: (a) *Zagrammosoma latilineatum* Ubaidillah, 2000., (b) *Cirrospilus brevicorpus* Shafee and Rizvi, 1988., (c) *Hemiptarsenus varicornis* (Girault, 1913), (d) *Closterocerus mirabilis* Edwards & La Salle, 2004 (e) wasp larva (species indistinguishable; wasp larva

indicated by solid arrow and host fly larvae indicated by dashed arrow) and (f) wasp pupa (species indistinguishable; three pairs of meconial pillars alongside the pupa); (Source: Hendrickson & Barth 1978)

The few published Australian field studies on the occurrence of agromyzid flies and their parasitoids show a large community of wasps attacking agromyzids, with species mainly from the Eulophidae, Pteromalidae and (Braconidae). The most abundant recorded species are two cosmopolitan eulophid species, *Hemiptarsenus varicornis* (Girault) and *Diglyphus isaea* (Walker), and four Australian species: two eulophid species, *Z. latilineatum* and *C. mirabilis* one pteromalid species, *Trigonogastrella* sp., and one braconid species, *Opius cinerariae* Fischer, for which there is little biological information. One deficiency in the known assemblage in Australia is the absence of parasitoids from the Eucoilinae (Hymenoptera: Figitidae) (Figures 20, 21, 22, 23, 24 and 25) [30].

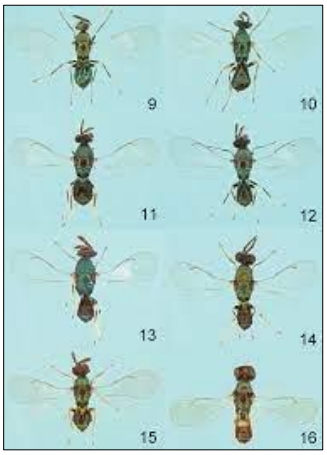

Figure 20 *Diglyphus* spp., length of body, habitus in dorsal view: 9*, Diglyphus isaea* (Walker, 1838) female, 1.7 mm; 10, *D. isaea* male, 1.3 mm; 11, *Diglyphus minoeus* (Walker, 1838) female, 1.7 mm; 12, *Diglyphus minoeus* (Walker 1838) male, 1.7 mm; 13, *Diglyphus poppoea* Walker 1848 female, 1.4 mm; 14, *D. poppoea* male, 1.3 mm; 15, *Diglyphus pusztensis* (Novicky 1951) female, 1.4 mm; 16, *D. pusztensis* male, 1.2 mm; (Source: illustrated by Marlene Cameron)

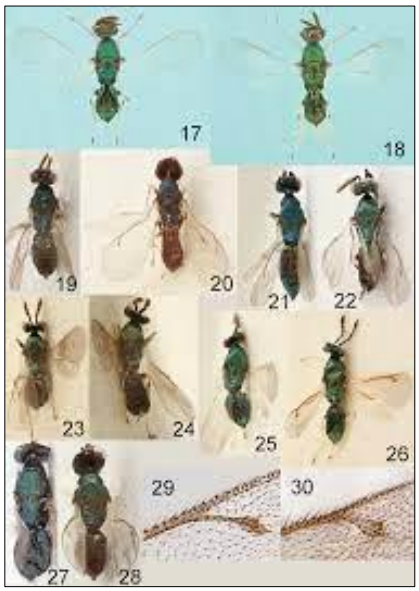

Figure 21 *Diglyphus* spp., length of body, habitus in dorsal view: 17, *Diglyphus sabulosus* Erdos 1951 female, 1.6 mm; 18, *Diglyphus sabulosus* Erdos 1951 male, 1.5 mm; 19, *Diglyphus begini* (Ashmead, 1904) female, 1.7 mm; 20, *Diglyphus begini* (Ashmead 1904) male, 1.1 mm; 21, *Diglyphus chabrias* (Walker 1838) female, 2.1 mm; 22, *Diglyphus chabrias* (Walker 1838) male, 1.6 mm; 23, *Diglyphus eleanorae* Graham 1981 female, 1.6 mm; 24, *D. eleanorae* male, 1.5 mm; 25*, Diglyphus pachyneurus* Graham 1963 female, 1.9 mm; 26, *D. pachyneurus* male, 1.6 mm; 27, *Diglyphus propodealis* Szelenyi 1978 female holotype, 1.5 mm; 28 *Diglyphus subplanus* Erdos, 1958 female, 1.3 mm. 29 & 30. Stigmal vein: 29, *D. chabrias*; 30, *D. propodealis*; (Source: illustrated by Marlene Cameron)

Figure 22 *Diglyphus* spp., head & antenna in lateral view: 49 *Diglyphus albiscapus* Erdos 1951 female; 50, *Diglyphus anadolucus* Doganlar 1982 female; 51, *D. anadolucus* male; 52, *Diglyphus begini* (Ashmead, 1904) female; 53, *D. begini* male; 54, *Diglyphus chabrias* (Walker 1838) female; 55, *D. chabrias* male; 56, *Diglyphus crassinervis* Erdös, 1958 female; 57, *Diglyphus eleanorae* Graham 1981 female; 58, *D. eleanorae* male; 59, *Diglyphus isaea* (Walker, 1838) female; 60, *D. isaea* male; (Source: Hansson C, Navone P. Review of the European species of Diglyphus Walker (Hymenoptera: Eulophidae) including the description of a new species. Zootaxa. 2017; 4269 (2): 197- 229.)

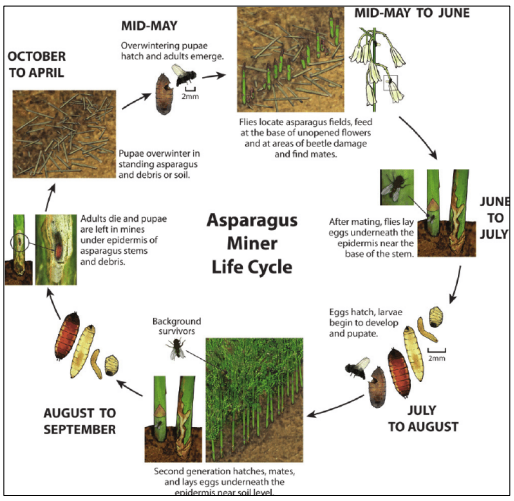

Figure 23 Life cycle of the *Asparagus* miner (*Agromyza simplex* Loew, 1869) based on previously published research; (Source: illustrated by Marlene Cameron)

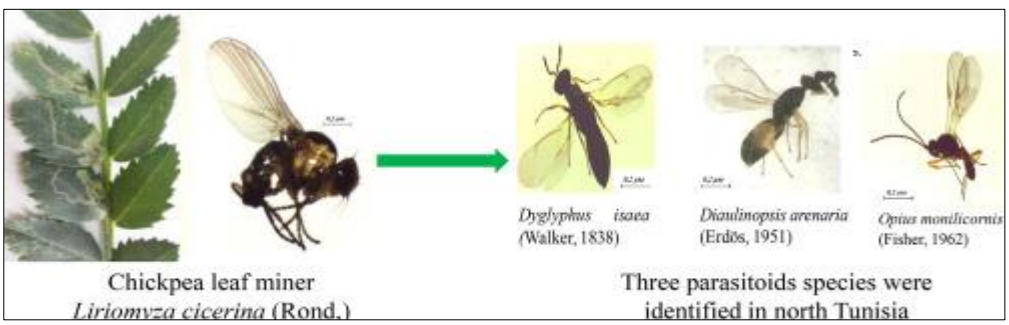

Figure 24 Parasitoids of chickpea leafminer *Liriomyza cicerina* (Rondani, 1875) (Diptera: Agromyzidae) and their parasitism rate on chickpea fields in North Tunisia; (Source: https://www.sciencedirect.com/science/article/abs/pii/S1226861518303443)

Figure 25 Embryonic development of *Opius caricivorae* Fischer, 1964 (Hymenoptera: Braconidae). (A) *O. caricivorae* female laying egg. (B) Egg, 0Ð2 h. (C) Egg, 4Ð6h; developing, embryosho wing cleava genuc leiandt hetrophamnion; arrow indicating micropyle. (D) Egg, 18 Ð20h; arrow indicating alimentary canal. (E) Egg,24Ð26h; arrow indicating dissociated trophamnion cell. (F) Egg,36Ð38h. (G) Egg, 46 Ð48 h; developed embryo showing three-layered egg membrane; arrow indicating inner embryonic membrane. (H) Egg, 46Ð48 h; arrow indicating appendage. Scale bars 1 mm (A) and 30 m (BÐH)

Both adults and miner fly larvae have natural enemies: (1) predators, such as trash insects (Crysopidae), spiders, mites (Phytoseidae)

3 Conclusion

Studies on taxonomy, biology, and ecology of the Agromyzidae family are incipient, so far, in Brazil. The species found in the studies contributes to the knowledge of this fauna that until then was not known in the region. The importance of species as an agricultural pest requires further studies.

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