Open Access Research Journal of
Multidisciplinary Studies
Journals home page: https://oarjpublication/journals/oarjms/
ISSN: 2783-0268 (Online)

(Review Article)

The damage the Family Psilidae to agriculture (Insecta: Diptera)

Carlos Henrique Marchiori *

Goiano Federal Institute, Goiânia Biological Sciences, Goiás, Brazil.

Open Access Research Journal of Multidisciplinary Studies, 2022, 04(01), 063–095

Publication history: Received on 20 July 2022; revised on 25 August 2022; accepted on 27 August 2022

Article DOI: https://doi.org/10.53022/oarjms.2022.4.1.0085

Abstract

Biology of the carrot fly *Psila rosae* (Fabricius, 1794) was described by the Danish zoologist Fabricius as early as the 18th century (Fabricius, 1794). The flies overwinter mainly as pupae in the soil near their host plants, in mild winters also as larvae in the host plant roots or in harvest residues. Depending on the temperature, the first generation of carrot flies hatches from mid/late April and reaches a peak in May. Little is known about the spread of adult flies and their migration to current carrot plots, but vegetation elements presumably play an important role in orientation and protection against dehydration. The aim of the mini review is to study on the biology, behavior and damage caused by the carrot fly (Diptera: Psilidae). The aim of this study is to report the characteristics of the Family Psilidae. For this, a bibliographic survey of Scoliidae was carried out in the years to 2022. Only complete articles published in scientific journals and expanded abstracts presented in national and international scientific events were considered.

Keywords: Management; Brachyceran dipterans; Vegetables; *Psila rosae*; Temperature

1. Introduction

The Psilidae are a family of brachyceran dipterans. These species are small flies measuring 3 to 6 mm on average, almost naked, that is, practically without bristles and with almost no pubescence in most species. Variable in color, yellow to red, brown, black, often bicolor, often glossy (Figures 1, 2, 3 and 4) [1,2,3].

Source: https://naturdata.com/especies-portugal/taxon/0@1-animalia:arthropoda:insecta:diptera/

Figure 1 Adult Psilidae Family

* Corresponding author: Carlos Henrique Marchiori
Goiano Federal Institute, Goiânia Biological Sciences, Goiás, Brazil.

Source: https://species.wikimedia.org/wiki/Psilidae

Figure 2 Adult Psilidae Family

Source: Dorset (August 2011) © Mark Dunkling Psilidae

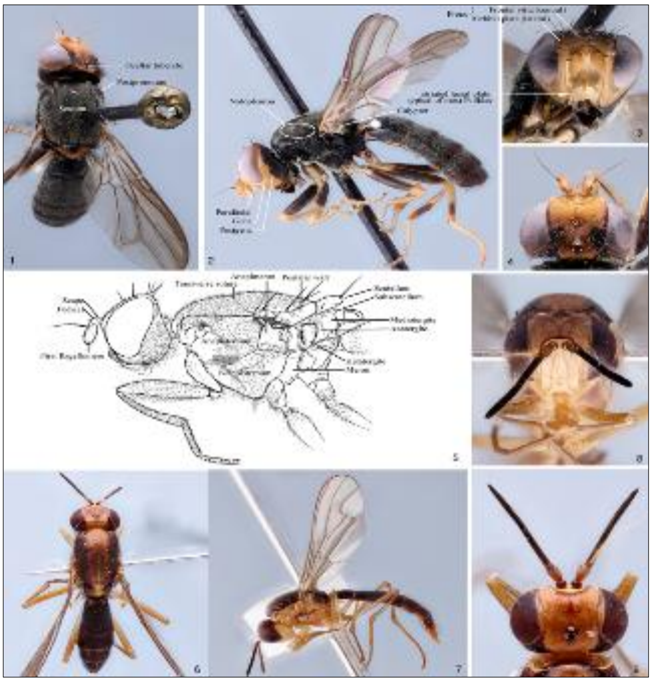
Figure 3 Psilidae male (a) and female (b)

Source: Dorset (August 2011) © Mark Dunkling Psilidae

Figure 4 Adult Psilidae Family

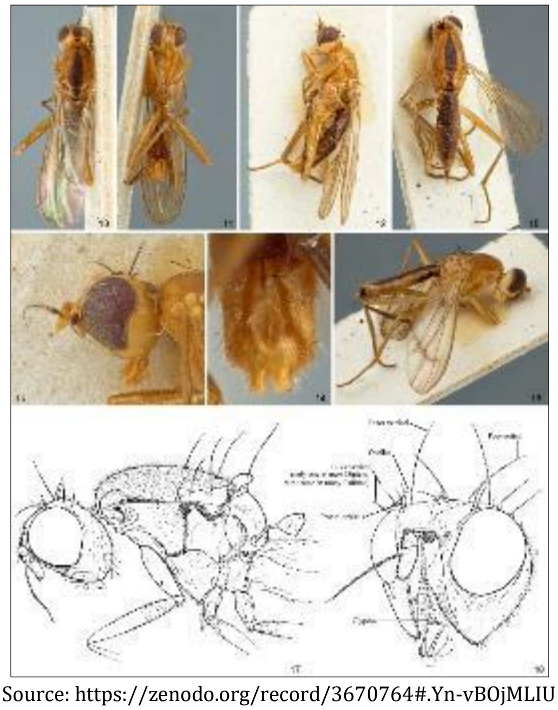
2. Different characters

- Adults Hemispherical or conical head in lateral view.
- Vibrissa absent. Midribs more or less divergent, anal vein short. Large basal cell. Cry without bristles, but most often a notopleural bristle.
- No preapical bristles on tibias (Figures 5, 6, 7, 8, 9 and 10) [4, 5, 6].



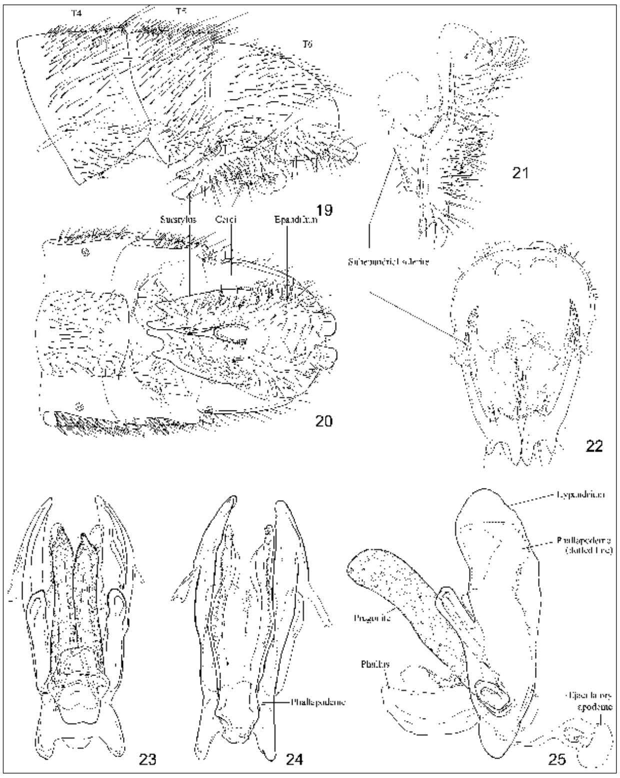
Source: https://zenodo.org/record/3670764#.Yn-vBOjMLIU

Figure 5 1–9. Figs 1–4: *Chyliza* sp. (Psilidae); 1: dorsal; 2: lateral; 3: head, anterior; 4: head, dorsal. Fig. 5: *Chyliza* sp., lateral. Figs 6–9: *Loxocera* sp.; 6: dorsal; 7: lateral; 8: head, anterior; 9: head, dorsal



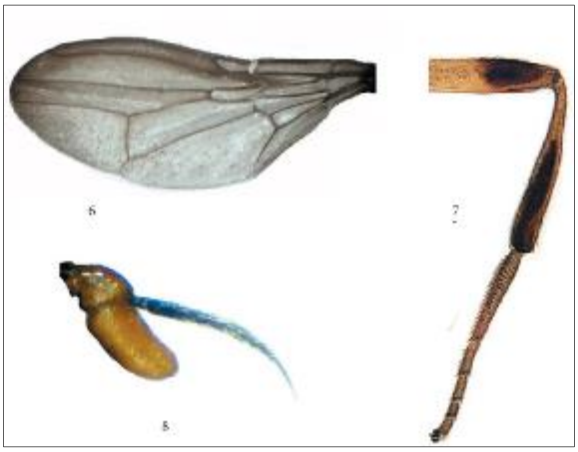
Source: https://zenodo.org/record/3670764#.Yn-vBOjMLIU

Figure 6 10–18. Figs 10–16: *Belobackenbardia cornicula* Shatalkin, 2001 (Psilidae), paratypes; 10: male dorsal; 11: male ventral; 12: male lateral; 13: male head, lateral; 14: male terminalia, ventral; 15: female dorsal; 16: female lateral. Figs 17–18: *Psila hennigi* (Thompson & Pont, 1994) (Psilidae); 17: lateral; 18: head



Source: © Lonsdale, Owen

Figure 7 19–25. Figs 19–25: *Belobackenbardia cornicula* Shatalkin, 2001, paratype, male abdomen; 19: segment 4 to genitalia, lateral; 20: same, ventral; 21: external genitalia, lateral; 22: same, anterior; 23: internal genitalia, ventral; 24: same, dorsal; 25: same, left lateral

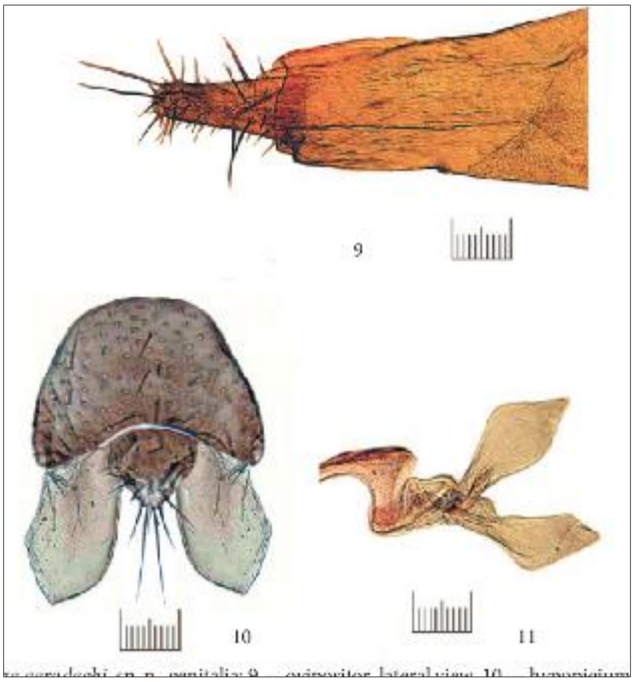


Source: Vestnik Zoologii. 2014: 275-280

Figure 8 6–8. *Chyliza qaradaghi*, sp. n., holotype: 6 — left wing, 7 — pattern of hind leg, 8 — antenna, lateral view

Source: Vestnik Zoologii. 2014: 275-280

Figure 9 2–5. *Chyliza qaradaghi* sp. n., head: 2, 3 — female (2 — lateral view, 3 — dorsal view), 4, 5 — male (4 — lateral view, 5 — dorsal view)



Source: https://tb.plazi.org/GgServer/html/BD15296C6A66FF9BFF1AFEB6DAC1A1B2

Figure 10 *Chyliza qaradaghi*, sp. n., genitalia: 9 — ovipositor, lateral view, 10 — hypopygium, dorsal view, 11 — aedeagus. Scale bar 0.1 mm

2.1. Larvae

More or less narrow at both ends. Posterior stigma with three pores and anterior stigma with six digitations. Last abdominal segment with small pointed protuberance (Figures 11 and 12) [7, 8, 9].

https://www.growveg.co.uk/pests/uk-and-europe/carrot-root-fly/

Figure 11 Psilidae larva

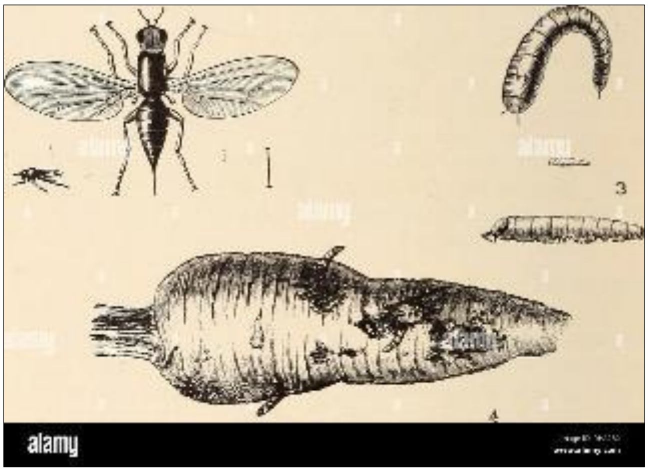
Source: http://www.downgardenservices.org.uk/carrotrf.htm

Figure 12 The rust-coloured tunnels can be seen in this affected parsnip which has also been infected by canker

2.2. Habitat

Root flies are most common in dense vegetation [10].

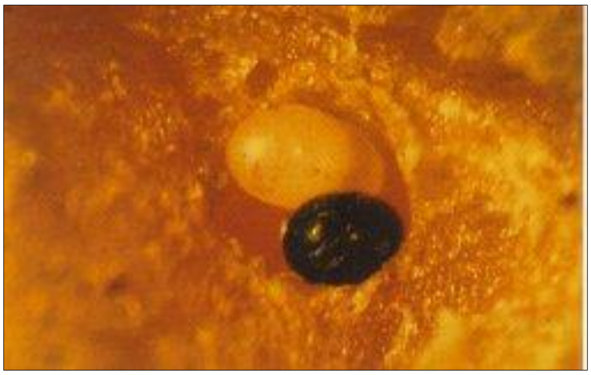
2.3. Biology



Source: https://www.alamy.com/the-book-of-gardening-a-handbook-of-horticulture-gardening-floriculture-the-book-of-gardening-drawn-in-the-autumn-the-roots

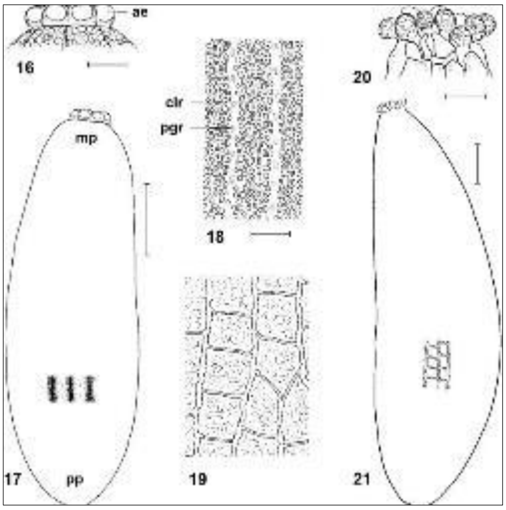
Figure 13 Larva, pupa and adult Psilidae and also been infected by cancer and also been infected by cancer and carrot parasite by Psyllidae larvae Psyllidae

The Psilidae are more common in cold places. This explains why this family is well represented in temperate zones. Larvae are almost exclusively phytophagous. They live in stems or roots. Some can cause galls. Several species are known as pests. Some associations are well documented, from horticultural and agricultural data, for example *Chamaepsila rosae* (Fabricius, 1794), pest of crops, especially carrots (*Daucus carota* Degen, 1998). The larvae feed on plants, often in roots, tubers and stems (Figures 13, 14A, 14B and 15) [10, 11, 12].



Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 14A Cavity in carrot root containing weevil eggs



Source: https://www.researchgate.net/figure/21-Eggs-of-Psilidae-Psila-Xenopsila-lateralis-Canada-Ontario-16-micropylar_fig4_270497406

Figure 14B Eggs of Psilidae.: 16 – micropylar cap, lateral view; 17 – egg, 18 – chorion, lateral surface, fine structure. *Chyliza notata* (USA, Virginia): 19 – chorion; 20 – micropylar cap, 21 – eae – aeropyle, clr – longitudinal ridge of chorion, pgr – patch of granular texture, mp – micropylar pole, pp – posterior pole

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 15 Pupa of carrot rust fly, left; larva, right

Carrot fly eggs hatch about a week after laying and the larvae mature into adults after about three months. The female lays her first eggs in April or May, when the cow parsley (a member of the carrot family) is in flower. This first generation lays its eggs in July or August, and these hatch into a second generation (Figures 16, 17, 18, 19, 20 and 21) [13, 14,].

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077htm

Figure 16 Feeding tunnels of the carrot weevil, formed mainly in the upper one-third of the root

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 17 Aster yellows of carrot, with excessive yellow, twisted foliage and hairy roots

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 18 Rust fly on yellow sticky trap in carrot field (Management)

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 19 Carrot weevil monitoring methods: wooden-plate trap, left; carrot-root sections, right (Management)

Source: https://au.gardenwikis.com/1322-carrot-fly-chamaepsila-rosae.html

Figure 20 Carrot fly: how to defend the vegetable garden – Collections

Source: https://www.shutterstock.com/pt/image-illustration/onion-overfly-carrot-fly-scientific-illustration-425888254

Figure 21 Onion overfly, carrot fly. Scientific Illustration. Insect pest's *Eumerus strigatus*, (Fallén, 1817) fall and *Chamaepsila rosae* (Fabricius, 1794). A mature insect, eggs, larvae, bulbs and carrot with larvae

2.4. Taxonomy and Phylogeny

There are about 200 species in the world, 75% occurring in the Holarctic region and 55 species in the Palearctic region. Adults are reddish or brownish.

List of subfamilies

Subfamilies: Chylizinae and Psilinae (Figures 22A and 22B).

Source: https://hmong.es/wiki/Chyliza

Figure 22A Subfamily Chylizinae

Source: https://es.frwiki.wiki/wiki/Psila

Figure 22B Subfamily Psilinae (Psilidae)

List of genera

2.4.1. Genus

Loxocera, Belobackenbardia, Chamaepsila, Chyliza, Loxocera, Loxocerosoma, Oxypsila, Phytopsila, Psila, Psilosoma, Schizostomyia, Synaphopsila and Tropeopsila (Figures 23, 24, 25, 26, 27, 28 and 29) [15,16,17,18].

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=453945

Figure 23 Genus *Loxocera*

Source: https://www.mindat.org/taxon-6183.html

Figure 24 Genus *Chamaepsila*

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=396928

Figure 25 Genus Chyliza

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=453945

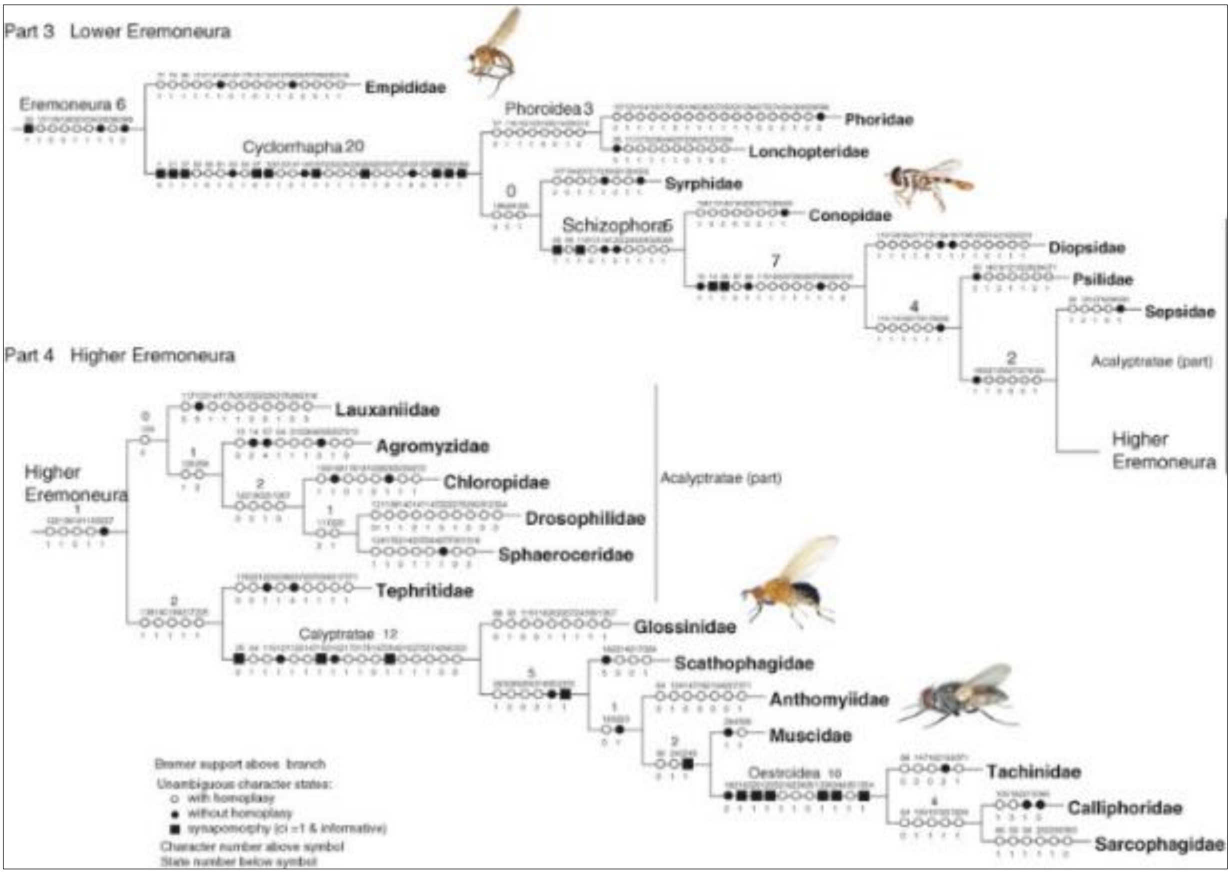
Figure 26 Genus *Loxocera*

Source: http://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=110918

Figure 27 Genus *Psila*

Source: naturalist.org/taxa/1094459-Psilosoma-audouini

Figure 28 Genus *Psilosoma*



Source: https://www.researchgate.net/figure/The-Bayes-combined-majority-rule-consensus-tree-showing-all-compatible-nodes-and-clade_fig3_234834619

Figure 29 The Bayes combined majority rule consensus tree showing all compatible nodes and clade credibility (posterior probability) values above branches

Objective

The aim of the mini review is to study on the biology, behavior and damage caused by the carrot fly (Diptera: Psilidae)

3. Methods

The method used to prepare this mini review was Marchiori 2021 methodology [19].

4. Studies conducted and selected

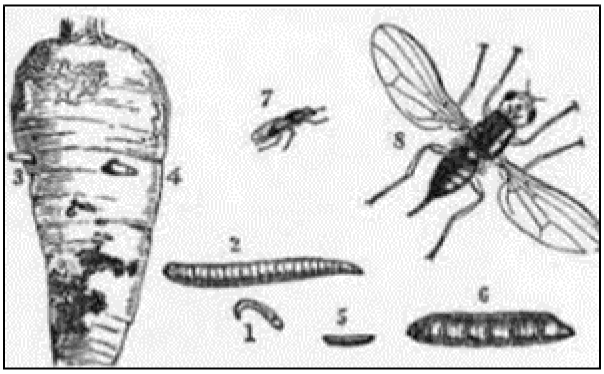
4.1. Study 1

The adult carrot larva is a fly. After fertilization, the female lays eggs in the soil next to her favorite plants. The carrot (fly) larva is born and penetrates the root where it develops, causing damage: bitter taste, rotten pulp, slower growth (Figure 30) [20].

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 30 Larva and pupa of carrot weevil, left; larva, right

After having spent the winter in hibernation in the form of a pupa, the flies appear during the month of May. They generally have two cycles of activity, from May to July, and sometimes a third that occurs in autumn in certain regions (Figure 31).



Source: https://www.countryfarm-lifestyles.com/growing-carrots.html#.Yn_qX6jMLIU

Figure 31 The life cycle of the carrot rust fly

The life cycle of the carrot rust fly They mate and bury their eggs near their favorite plants. The larva that is responsible for the damage is born after 10 to 12 days. From the ground, it approaches the carrot and penetrates its root, digging galleries as it feeds. After a month, having completed its development, the larva leaves the root and settles in the soil, nearby, to spend the winter in the form of a pupa (Figure 32) [20].

Source: https://pt.wikipedia.org/wiki/carrot%20fly

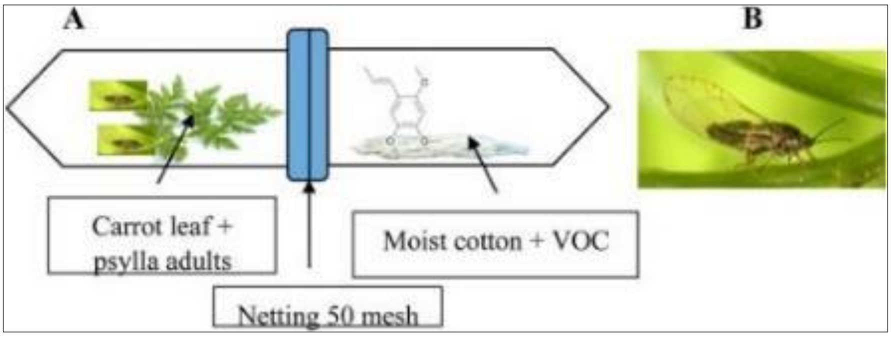
Figure 32 Larvae of the Psilidae

We offer you an effective treatment against carrot (fly) larvae. You can consult, immediately below, the list of our organic products against carrot (fly) larvae (Figure 33) [20].

Source: Len McLeod

Figure 33 Carrot root fly *Psila rosae* (Fabricius, 1794) larva in damaged carrot

It is a fly that gives rise to carrot larvae. The female lays her eggs in the ground, next to the sedlings of the plantations. At birth, the larva penetrates the carrot to feed and develop, causing damage (Figure 34) [20].



Source: https://www.sciencedirect.com/science/article/abs/pii/S0168945221002077

Figure 34 Identification of a wild carrot as carrot *Psylla* attractant and host plant chemistry

A guaranteed effective method that does not harm either the plantations or the soil, the pheromone associated with the trap makes it possible to selectively attract and capture a large number of harmful male insects. Pheromones are volatile substances secreted by females whose function is to sexually attract males (Figure 35) [20].

Source: https://www.google.com/search?q=Delta+trap

Figure 35 Delta trap pheromone trap

Each species produces a specific pheromone, allowing it to capture each type of harmful insect in a way that is as accurate as it is effective. Pheromones are tools for detecting and controlling populations through mass capture (Figure 36) [20].

Source: Stock Photo – Alamy

Figure 36 Adult carrot root fly *Chamaepsila rosae* (Fabricius, 1794) on a carrot

4.1.1. Delta trap

Pheromone trap, recommended to fight garden pests (carrot fly and leek or leek moth) (Figure 37) [20].

Source: https://www.google.com/search?q=Delta+trap

Figure 37 Pheromone trap, recommended to fight garden pests (carrot fly and leek or leek moth) (Management)

A guaranteed effective method that does not harm either the plantations or the soil, the pheromone associated with the trap makes it possible to selectively attract and capture a large number of harmful male insects.

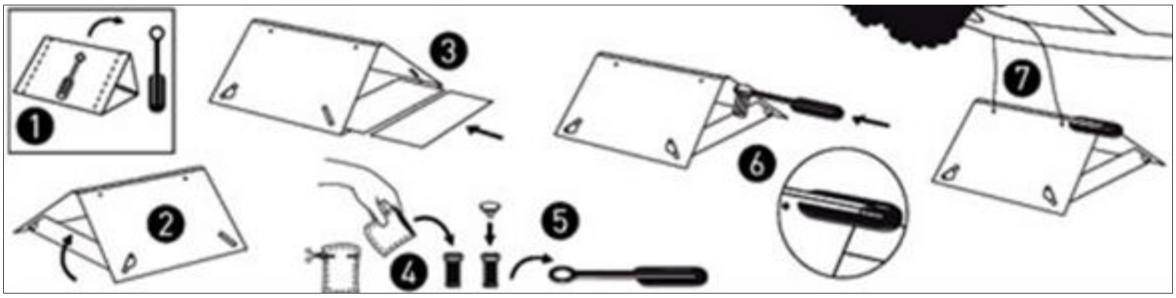
4.1.2. Protection

Potatoes, vegetables and chopped crops.

Placing: Mode of use.

- Remove the pheromone basket holder from the trap.
- Assemble the trap and lift one side, as shown in the diagram.
- Insert the mistletoe plate.
- Remove the protective paper from the mistletoe plate and insert it into the trap.
- Raise the other side of the trap.
- Add the pheromone capsule (which must be purchased separately). To avoid contact with fingers, cut the top of the sachet and drop the capsule directly into the small pheromone basket of the trap.

- Place the pheromone basket in the plastic support provided for this purpose. Fix the set (support + basket with capsule) to the top of the trap. Insert the suspension string (Figure 38) [20].



Source: https://www.google.com/search?q=Delta+trap

Figure 38 Construction of the Delta pheromone trap

Place the trap before the foreseeable attack by the insects (see treatment periods in the pheromone leaflet). For good effectiveness, it is recommended to place 1 trap for 5m linear or $4m^2$. Insects are attracted to the pheromone and end up sticking to the mistletoe board. Traps can be removed at the end of the season and stored for use the following year. Mistletoe plates and pheromone capsules, available separately, can be replaced (Figures 39, 40, 41 and 42) [20].

4.1.3. Growing carrots from seed in seeds, obtainers or Pots

Source: https://www.countryfarm-lifestyles.com/growing-carrots.html#.Yn_t96jMLIV

Figure 39 Heirloom carrot varieties for growing carrots

Source: https://www.countryfarm-lifestyles.com/growing-carrots.html#.Yn_t96jMLIV

Figure 40 Good soil preparation for your carrots and vegetables is essential

Source: https://www.countryfarm-lifestyles.com/growing-carrots.html#.Yn_t96jMLIV

Figure 41 Growing carrots in containers and pots

Source: https://www.agroscope.admin.ch/agroscope/de/home/themen/pflanzenbau/pflanzenschutz/flyipm.html

Figure 42 IPM will improve control of pest root-feeding fly larvae of vegetables using IPM approaches. Collaborative research and extensive communication within the project consortium will assimilate information from basic and applied research to foster commercially-effective pest management practices

4.2. Study 2

The Montseny massif (Barcelona, Spain) is a recent object of indirect and periodic surveys of its entomological fauna (Figure 42A).

Source: https://deims.org/19fd543e-53b2-478e-b9c8-7d1160a0ee82

Figure 42A The Montseny massif (Barcelona, Spain)

Although it may seem banal, we will insist on this occasion on the uses that the sequential and indirect methodology implies. Despite its shortcomings, its application is not only useful in obtaining auto-ecological information, but also provides another strictly faunal utility (Figure 42B).

Source: https://www.inaturalist.org/taxa/326588-Chamaepsila

Figure 42B Psilidae *Chamaepsila*

Thus, among the abundant batch of samples obtained in a program developed between July 1988 and August 1989 near San Margal Spain, in four plots of the oak domain, a total of 4075 dipterans were obtained. After a first study of the referred material, two specimens belonging to two species were identified, which constitute the first date for the Spanish fauna. This interesting material was collected and is deposited in the collection of Carles-Tolrá M (Figure 42C).

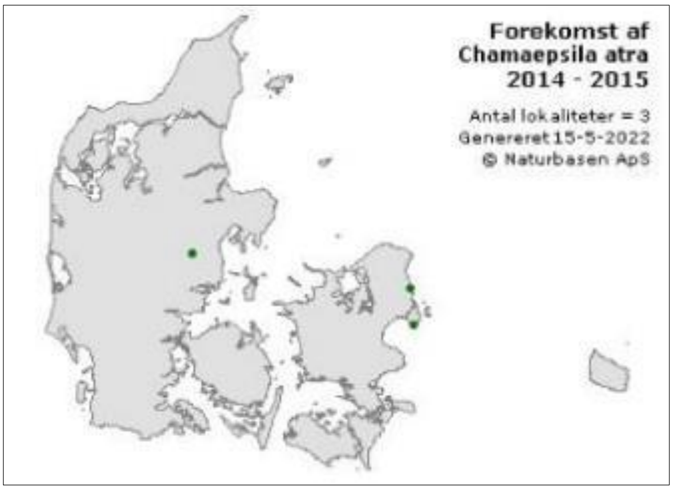
Source: https://www.ricksteves.com/watch-read-listen/read/articles/spains-toledo-a-living-monument

Figure 42C San Margal Spain

Psilidae *Chamaepsila clunalis* (Collin, 1944) Material studied: San Margal (Barcelona), 25.5.1989, 19. Species originally described from Great Britain; was later quoted from Germany (East) and Czechoslovakia. It is related to *Chamaepsila atra* [(Meigen, 1826) (Meigen). The male has wide genitalia with a finger-shaped surstylus. The female has a much narrower ovipositor than the 7th abdominal tergite. Unfortunately, its biology is unknown (Figures 43 and 44) [21,22,23].

Source: https://www.naturbasen.dk/art/28940/chamaepsila-atra

Figure 43 *Chamaepsila atra* (Meigen, 1826)



Source: https://www.naturbasen.dk/art/28940/chamaepsila-atra

Figure 44 Distribution of (Meigen, 1826) based on nature base observations

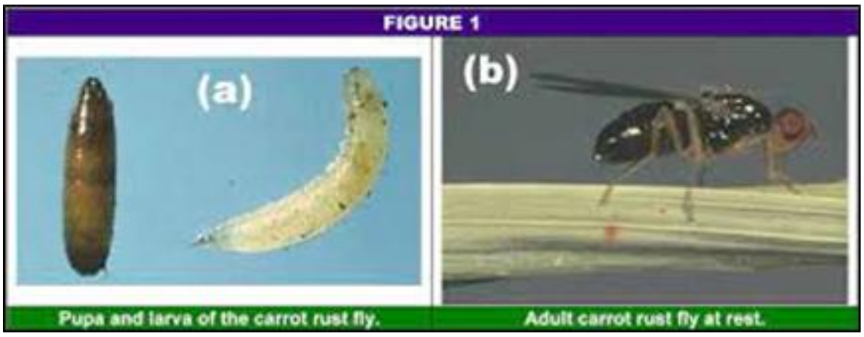
4.3. Study 3

Biology of the carrot fly *Psila rosae* (Fabricius, 1794) was described by the Danish zoologist Fabricius as early as the 18th century (Fabricius, 1794). The flies overwinter mainly as pupae in the soil near their host plants, in mild winters also as larvae in the host plant roots or in harvest residues. Depending on the temperature, the first generation of carrot flies hatches from mid/late April and reaches a peak in May. Little is known about the spread of adult flies and their migration to current carrot plots, but vegetation elements presumably play an important role in orientation and protection against dehydration (Figure 45).

Source: http://www.omafra.gov.on.ca/english/crops/facts/93-077.htm

Figure 45 Pupa of carrot weevil, left; larva, right

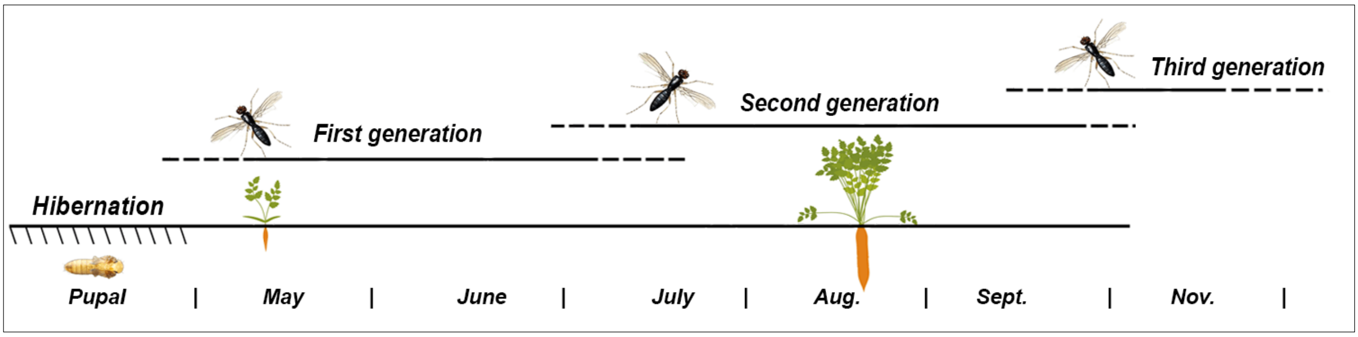
After mating, about 50–150 eggs are laid in crevices in the ground near the host plants. In the evening and morning hours, the females fly repeatedly over several days from the vegetation edge to the carrot stand and then back to the vegetation edge to lay their eggs. The result is a typical edge infestation in the carrot field within the first 40 meters (Figure 46).



Source: https://www.semanticscholar.org/paper/Managing-Carrot

Figure 46 (a) larva and pupa; (b) adult

The larval development extends over three larval stages (L1, L2 andL3), of which the first feeds on the fine lateral roots of the carrots, while from the second larval stage immigration into the main root takes place. The resulting feeding tunnels with the excretions of the larvae then cause the typical damage of the so-called "iron fatigue". After pupation has taken place outside the carrot, the more numerous second generation of carrot flies hatch from the beginning of July (Figure 47).



Source: https://pireco.eu/en/application/controling-carrot-fly/

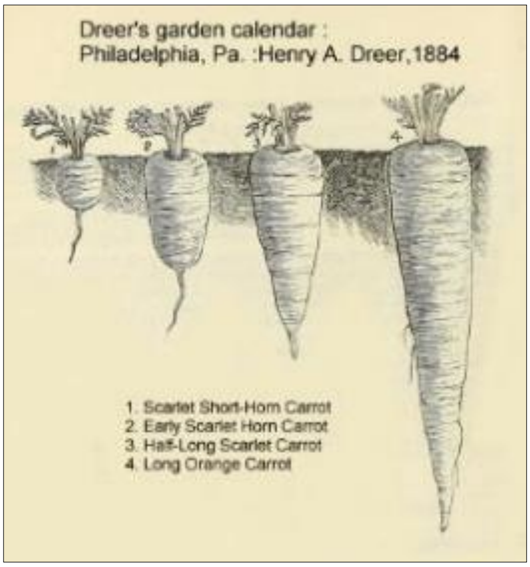
Figure 47 Life cycle diagram of carrot rust fly *Psila rosae* (Fabricius, 1794) in the Holland Marsh, Ontario. This life cycle has an egg stage, 3 larval stages, a pop stage and the imago. About 1 to 10 days after emerging to an adult the flies lay their eggs around the base of the crops

The oviposition of the adult carrot flies in the second generation extends over a longer period than in the first generation and continues into September. A separation from the appearance of a third generation in autumn is not always clear. Second and third generations in turn infect or spread beyond the carrot crop, which may also affect later carrot sets that may have been spared by the first generation. The pest finds its host plants within the Family (Apiaceae). Cultivated carrots (*Daucus carota sativus* L.) are preferentially attacked and represent the greatest propagation potential due to their attractiveness and extensive cultivation (Figure 48).

Source: Nigel Cattlin

Figure 48 Carrot root fly *Psila rosae* (Fabricius, 1794) labral damage to mature carrot tap root, Devon, September captions are provided by our contributors

Herbs such as hogweed (*Heracleum* sp.) are documented occasional host plants for the carrot fly. Even more rarely, non Fapiaceae are attacked such as chicory (*Cichorium intybus* var. *foliosum*), endive *Cichorium endivia* (Asteraceae) and lettuce (*Lactuca* sp.). Due to the continued presence of several alternative host plant species in the cultivated landscape, the carrot fly is ubiquitous in temperate latitudes with low population (Figure 49).



Source: http://www.carrotmuseum.co.uk/historyusa.html

Figure 49 Carrot development *Daucus carota* L. (Apiaceae)

It should be mentioned that in the investigated growing regions there is a general occurrence of *Anthriscus sylvestris* (L.) (Apiaceae) bovine parsley along the roads, as well as isolated occurrences of Giersch *Aegopodium podagraria* L. (Apiaceae) and Hogweed *Heracleum sphondylium* L. (Apiaceae), of which the first two wild herbs have been described as non-host plants *Pastinaca sativa* L. (Asteraceae) and *Daucus carota* l. subsp. *call carota* (Apiaceae). Except for the contribution to the weak infestation background, its influence can be classified as negligible compared to the host range of extensive carrot cultivation (Figure 50) [24, 25, 26, 27, 28}.

Source: https://gardening.which.co.uk/hc/en-gb/articles/115001802005-Carrot-fly

Figure 50 Growing carrots under insect-proof mesh will keep out carrot fly

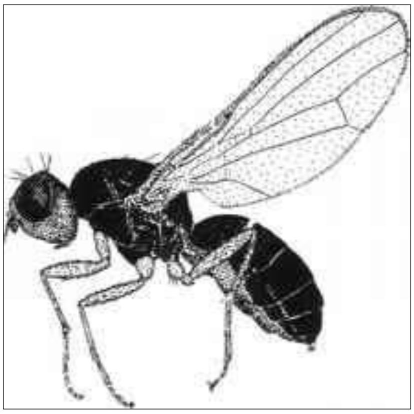
4.4. Study 4

Carrot fly, *Psila rosae* (Fabricius, 1794).

The damage in short.

4.4.1. Boss

an insect of the order Diptera, small, thin black fly, 4-5 mm long. Adult females fly over the rows of carrots from April to May and stay at the foot of the plants. The small whitish larvae gain the roots they dig. These larvae then pupate to give birth to a second generation of flies (Figure 51).



Source: https://www.progressivegardening.com/infested-plants/psila-rosae-f-carrot-fly.html

Figure 51 Carrot fly, *Psila rosae* (Fabricius, 1794)

4.4.2. Apparent damage

The roots are excavated from very thin galleries that may or may not harbor the larvae. When the attack is severe, plant growth is affected, the foliage turns yellow and withers. At this point, the crop is destroyed (Figure 52).

Source: https://commons.wikimedia.org/wiki/File:Psila_rosae_maggot,_wortelvlieg_made.jpg

Figure 52 Larva of carrot fly, *Psila rosae* (Fabricius, 1794)

4.4.3. Damage period

From April to May to fall; two to three generations of flies may succeed each other in the season depending on the region. More sensitive plants: carrots, but also other roots of plants of the Apiaceae family such as parsley, tuberous parsley, celery, parsnip (Figure 53).

Source: https://www.canalagricola.com.br/atratativo-controle-mosca-domestica-varejeira-estabulo-target-5-litros

Figure 53 This attractant, combined with the target fly trap, is the ultimate solution for the biological control of flies, and considerably reduces their population in the control area. Unlike other control solutions, the attractant is 100% organic and does not contaminate the environment. It does not contain components harmful to health, so it can be applied without risk, ensuring the safety of people and animals

4.4.4. Favorable conditions

The most favorable periods for attacking the carrot fly correspond to adult flights, mainly in April-May (with regional change, from north to south), then in August-September (Figure 54).

Source: Photo: Ecycle

Figure 54 Trap for fly control that does not harm the environment

4.5. Study 5

4.5.1. Biological control of the carrot fly

15 plants that help in the biological control of carrot fly an organic garden

Having an organic garden at home requires care and dedication. To control the area naturally, without using chemicals such as pesticides or pesticides, keep the plants listed below close to the crop. The list is from the Domestic Organic Garden Manual, prepared by Clube do Jardim (Figure 55).

Source: https://www.themarket.com.br/13-beneficios-do-manjericao-para-a-saude/

Figure 55 Basil

4.5.2. Basil

Also known as broadleaf basil, this plant is very common in fish seasoning. In addition, its strong smell repels flies and mosquitoes. But be careful, basil should not be planted close to rue.

4.5.3. Garlic

Source: https://www.healthline.com/nutrition/11-proven-health-benefits-of-garlic

Figure 56 Garlic

In addition to being one of the most commonly used spices in cooking, growing garlic in your garden is beneficial, especially if you grow tomatoes. The plant acts as a repellent for pests that usually attack them (Figure 56).

4.5.4. St. Mark's Wort

Also known by the names of tansy or tansy, the strong aroma of this medicinal plant repels flying insects. It can be planted in any area of the garden (Figure 57).

Source: https://www.gardeningknowhow.com/edible/herbs/st-johns-wort/st-johns-wort-plant-care.htm

Figure 57 St. Mark's Wort

4.5.5. Mint

The herbaceous plant is widely cultivated around the world due to its aromatic essences. The smell of mint repels lepidopterans such as the cabbage butterfly, ants and mice. It is a good option to grow mint on the edges of crops (Figure 58).

Source: http://www.ihavilah.com/product/mint

Figure 58 Mint

4.5.6. Thyme

Source: https://www.bolster.eu/summer-thyme-thymus-vulgaris/p9791

Figure 59 Thyme

The plant, widely used in cooking in meat seasonings and sauces, requires little care and prefers dry land. The thyme bush has the power to ward off the cabbage butterfly, considered a pest in some cultivated plants, especially cabbage, cauliflower and broccoli, where the caterpillars defoliate the plant (Figure 59).

4.5.7. Sage

With long and velvety leaves, sage has a strong yet refreshing flavor, slightly resembling rosemary. The herb repels the cabbage moth.

4.5.8. Tagetes

Commonly known as marigold, for having a strong and even unpleasant odor, it is a great natural repellent for many insects and protects against nematodes (Figure 60).

Source: https://www.significados.com.br/alecrim/

Figure 60 Rosemary

4.5.9. Coriander

Coriander, widely used in Brazilian cuisine, mainly in the north and northeast, is efficient in controlling aphids and mites.

4.5.10. Geranium

In addition to being very beautiful and having different colors of flowers, geraniums help protect the garden, as the species is a natural insect repellent (Figure 61).

Source: https://pt.wikipedia.org/wiki/Geranium_sanguineum

Figure 61 Geranium

4.5.11. Citronella

Citronella is a medicinal plant widely used as an insect repellent, being effective against flies, mosquitoes and ants. It helps keep even dengue mosquitoes away (Figure 62).

Source: https://www.thespruce.com/citronella-grass-plant-profile-5119502

Figure 62 Citronella

4.5.12. Anise

Also known as fennel, its stem is widely used in salads and its seed-shaped fruit is used in confectionery and liqueur. Anise has the ability to repel moths.

4.5.13. Nasturtium

Source: https://www.google.com/search?q=Nasturtium&oq=Nasturtium&aqs=chrome

Figure 63 Nasturtium

Also popularly known as C, blood flower and Mexico cress, it is a flower that can be edible, as long as it is grown without the use of pesticides. It repels nematodes, worms that attack and kill plants, and insects (Figure 63) [29,30,31,32].

4.5.14. Wormwood

Medicinal plant, also known as Absinthe, Herb-do-fel, Alenjo, Herb-de-santa-daisy, Sintro or Herb-of-worms. In addition to having an insecticidal odor, it keeps animals away from your garden [29,30,31,32].

4.6. Study 6

4.6.1. 6 garden-friendly animals

Maintaining biological control of your crop is essential; meet animals that are beneficial to farming [33, 34, 35, 36, 37, 38, 39].

4.6.2. Bee

Bees are fundamental to the pollination process (Photo: Creative Commons)

A hive is not just important for the production of honey. Bees are extremely effective in the pollination process, essential for some plants. Its importance is so great that some beekeepers rent their creations to farmers to pollinate their crops.

The presence of bees indicates that there is diversity and that the flowers will multiply. Do not exterminate them. Now, if the swarm is too large, call the fire department for more proper guidance (Figure 64).

Source: (Photo: Creative Commons)

Figure 64 Bees are fundamental to the pollination process

4.6.3. Ladybird

Ladybugs are natural enemies of aphids (Photo: Creative Commons)

The ladybird is one of the main responsible for the biological control of aphids, the famous aphids, which feed on the sap of plants and wreak havoc in gardens. In addition, their diet also includes larvae, mites and small caterpillars harmful to plants and humans.

A ladybug is capable of devouring 200 aphids in a day (Figure 65).

Source: (Photo: Creative Commons)

Figure 65 Ladybugs are natural enemies of aphids

4.6.4. Spider

Spiders are the biggest predators of insects harmful to the garden (Photo: Creative Commons).

Major predators, spiders eat more pests and harmful insects than all other critters combined. So, think twice before stepping on that little spider that decided to take a little walk in your plantation.

Of course, be very careful when you are around: spiders, to defend themselves, can attack humans as well (Figure 66).

Source: (Photo: Creative Commons)

Figure 66 Spiders are the biggest predators of insects harmful to the garden

4.6.5. Worm

Earthworms dig tunnels and produce humus.

One of the main success factors of a good vegetable garden, the earthworm digs tunnels and holes that, in addition to aerating the soil so that the plants "breathe" better, drains rain and irrigation water.

The earthworm also dumps its faeces in the soil and collaborates in the production of humus, organic matter that includes faeces and decomposition of animals and organic remains of plants. Humus is essential for soil enrichment and strengthening (Figures 67 and 68).

Source: (Photo: Creative Commons)

Figure 67 Earthworms dig tunnels and produce humus

Source: (Photo: Creative Commons)

Figure 68 Bed bugs exterminate small pests such as ants

4.6.6. Bug

Bed bugs exterminate small pests such as ants.

Along with the beetles, the bed bugs constitute the “army of the most feared” of the vegetable gardens. Small pests such as aphids and ants that feed on the stem and plants tend to flee the bed bug habitat. The ones that remain are devoured by them, which help maintain biological control of the garden (Figure 69).

Source: (Photo: Source: Creative Commons)

Figure 69 Dragonfly: top of the insect food chain

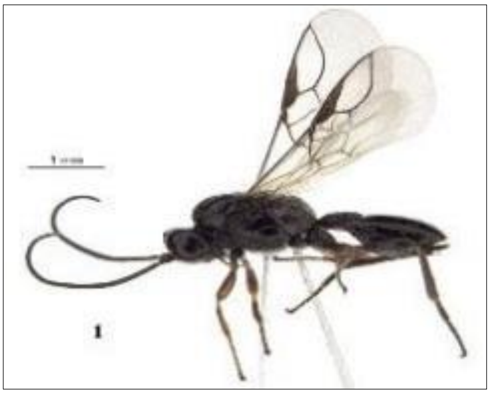
Known as the insect bird of prey, the dragonfly is at the top of the insect food chain, maintaining important control over unwanted or harmful pests and animals.

According to biologists, they eat non-stop and, despite their fragile appearance, are capable of consuming up to 30 flies in a day.

It is important that your garden is not located in places where large predators of the dragonfly live, such as large spiders, frogs and toads [33, 34, 35, 36, 37, 38, 39].

4.7. Study 7

Biological. Natural enemies of carrot rust flies include the parasitoids *Chorebus gracilis* (Nees, 1834) (Hymenoptera: Braconidae), *Eutrias tritoma* (Thomson 1862) (Hymenoptera: Figitidae), and *Aleochara sparsa* Heer, 1839 (Coleoptera: Staphylinidae) which target the early larval and pupa stages of the carrot rust fly (Figures 70, 71 and 72) [40, 41, 42, 43].



Source: https://bugguide.net/node/view/1778394

Figure 70 *Chorebus gracilis* (News, 1834) (Family: Braconidae)

Source: http://www.waspweb.org/Cynipoidea/Figitidae/Classification/Classification_World_Figitidae.htm

Figure 71 *Eutrias tritoma* (Thomson 1862) (Hymenoptera: Figitidae)

Source: https://www.coleoptera.org.uk/species/aleochara-sparsa

Figure 72 *Aleochara sparsa* Heer, 1839 (Coleoptera: Staphylinidae)

5. Conclusion

Biology of the carrot fly *Psila rosae* (Fabricius, 1794) was described by the Danish zoologist Fabricius as early as the 18th century (Fabricius, 1794). The flies overwinter mainly as pupae in the soil near their host plants, in mild winters also as larvae in the host plant roots or in harvest residues. Depending on the temperature, the first generation of carrot flies hatches from mid/late April and reaches a peak in May. Little is known about the spread of adult flies and their migration to current carrot plots, but vegetation elements presumably play an important role in orientation and protection against dehydration.

References

[1] Somerfield KG. Carrot rust fly in Canterbury (Diptera: Psilidae). New Zealand Entomologist. 1982; 7(3): 338-340.

[2] Freuler J, Fisher S, Bertuchoz P, Suetsugu K. Infestation of the mycoheterotrophic orchid Yoania japonica by the two-winged fly, Chyliza vittata (Diptera: Psilidae). European Journal of Entomology. 2016; 113: 393-396.

[3] Coppock LJ. Notes on the biology of the carrot fly in Eastern England. Plant pathology. 1974; 423: 93-100.

[4] Collier RH, Finch S, Field and laboratory studies on the effects of temperature on the development of the carrot fly (Psila rosae F.). Annals of Applied Biology. 1996; 128: 1-11.

[5] Sugiura N. Mate-seeking and oviposition behavior of Chyliza vittata (Diptera: Psilidae) infesting the leafless orchid Gastrodia elata. Entomological Science. 2016; 19: 129-132.

[6] Sumner DP. European Atlas: Micropezids & Tanypezids 1 (Diptera, Nerioidea & Diopsoidea). Dipterists Forum Recording Scheme Report. 2018; 1(1): 1-7.

[7] Judd GRR, Vernon RS, Borden JH. Monitoring programme for Psila rosae (Diptera: Psilidae) in the lower Fraser Valley, British Columbia. Canadian Entomologist. 1985; 117, 375-378.

[8] Ashby DG, Wright DW, The immature stages of the carrot fly. Transactions of the Royal Entomological Society of London. 1946; 97: 355-379.

[9] Sheppard AW. Heracleum sphondylium L., biological flora of the British Isles. Journal of Ecology. 1991; 79(31): 235-258.

[10] Berry NA, Wratten SD, Frampton C. Effects of sowing and harvest dates on carrot rust fly (Psila rosae) damage to carrots in Canterbury, New Zealand, New Zealand Journal of Crop and Horticultural Science. 1997; 25(2): 109-115.

[11] Collier R, Elliott M, Finch S. Development of hibernation stages of the carrot fly, Psila rosae (Diptera: Psilidae). Boletim de Pesquisa Entomológica. 1994; 84(4): 469-476.

[12] Buck MMA, Shall S. Revision of new world Loxocera (Diptera: Psilidae), with phylogeneic rede-nition of Holarctic subgenera and species groups. European Journal of Entomology. 2016; 103(1): 193-219.

[13] Ellis PR, Hardman JA, Cole RA, Phelps K. The complementary effects of plant resistance and the choice of sowing and harvest times in reducing carrot fly (Psila rosae) damage to carrots. Annals of applied biology. 1987; 111: 415-424.

[14] Ithers P, Claude J. The Psilidae of France (Diptera: Acalyptrata): checklist and keys for determining genera and species. Nature. 2021; 9: 115-135.

[15] Ellis, P. The Identification and exploitation of resistance in carrots and wild Umbelliferae to the carrot fly, Psila rosae (F.). Integrated Pest Management Reviews. 1999; 4: 259–268.

[16] Boivin G. Seasonal occurrence and geographical distribution of the carrot rust fly (Diptera: Psilidae) in Quebec. Environmental Entomology. 1987; 16(2): 503-506.

[17] Burn AJ, Coaker TH. Diapause and overwintering of the carrot fly, Psila rosae (F.) (Diptera: Psilidae). Bulletin of Entomological Research. 1981; 71(4): 583-590.

[18] Bohlen E. Investigations on the behavior of the carrot fly, Psila rosae Fab. (Dipt. Psilidae), in the oviposition function circle, Journal of Applied Entomology. 2009; 59(1-4): 325-360.

[19] Marchiori CH. Diptera species ectoparasitic of mammals and parasitoid insect pests. Open Access Research Journal of Life Sciences. 2021; 1(2): 6–14.

[20] Collier RH, Finch S. Some factors affecting the efficiency of sticky board traps for capturing the carrot fly, Psila rosp (Diptera: Psilidae). Bulletin of Entomological Research. 1990; 80(2):153-158.

[21] Guerin PM, Visser JH. Electroantennogram responses of the carrot fly, Psila rosae, to volatile plant components. Physiological Entomology. 1980; 5(2): 111-119.

[22] Collier RH, Finch S. Field and laboratory studies on the effects of temperature on the development of the carrot fly (Psila rosae F.). Annals of Applied Biology. 1996: 128(1): 1-11.

[23] Suetsugu K. Delayed autonomous self-pollination in two Japanese varieties of Epipactis helleborine (Orchidaceae). Botanical Journal of the Linnean Society. 2013; 173: 733-743.

[24] Whiters P, Claude J. The Psilidae of France (Diptera: Acalyptrata): checklist and keys for determining genera and species. Nature. 2021; 9: 115-135.

[25] Degen T, Städler E, Ellis PR. Host plant susceptibility to the carrot fly, Psila rosae. 3. The role of oviposition preferences and larval performance. Annals of Applied Biology. 1999; 134: 27–34.

[26] Telfer Z, Lemay J, McDonald MR, Scott-Dupree C. Evaluating the current integrated pest management recommendations in Canada for carrot weevil (Coleoptera: Curculionidae) and carrot rust fly (Diptera: Psilidae). The Canadian Entomologist. 2019; 151(3): 391-405.

[27] Ferrar P. A Guide to the breeding habits and immature stages of Diptera Cyclorrhapha. 1th ed. Copenhagen: Scandinavian Science Press. 1987.

[28] Finch S, Collier, RH. A simple method based on the carrot fly for studying the movement of pest insects. Entomologia Experimentalis et Applicata. 2004; 110: 201–205.

[29] Tulipa LC, Biswas SS, Kalaivanan NS. Organic plant nutrient, protection and production management, Advances in Organic Farming. 2021; 10(9): 115-131.

[30] Burn A, Coaker T. Diapause and overwintering of the carrot fly, Psila rosae (F.) (Diptera: Psilidae). Bulletin of Entomological Research. 1981; 71(4): 583-590.

[31] Beirne BP. Pest insects of annual crop plants in Canada. Memoirs of the Entomological Society of Canada. 1971; 78: 63-65.

[32] Hooper IRE, Dixon PL, Larson DJ. Distribution and scasonal activity of adult carrot rust fly (Diptera: Psilidae). The Canadian Entomologist. 2002; 134(5): 703-706.

[33] Kato M, Tsuji K, Kawakita A. Pollinator and stemand corm-boring insects associated with mycoheterotrophic orchid Gastrodia elata. Annals of the Entomological Society of America. 2006; 99: 851-858.

[34] Phelps K, Collier RH, Reader RJ, Finch S. Monte Carlo simulation method to predict the timing of insect pest attack. Crop Protection. 1993; 12: 335-342.

[35] Sheppard AW. Heracleum sphondylium L., biological flora of the British Isles. Journal of Ecology. 1991; 79: 235-258.

[36] Coppock LJ, Maskell FE, Gair R. Attempts at cultural control of carrot fly damage to carrots in East Anglia. Plant Pathology. 1975; 24(2): 97-101.

[37] Hill DS. Agricultural insect pests of the tropics and their control. 2th ed. Cambridge: Cambridge University Press. 1987.

[38] Wakerley SB. Climate and behavior of the carrot fly (Psila rosae fab. Dipt. Psilidae) with particular reference to oviposition. Entomology Experimentalis et Applicata. 1963; 6: 268–278.

[39] Platoni AM, Stephanie B, Waghorn I, Perry P, Collier R, Clover G. Using physical barriers to prevent carrot fly (Psila rosae) (Fabricius) damage in domestic production. Journal of Applied Entomology. 2019; 143(10): 1089-1095.

[40] van Noort S, Matthew LB, Mattias F. Afrotropical Cynipoidea (Hymenoptera). Zookeys. 2015; 493: 1-176.

[41] Novkovic B, Mitsui H, Suwito A, Kimura MT. Taxonomy and phylogeny of Leptopilina species (Hymenoptera: Cynipoidea: Figitidae) attacking frugivorous drosophilid flies in Japan, with descripton of three new species. Entomological Science. 2011; 14: 333–346.

[42] Wilson W, et al. Staphylinidae (Coleoptera) associated to cattle dung in Campo Grande, MS, Brazil. Neotropical Entomology. 2002; 31(4): 641-645.

[43] Wakerley SB. The sensory behavior of the carrot fly (Psila rosae Fab., Dipt. Psilidae). Entomologia Experimentalis et Applicata. 1964; 7, 167–178.

[44] Hardman JA, Ellis PR. An investigation of the host range of the carrot fly. Annals of Applied Biology. 1982; 100: 1–9.