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Study of the ecology of the Tephritidae family (Insecta: Diptera)

Carlos Henrique Marchiori *

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

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Abstract

Fruit flies belong to the Tephritidae Family which is one of the largest within the Order Diptera. This family is among the pests with the greatest economic expression in the world's fruit industry, as they attack the reproductive organs of plants, fruits with pulp and flowers. These insects are an important group of pests in the fruit industry worldwide, as they have a life cycle in which their larval period develops especially inside the fruits, feeding, in general, on their pulp. The objective of this study is to report the Ecology and Biology of Tephitidae. The research was carried out in studies related to quantitative aspects of the Family, Subfamily and Species (taxonomic groups) and conceptual aspects such as: biology, geographical distribution, methodologies, and traps for collecting and their parasitoids and strategies for Drosophlidae with control, species, life cycle, damage, economic importance, medicinal importance, biological aspects, monitoring and control and reproduction. A literature search was carried out containing articles published from 1993 to 2021. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Portal of Scientific Journals in Health Sciences, Pubmed, Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Biological Abstract, Publons, Qeios, Portal of Scientific Journals in Health Sciences, and Pubmed, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periódicos CAPES, Google Academic, Bioline International and VADLO.

Keywords: Biology; Baites; Goías; Medicinal importance; Scielo

1. Introduction

Fruit flies belong to the Tephritidae Family which is one of the largest within the Order Diptera. This family is among the pests with the greatest economic expression in the world's fruit industry, as they attack the reproductive organs of plants, fruits with pulp and flowers. These insects are an important group of pests in the fruit industry worldwide, as they have a life cycle in which their larval period develops especially inside the fruits, feeding, in general, on their pulp (Figure 1) [1,2].

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

Figure 1 Tephritidae family

The damage caused by this insect can be divided into three levels: Direct damage to production, Damage during marketing and closing of export markets, through quarantine implications, as countries that import fruit do not want products that can transport this pest (Figure 2) [3,4].

Figure 2 (a) Photograph of an adult *Bactrocera dorsalis* (Handel, 1912) fruit fly; (b) infection of the fruit guava by *B. dorsalis*; (c, d) eggs of *B. dorsalis* laid below the skin of the host fruit and the attacked fruit shows the signs of the ovipositional damage in the form of minute depressions; (e) the affected fruits soften at the site of infestation which then rot and drop down prematurely and (f) the maggots feed on the pulp of the fruits; (Source: https://www.researchgate.net/figure/a-Photograph-of-an-adult-B-dorsalis-fruit-fly-b-infection-of-the-fruit-guava-by_fig1_275116861)

Figure 3 Fruit family host to fruit flies; (Source: https://www.wizard.com.br/idiomas/aprenda-os-nomes-das-frutas-em-ingles/)

Currently, it is known that fruit flies (Tephritidae) attack more than 400 species of fruit, where the following families can be highlighted: Rutaceae, Rosacea, Anacardiacea, Myrtaceae, Annonaceae, Caricaceae, Malpighiaceae, Passifloraceae and Sapotaceae (Figure 3) [3,4].

The Tephritidae family has a wide geographic distribution, predominantly in the Neotropical region, with about 4,352 species grouped in 481 genera, of which only five are of economic importance: *Anastrepha, Ceratitis, Bactrocera, Rhagoletis* and *Toxotrypana* [5,6].

Males release pheromones that attract females to copulation. The pre-oviposition period varies from 13 to 19 days (period spent for the maturation of the eggs). During this period, females consume protein-rich foods for ovarian development (Figure 4) [5,6].

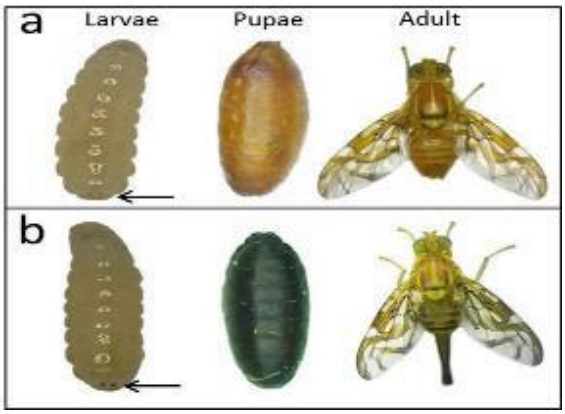

Figure 4 1-Larvae, pupae and adults from the GSS *Tapachula* based on the bp mutation. The males can be identified in the larval stage based on the brown coloration of their anal lobes compared to the black coloration of the females. a) wild-type males. b) black pupae females. Arrows point to the anal lobes; (Source: https://europepmc.org/backend/ptpmcrender.fcgi?accid=PMC4255765&blobtype=pdf)

Oviposition is influenced by temperature, luminosity and fruit characteristics (shape, size, peel properties) and is preferably done on ripe or ripening fruits, where females leave their eggs exactly in the pulp of the fruit, just below of the epidermis. Several eggs are placed inside the fruit with the help of the aculeus (ovipositor), and although females mark the fruit with pheromone after oviposition, several females can oviposite in the same fruit (Figure 5) [5,6,7].

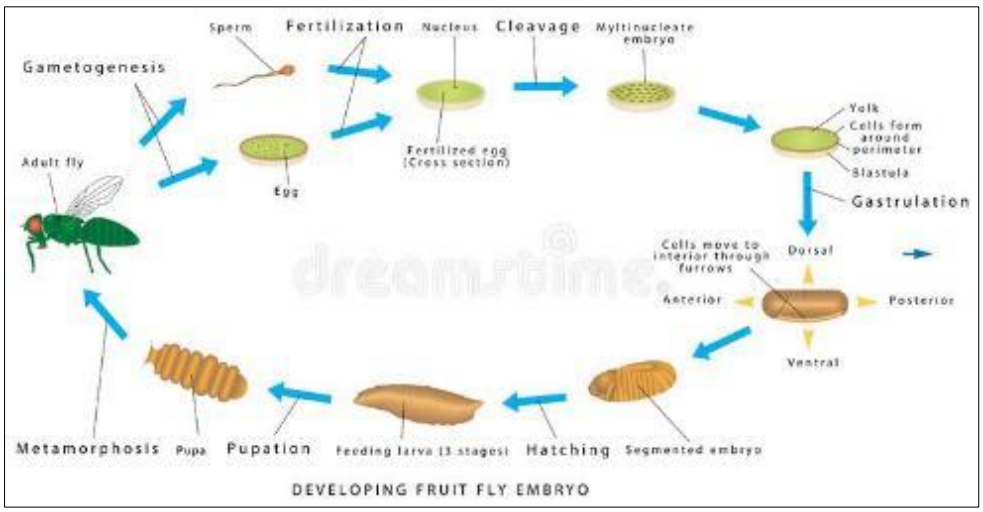

Figure 5 Life cycle of the Tephritidae Family; (Source: https://www.dreamstime.com/illustration/fruit-fly.html)

The embryogenesis process depends on temperature, and usually lasts 48 hours (at 25º C). These eggs hatch, originating larvae that develop inside this pulp. As these larvae develop, passing through three stages (larvae 1, 2 and 3), they cause deterioration inside the fruit with the growth of bacteria and fungi, and the fruit eventually falls to the ground. When

falling to the ground, the larvae leave this fruit, moving a little and bury themselves, reaching the pupa stage. This pupa stage takes place between 2 and 8 centimeters buried in the ground, which remains for a period of 10 to 15 days, depending on the temperature to which they are submitted. After this period, the pupa leaves the ground and an adult emerges with its wings curled, which walks to the top of a tree, maturing.

Objective

The objective of this study is to report the Ecology and Biology of Tephitidae.

2. Methodologies and traps for collecting fruit flies and their parasitoids and strategies for fruit fly control

2.1. Fruit fly collections

Fruit fly collections were carried out in McPhail type plastic traps, containing as an attractant food, hydrolyzed corn protein stabilized with borax (pH between 8.5 and 9.0) and diluted to 5%, installed in the cups of trees (hosts or not) the material captured was collected weekly. The copies of *Anastrepha* were sexed and females stored in flasks glass containing 70% ethanol for later identification (Figure 6).

Figure 6 McPhail model trap recommended for monitoring *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera, Tephritidae) and *Ceratitis capitata* (Wiedemann, 1824) (Diptera, Tephritidae); (Source: https://www.researchgate.net/figure/Figura-4-Armadilha-modelo-McPhail-recomendada-para-o-monitoramento-de-Anastrepha_fig2_305073720)

2.2. Association between the host plant and the fruit fly species.

To determine the association between the host plant and the fruit fly species, systematic fruit collections were carried out. Samples of ripe or ripening fruits were collected directly from trees or from the ground (fresh fruit). The fruit samples varied throughout the year, according to the fruiting season of each species. The collected puparia were kept in cages until the emergence of adults (Figure 7).

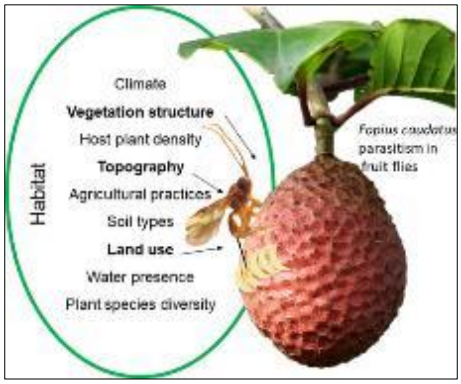

Figure 7 Association between the host plant and the fruit fly species; (Source: https://onlinelibrary.wiley.com/doi/full/10.1111/eea.12858)

2.3. To obtain the parasitoids.

Fruits are randomly collected from the ground and canopy at the physiological maturity stage. To verify the possibility of migration of parasitoids from native hosts to commercial orchards, fruits are collected from plants located in areas close to fruit orchards (Figure 8).

Figure 8 *Ceratitis capitata* (Wiedemann, 1824) in a rearing cage, water; artificial fruit; adult food; papaya; (Source: https://www.scielo.br/j/rbent/a/K3GqqMyQ8NbBBjYPC8qKxpF/?lang=en)

2.4. Obtaining fruit flies and parasitoids in the laboratory

After collection, the fruits are transported to the laboratory, placed in plastic containers containing a layer of approximately 1cm of sterilized sand, and kept in an air-conditioned room. After seven, the sand is sieved to count the pupae, which are transferred to Petri dishes containing sterilized sand as a substrate and placed in cages until the emergence of flies and/or parasitoids (Figure 9).

Figure 9 Packaging of fruits in boxes for the emergence of flies and parasitoids under laboratory conditions; (Source: https://www.grupocultivar.com.br/noticias/estrategias-para-controle-da-mosca-das-frutas)

2.5. Jackson Trap

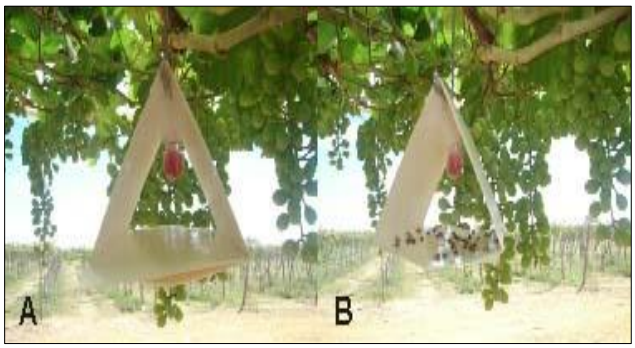

Figure 10 Jackson trap set in a vine: freshly placed baited trap (A); baited trap after Moscamed collection (B); (Source: https://www.agencia.cnptia.embrapa.br/gestor/uva_de_mesa/arvore/CONT000g88nyjz902wx5)

It is the standard trap for collecting males of *Ceratitis capitata* (Wiedemann, 1824), using the parapheromone trimedilure as attractant. It is made of white paraffin cardboard in the shape of a triangle, with an adhesive card placed on the inside and bottom of the trap. Males are attracted to parapheromones and end up stuck to the adhesive card (Figure 10).

2.6. Yellow sticky trap

Yellow sticky traps can be used as an effective method for controlling whiteflies in the greenhouse and in the field. This information will be useful for the effective management of the whitefly in greenhouses also in the field. Target Pests: Whitefly, Leaf Miner, Aphid, Cabbage Root Fly, White Cabbage Butterfly, Cucumber Beetle, Capsids, Travel, Mesquite, leafhopper, leafhopper, fruit fly, moth, and other flying insects. Crops: vegetables and flowers. How to use: simply hang above your crop at regular intervals and count insect catches regularly to determine population size and source of problem. Glue traps are designed to make a real impact on your greenhouse. Monitors and detects insects in the field. Attracts all the flying insects that damage crops (Figures 11 and 12).

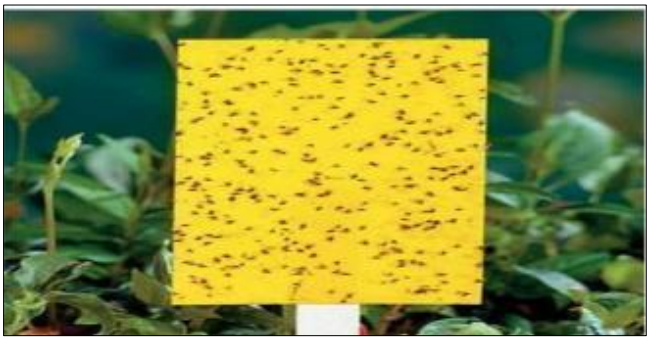

Figure 11 Yellow sticky trap (A); (Source: https://vikaspedia.in/agriculture/agri-inputs/bio-inputs/production-of-ipm-inputs/traps/yellow-sticky-traps)

Figure 12 Yellow sticky trap (B); (Source: https://vikaspedia.in/agriculture/agri-inputs/bio-inputs/production-of-ipm-inputs/traps/yellow-sticky-traps)

3. Methods

The research was carried out in studies related to quantitative aspects of the Family, Subfamily and Species (taxonomic groups) and conceptual aspects such as: biology, geographical distribution, methodologies, and traps for collecting and their parasitoids and strategies for Drosophlidae with control, species, life cycle, damage, economic importance, medicinal importance, biological aspects, monitoring and control and reproduction. A literature search was carried out containing articles published from 1993 to 2021. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the. The mini-review was prepared in Goiânia, Goiás, from September to October 2021, through the Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu, Frontiers, Publons, Qeios, Portal of Scientific Journals in Health Sciences, Pubmed, Online Scientific Library (Scielo), internet, ResearchGate, Academia.edu,

Frontiers, Biological Abstract, Publons, Qeios, Portal of Scientific Journals in Health Sciences, and Pubmed, Dialnet, World, Wide Science, Springer, RefSeek, Microsoft Academic, Science, ERIC, Science Research.com, SEEK education, Periódicos CAPES, Google Academic, Bioline International and VADLO.

3.1. Study 1

In Brazil there are also representatives of the genus *Toxotrypana*, extremely important in Mexico. However, the papaya fly, which is a species of economic importance, does not occur in our country. Another genus that occurs, but which does not have any important species for Brazilian fruit production, is the genus *Dacus*. Another family that occurs in Brazil is the Lonchaeidae family, but there is controversy about its potential as a pest. Many cite that these insects use wounds already left by other species of flies to lay their eggs inside the fruit. Genres of economic importance *Bactrocera, Keratitis, Paracantha, Rhagoletis*, *Tephritis* and *Urophora*. I edge damage Fruit flies can cause damage in the following ways:

The fly larva, when developing inside the fruit, causes a violent hormonal imbalance, which in turn causes uneven ripening and culminates in necrosis in the affected region and early fruit drop. Fruits may show deformations and spots where females drill to test the oviposition substrate (proof bite) or where they oviposited, but without larvae hatching.

There is the possibility of entry of opportunistic microorganisms in lesions left by females. Many species of fruit flies that occur in Brazil are considered quarantine pests in many importing countries, which creates a series of barriers preventing the export of fruits for consumption in "in natura" form (Figure 13) [6,7,8].

Figure 13 Leaves of the hosts with symptoms of *Ceratocystis* spp. (A-F): (A) cacao tree; (B) eucalyptus; (C) rubber tree; (D) soursop; (E) custard-apple tree; (F) coffee plant; methodologies of isolation (G-H): (G) from fragments of leaves placed between slices of unripe cacao fruits, (H) from infected trunk of cacao, (I) *Ceratocystis cacaofunesta* colony and perithecia; inoculation tests (J-L): (J) detached leaves with culture dishes, (K) detached leaves with droplets of inoculum suspension, (L) leaves of adult plants in the field; (Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F)

3.2. Study 2

In Brazil the species reported as causing damage in at least one crop are distributed in only four genera, all belonging to the Tephritidae family.

Bactrocera - genus represented by only one species restricted to Oiapoque, *B. carambolae* and known as the carambola fly. Originally from Asia and introduced through baggage.

Rhagoletis - four species are found throughout Brazil, but only in the south of the country have been mentioned as occasional pests.

Anastrepha - is the most important genus in Brazil, with 94 species described in the country. However, only seven are of real economic importance. Are they:

Anastrepha fraterculus (Wiedemann, 1830) - South American fruit fly one of the main and most feared pests of Brazilian fruit production. It mainly attacks fruits of the Myrtaceae family, but it also has 14 other families that can be its possible hosts. It is a primary pest and is much attacked in apple, peach, plum, papaya, grape, myrtle, kiwi (kiwi or quive) orchards (Figure 14).

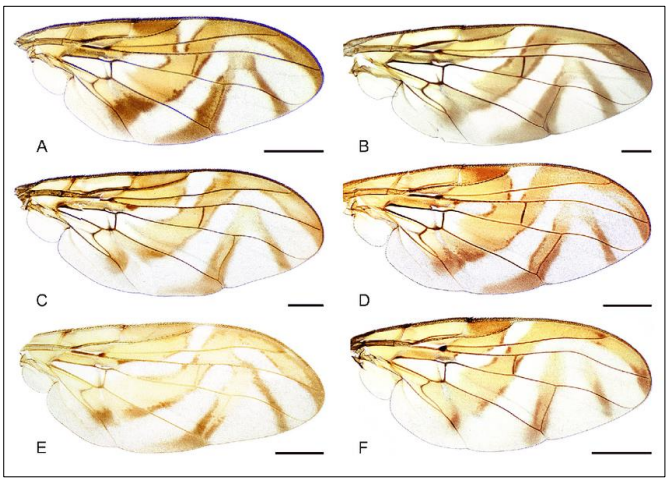

Figure 14 Wing patterns of new records of species of *Anastrepha* from Paraná. A. *Anastrepha amita*. B. *A. barnesi*. C. *A. consobrina*. D. *A. manihoti*. E. *A. morvasi*. F. *A. punctata*. Scale bars:1 mm. *Anastrepha punctata* Hendel, 1914 Figure 2F; (Source: https://www.researchgate.net/figure/Wing-patterns-of-new-records-of-species-of-Anastrepha-from-Parana-A-Anastrepha-amita_fig2_342606547)

Anastrepha grandis (Macquart, 1846) - Pumpkin fly. Its hostesses, as the name implies, belong to the Cucurbitaceae family. It is a secondary pest in melon crop but is considered a quarantine pest in many importing countries.

Anastrepha obliqua - its most common hosts are found in the Anacardiaceae and Myrtaceae families.

Anastrepha pseudoparalella (Loew, 1873) - Its main host is the passion fruit.

Anastrepha sororcula Zucchi, 1979 - attacks mainly Myrtaceae and can be a pest in mangoes and coffee.

Anastrepha striata Schiner, 1868 - mainly attacks Myrtaceae and passion fruit.

Anastrepha zenildae Zucchi, 1979 - attacks *Myrtles* and other families.

Ceratitis- among the four genera of economic importance is the only exotic (Fly of carambola is also exotic). It is represented by only one species: *Ceratitis capitata* (Wiedemann, 1824), known as the Mediterranean fly [6,7, 8].

A total of 611 specimens of *C. capitata* and 11,875 of *Anastrepha* spp. The predominance of *Anastrepha* in relation to *Ceratitis* was verified in the four areas evaluated, mainly in the Mata do Córrego do Paraíso, a natural preservation area in which the frequency of *C. capitata* was extremely low (Figures 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24).

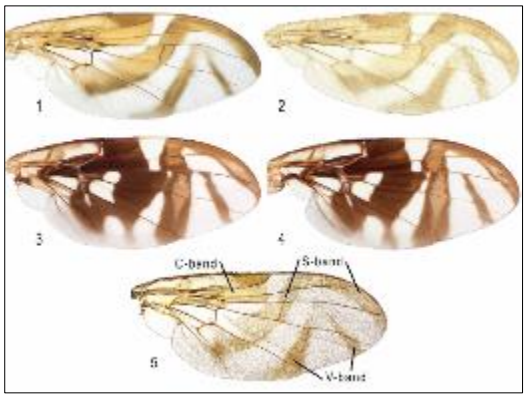

Figure 15 Wings: 1, *A. matogrossensis* (holotype); 2, *A. oiapoquensis* (holotype); 3–4, *A. rafaeli* (Brazil: Chácara Arara Azul, USNMENT00671865, USNMENT00671867); 5, *A. siculigera* (holotype)

Fifteen species of *Anastrepha* were identified*: A. bezzi* Lima, A. bistrigata Bezzi, *A. dissimilis* Stone, *A. distincta Greene*, *A. fraterculus* (Wied.), *A. furcata* Lima, *A. grandis* (Macquart), *A. manihoti* Lima, *A. minensis* Lima, *A. montei* Lima, *A. obliqua* (Macquart), A. pseudoparallela (Loew), A. pickeli Lima, A. serpentina (Wied.) and *A. sororcula* Zucchi thus, in *A. fraterculus* it was the most frequent species, representing 83.08% of the specimens collected. *A. fraterculus* was the most frequent species, representing 83.08% of the specimens collected.

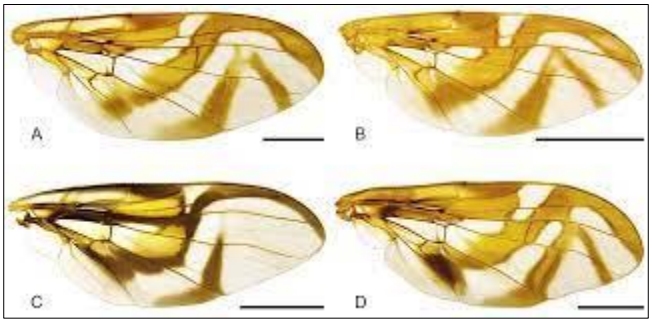

Figure 16 Wing patterns of new records of species of Anastrepha from Amazonas. A. A. elongata Fernández, 1953. B. A. fraterculus (Wiedemann, 1830) (sensu lato). C. A. pseudanomala Norrbom, 2002. D. A. sodalis Stone, 1942. Scale bars = 2 mm; (Source: file:///C:/Users/Sti/Downloads/CheckList_article_52184_en_1%20(3).pdf)

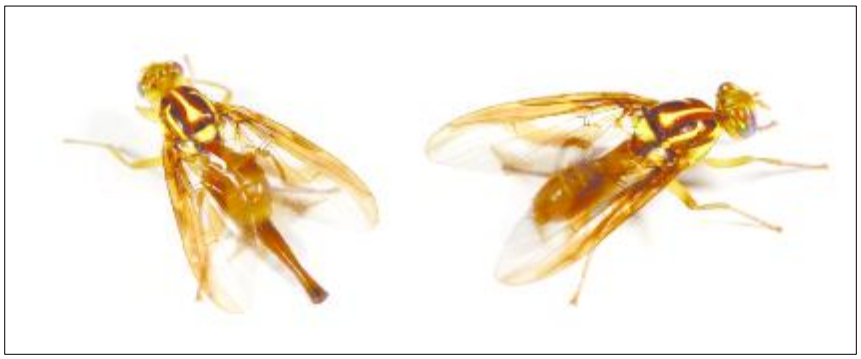

Figure 17 Adults of *Anastrepha grandis*. Female on the left and male on the right; (Source: https://www.researchgate.net/figure/Figura-1-Adultos-de-Anastrepha-grandis-Femea-a-esquerda-e-macho-a-direita_fig1_303679318)

Figure 18 Biological cycle of *Anastrepha grandis*. With the ovipositor, the females pierce the epicarp (shell) of the fruit and oviposition (puncture) inside the fruit. In a single puncture, females can lay up to 110 eggs. The eggs are white in color and elongate in shape, 2.06 to 2.25 mm in length. When hatching, the larvae feed on the pulp and go through three instars. Due to feeding, the larvae form galleries inside the fruit that favor the entry of pathogenic microorganisms that cause rot; consequently, they make the fruits unfeasible for consumption, commercialization, and industrialization. The larvae are yellowish in color and in the third instar they can measure up to 17.0 mm in length. At the end of the larval stage, they leave the fruit and puff up on the ground. The pupae are of the coarcted type, that is, they are surrounded by indurated larval skin, can measure from 8.0 to 9.1 mm in length and have a golden-brown color; (Source: https://www.researchgate.net/figure/Figura-1-Adultos-de-Anastrepha-grandis-Femea-a-esquerda-e-macho-a-direita_fig1_303679318)

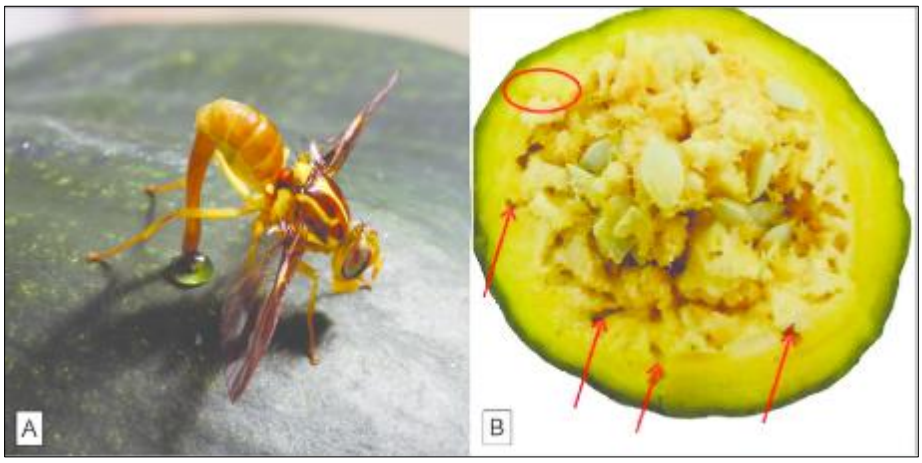

Figure 19 Damage caused by *Anastrepha grandis* on trunk pumpkin. A) Female inserting the ovipositor in the fruit. B) Pumpkin trunk sectioned in half. The circle shows an *A. grandis* larva and the arrows show the galleries made by the larvae; (Source: https://www.researchgate.net/figure/Figura-1-Adultos-de-Anastrepha-grandis-Femea-a-esquerda-e-macho-a-direita_fig1_303679318)

Of the 37 samples collected from 18 fruit species, belonging to six families, 10 were infested by fruit flies and from seven of these emerged parasitoids, obtaining 2,263 puparia of Anastrepha and 169 specimens of the families Braconidae (161), Figitidae (1) and Pteromalidae (7). Four species of braconids *Doryctobracon areolatus* (Szépligeti), *Doryctobracon braziliensis* (Szépligeti), *Opius bellus* Gahan and *Utetes anastrephae* (Viereck)], a species of Figitidae, *Aganaspis pelleranoi* (Brèthes)] and an unidentified species of Pteromalidae were obtained. *D. areolatus* was the most frequent, representing 68.05% of the collected parasitoids.

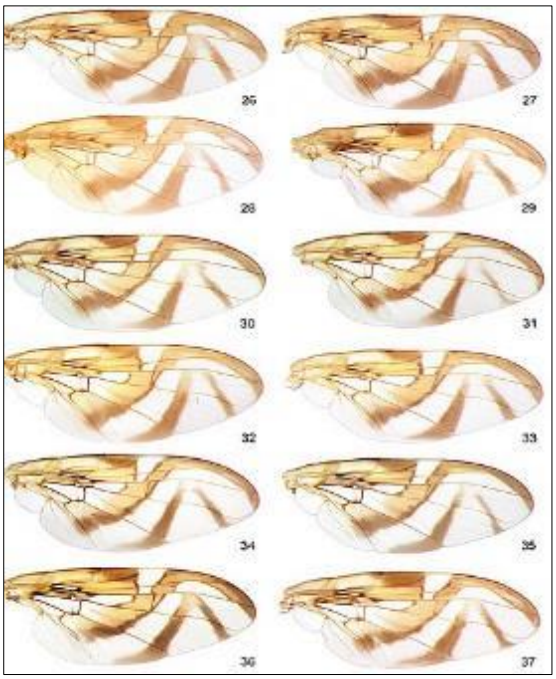

Figure 20 Wing patterns of major lineages within *Anastrepha fraterculus* complex. Taken from Hernadez-Ortiz et al. 2015

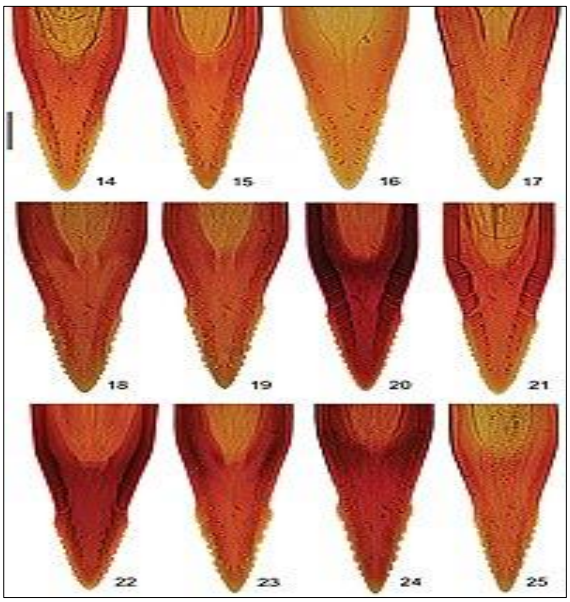

Figure 21 Aculeus tips of major lineages within *Anastrepha fraterculus* complex. Taken from Hernadez-Ortiz et al. 2015

This species has been the most frequent of the tephritid parasitoids in most regions of Brazil (it was associated with cherry and star fruit and *A. obliqua* with star fruit, seriguela, cherry and star fruit

cambuca, the latter being the first recorded plant. The minimum limit of infestation by fruit flies for a host to be considered primary is 30 puparia/kg of fruit Since the *Anastrepha* infestation rates obtained in cambuca, guava, jabuticaba, cherry, star fruit and were above this limit, they could be considered primary hosts in the Mineira region.

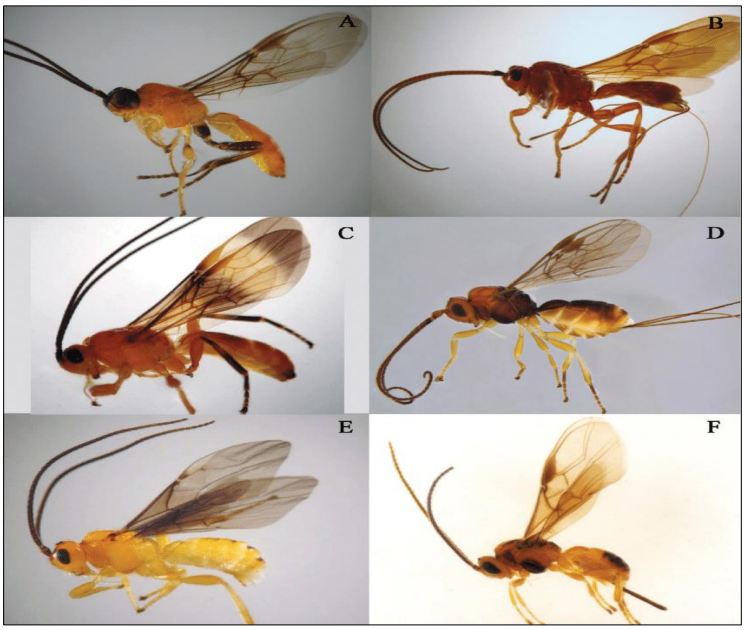

Figure 22 Fruit fly braconid parasitoids. *Doryctobracon crawfordi* (A); *D. fluminensis* (B); *D. whartoni* (C); *Fopius arisanus* (D); *Opius bellus* (E); *Utetes anastrephae* (F) (figures are not on the same scale); (Source: https://www.researchgate.net/figure/Fruit-fly-braconid-parasitoids-Doryctobracon-crawfordi-A-D-fluminensis-B-D_fig2_329398256)

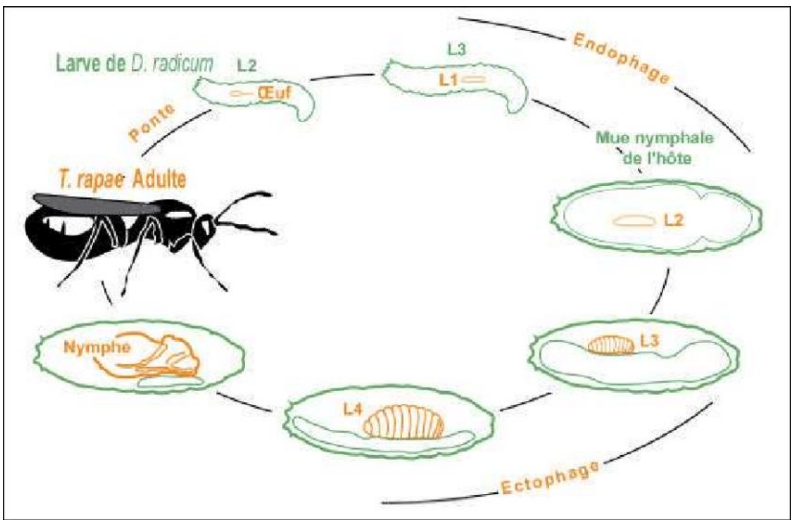

Figure 23 Cycle de développement de *Trybliographa sp*; (Source: https://www.researchgate.net/figure/Cycle-de-developpement-de-Trybliographa-rapae-illustration-S-Dourlot_fig3_11018899)

The other species of parasitoids were found for the first time in Viçosa and the occurrence of *O. bellus* the first recorded in Minas Gerais. Cand loquat had the highest infestation rates, 683.6 and 329.1, respectively. Seriguela, carambola, jabuticaba, cambucá and guava presented rates above 30 pupae/kg. Four species of fruit flies associated with host fruits were obtained: *C. capitata, A. fraterculus, A. obliqua* and *A. sororcula*. Although *C. capitata* is considered the most polyphagous species of tephritid it was found to infest only *A. fraterculus* was the species associated with the largest number of hosts (cambuca, guava, jabuticaba and cherry and sweet passion fruit, loquat, and orange). *A. sororcula* was associated with pitanga and carambola and *A. obliqua* with seriguela, pitanga, carambola and cambucá, the latter being the first host plant record for the species. These three species of *Anastrepha* are the ones with the highest number of host associations in Brazil.

Figure 24 Natural parasitoids of the genus *Dasiops* flies. A, *A. pelleranoi* male; B, *Microcrasis* sp. female; C, *Trichopria* sp. female; D, *Pentapria* sp; (Source: hrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fpdfs.semanticscholar.org%2F6556%2F639b55cf007c5afc3c60681e33c16f911752.pdf%3F_ga%3D2.119793480.1981173269)

These emerged flies mature in approximately one week, with a sex ratio of 1:1. After that, the mating behavior begins, where a female can lay 500 to 1,000 eggs during her adult life period, which generally lasts from 10 to 60 days, depending on the conditions. The natural enemies of fruit flies are parasitoids belonging mainly to the Braconidae and Figitidae families. In the first family, species of the genera *Doryctobracon, Opius* and *Utetes* stand out, and in the second family, species of the genera *Aganaspis, Odontosema, Tropideucoila, Diceratas pis* and *Lopheucoila* [9].

3.3. Study 3

Ceratitis capitata Wiedemann, 1824

Mediterranean fly (Figures, 25, 26, 27, 28, 29, 30, 31 and 32)

Figure 25 *Ceratitis capitata* Wiedemann, 1824; (https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Crops Affected avocado, acerola, plum, anonaceas, cocoa, coffee, caja, star fruit, castanets, citrus, guava, kiwi, apple, papaya, mango, passion fruit, nectarine, loquat, pear, peach, pepper, pomegranate, seriguela and grape.

The attack of this pest causes serious damage to fruits of various cultures, such as citrus, avocado, acerola, plum, araçá, coffee, cajá, persimmon, carambola, apricot, fig, guava, jambo, apple, papaya, mango, passion fruit, quince, nectarine, loquat, pear, peach, cherry and sapodilla.

Figure 26 Fruit fly (*Ceratitis capitata* Wiedemann, 1824); (Source: https://www.ecoregistros.org/site_en/imagen.php?id=435516)

Figure 27 Mediterranean fruit fly eggs in an apple; (Source: https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Figure 28 Larvae of *Ceratitis capitata* Wiedemann, 1824; (Source: https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Figure 29 Pupa of *Ceratitis capitata* Wiedemann, 1824; (Source: https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Damage: Fruits attacked by flies present very characteristic symptoms: around the place where they were laid, there is a halo approximately 2 cm in diameter and dark in color. When the larvae hatch, this halo turns brownish due to the rotting of the bark. It is exactly there, on these destroyed tissues that certain fungi develop. The pest preferentially attacks fruits exposed to the sun. Because it has a shorter ovipositor, the species only attacks fruits that are in a more advanced stage of maturity (ripe). The pest is predominant in coffee, where the eggs are deposited inside the ripe fruit and where the larvae reach maturity, causing a loss of coffee quality and great damage to the crop. When harvested, the Mediterranean fly will attack late varieties of other crops.

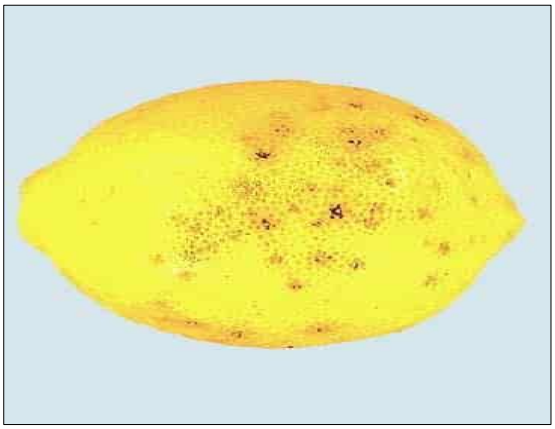

Figure 30 Damage to lemon of Mediterranean fruit fly; (Source: https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Control: Before controlling the infestation, it is necessary to carry out monitoring with the use of traps, to obtain data on the presence and population of flies.

For monitoring, McPhail-type traps or traps made of plastic packaging, containing food attractants, are used. As food attractant, 5% hydrolyzed protein, 10% cane molasses, fruit juices, brown sugar, wine vinegar and torula can be used, with the hydrolyzed protein being considered more efficient. It is also possible to mix the protein with molasses, in the proportion of 2.5 and 5% respectively, to improve the attractive efficiency. The evaluation and change of attraction must be carried out every 10 or 15 days. To avoid rapid decomposition, the attractant can be stabilized with borax (pH between 8.5 and 9.0). This type of trap attracts fruit fly species of the *Anastrepha* genus.

For specific capture of the Mediterranean fly, Jackson trap is used, with trimedilure sex pheromone bait (tert-butyl-4 [or 5]-chloro-2-methyl-cyclohexanecarboxylic acid). In uniform areas the indication is that a trap is placed every three hectares. For irregular areas, the indicated use is one trap for each hectare. In the plan it should be placed approximately

1.60 - 1.70 m high and in the center of the area to be monitored. Trap and pheromone should be changed every 6 weeks (Figure 32).

Figure 31 Sterile medfly production, at tray of male medfly pupae; (Source: https://www.kalliergeia.com/en/ceratitis-capitata-mediterranean-fruit-fly/)

Figure 32 *Ceratitis capitata* Wiedemann, 1824 life cycle

The control level for this species is two males/trap/day or fourteen males/trap/week. The control is carried out with the application of toxic baits, which consists of a mixture composed of an attractive substance, hydrolyzed protein, or molasses, at a dilution of 5 and 10% respectively, and insecticide [10].

3.4. Study 4

Fruit flies (Diptera: Tephritidae) are insects that affect fruit production due to their oviposition, as well as by feeding the larvae, which accelerate maturation and cause premature fruit drop. Some quarantine species cause restrictions on the sale of fresh fruit in various parts of the world. A survey of fruit fly species in fruits was carried out in the municipality of Rio Branco, AC, from June 2016 to June 2017.

Fruits were collected directly from fruit species and/or fallen on the ground and taken to the Embrapa Acre Entomology Laboratory. In laboratory, the fruits were weighed, conditioned by elastic alloys. The fruits were inspected every three days, looking for pupae and/or adults of fruit flies, as well as possible natural enemies. The captured flies were preserved in alcohol (70%) and sent for identification (Figure 33).

Figure 33 *Psidium guajava* L. (Myrtaceae) being parasitized by *Ceratitis capitata* Wiedemann, 1824; (Source: hrome extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww2.unifap.br%2Fppgbio%2Ffiles%2F2020%2F02%2FDisserta%25C3%25A7%25C3%25A3o-Sebasti%25C3%25A3o-Chaves-Favacho.pdf&clen=871074)

In two fruit samples: guava *Psidium guajava,* stars fruit, *Averrhoa carambola* tephritid specimens identified as *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae). This fly is considered cosmopolitan and highly polyphagous, being reported as an important pest of fruit culture in several countries, but which had not yet been registered in the state of Acre. Based on this work, seven of the nine states that make up the Brazilian Amazon region are now registered for this pest, and only the states of Amazonas and Amapá are currently except (Figure 34) [11].

Figure 34 *Averrhoa carambola L*. (Oxalidaceae) with fruit fly damage; (Source: https://www.dreamstime.com/stock-photo-carambola-starfruit-fruit-damage-fruit-fly-carambola-starfruit-fruit-damage-fruit-fly-tropical-fruit-image94289958)

3.5. Study 5

Fruit fly **(***Anastrepha* spp.) (Figures 35 36, 37, 38, 39, 40 and 41).

Crops Affected: acerola, plum, guava, mango, peach, grape. Group of flies that cause great damage in papaya, citrus, apple, passion fruit, nectarine, loquat, pear, acerola and plum.

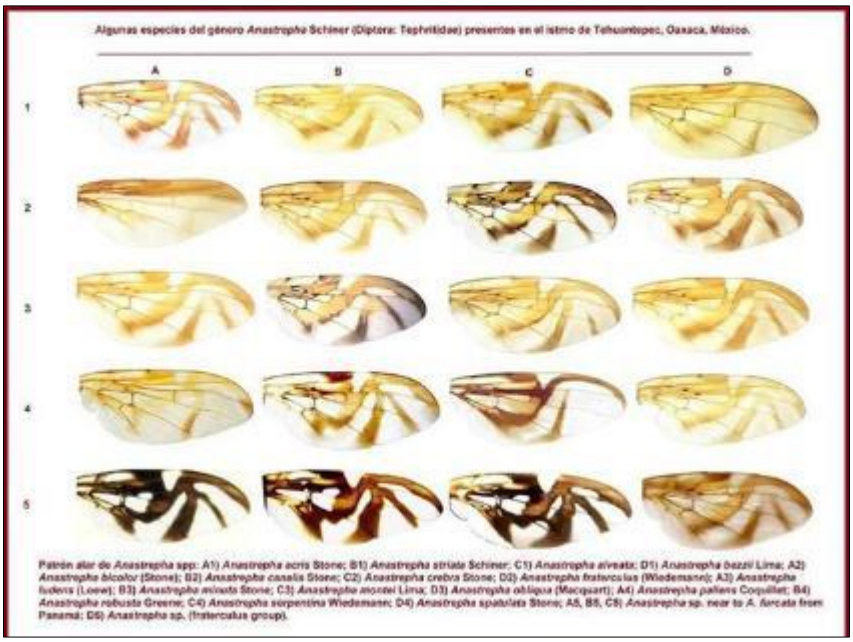

Figure 35 *Anastrepha* species; (Source: Photo credit Enrique Antonio Hernandez)

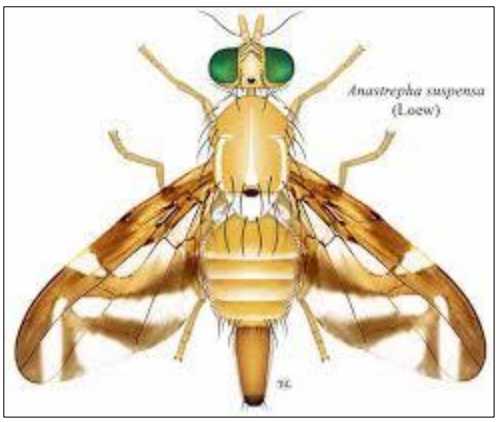

Figure 36 Female of *Anastrepha* spSource: intkey.com/anatox/images/suspens1.jpg

Figure 37 Male of *Anastrepha* sp; (Source: https://v3.boldsystems.org/index.php/Taxbrowser_Taxonpage?taxid=79319)

Damage - Fruits attacked by flies present very characteristic symptoms, with the appearance of a dark colored halo with approximately 2 cm in diameter around the place where the laying was made. When the larvae hatch, this halo turns brownish due to the rotting of the bark. It is exactly there, on these destroyed tissues, that certain fungi develop. The

pest preferentially attacks fruits exposed to the sun. As they have a longer ovipositor, the species *Anastrepha fraterculus* and *A. obliqua* attack green and ripe fruits indistinctly. Due to the "host succession", flies of the Anastrepha genus will transfer from several fruit trees, which are harvested during the summer, to early varieties of other crops. The species of this genus occur in all Brazilian regions.

Figure 38 Elongated larva, without feet and without capsule in the fruit fly's head and galleries formed by its feeding;

(Source: Image: Claudio de Andrade Barros)

Control - Before controlling the infestation, it is necessary to carry out monitoring with the use of traps, to obtain data on the presence and population of flies.

For monitoring species of this genus, McPhail traps or traps made of plastic packaging containing food attractants are used. This trap also catches flies of the species *Ceratitis capitata*. As food attractant, 5% hydrolyzed protein, 10% cane molasses, fruit juices, brown sugar, wine vinegar and torula can be used, with sugarcane molasses being considered more efficient. It is also possible to mix the protein with molasses, in the proportion of 2.5 and 5% respectively, in order to improve the attractive efficiency. The evaluation and change of attraction must be carried out every 10 or 15 days. To avoid rapid decomposition, the attractant can be stabilized with borax (pH between 8.5 and 9.0**)** [12].

Figure 39 Male, female, damage, Macphail trap and Jackson trap. Sampling method monitoring of adults: in the traps *Anastrepha* spp. - placing a McPhail/05 ha trap on the periphery of the orchard. Inspections will be carried out every seven days, quantifying the number of specimens of *Anastrepha* captured*. Ceratitis capitata* - placing a Jackson/05 ha

trap on the outskirts of the orchard. Inspections will be fortnightly, quantifying the number of *Anastrepha* captured. Perform pheromone exchange every 45 days. Source: file:///C:/Users/Sti/Downloads/Arquivo2%20(1).pdf

Figure 40 Head and face of *Anastrepha*; (Source: https://www.wikiwand.com/en/Anastrepha)

3.6. Study 6

The peach tree can be attacked by several species of insects and mites that damage leaves, branches, and fruits. Among these arthropods, the South American fruit fly *Anastrepha fraterculus* (Wiedemann, 1830) (Diptera: Tephritidae) is considered the most important pest of the crop in Brazil and the most feared by producers, demanding systematic control to enable production [13,14,15].

In Brazil, it is a key pest of several commercial and native fruit trees in the southern and southeastern states. In Rio Grande do Sul and Santa Catarina, *A. fraterculus* is the predominant species, and for RS it represents about 95% of the species of *Anastrepha* captured in traps in orchards [16,17].

Adults of the South American fruit fly have a yellow body with transparent wings, with two characteristic spots, one in an "S" shape in the central part and one in an inverted "V" shape at the apex. Adults measure about 7 mm in length and 16 mm in wingspan. Normally, females are larger than males and differ from these in that they have, at the end of the abdomen, the ovipositor, called the aculeum. Fruit flies are fully metamorphosed insects passing through the egg, larva, pupa and adult stages [18,19].

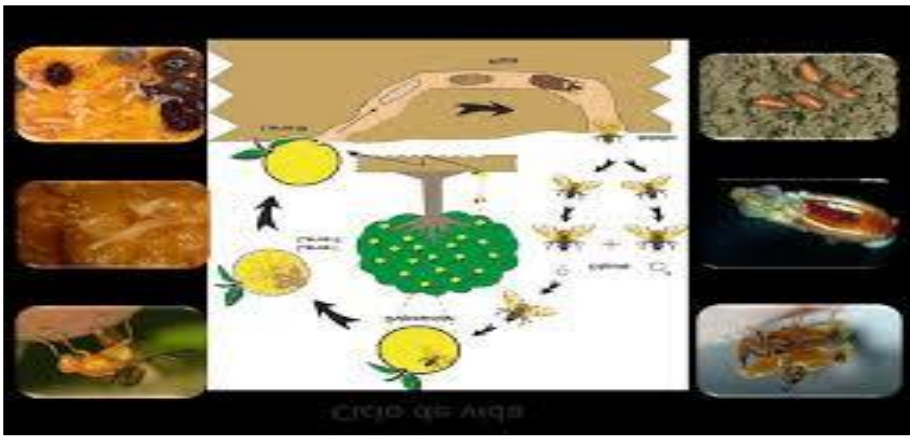

Figure 41 *Anastrepha* spp. life cycle; (Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Frepositorio.ucs.br%2Fxmlui%2Fbitstream%2Fhandle%2F11338%2F672%2FDissertacao%2520Flaviane%2520Eva%2520Magrini.pdf)

Fruit flies need to ingest protein food to complete the development of the ovaries within 7 to 30 days after emergence when they become mating able. Laying is performed below the epidermis, depositing one to two eggs per puncture, which are white with an elongated shape. More than one egg can be placed in each fruit and each female can lay an average of 400 eggs depending on the host (Figure 41) [20,21,22].

After approximately three days, the larvae hatch, passing through three instars. The larvae are vermiform and white to yellowish white in color, with a smooth body. During its development, they build galleries and feed on the pulp, leaving the excrement inside the fruit. The duration of the larval stage varies with temperature and can be from 34.5 days at 15°C to 14 days at 30°C, with no development occurring at temperatures below 10°C and above 35° [23,24].

At the end of the larval stage, these leave the fruits and puff up in the soil in a layer that goes from 2 to 6 cm in depth. Adults emerge after a variable period of 38.6 to 13.5 days for the thermal range of 17.5ºC to 30ºC, respectively, with males remaining perched on nearby vegetation, attracting females to mating through movements, emission of sounds and release of sexual pheromone. Once the female is ready, mating occurs. This is normally carried out on plants, in areas with incidence of sunlight during the first hours of the day and can last from 60 to 80 minutes [23,24,25].

One of the factors that has favored the adaptation of the South American fruit fly as the main pest of fruit growing in southern Brazil is the average longevity of adults, which can vary from 128.7 to 55.5 days in the thermal range of 15ºC at 25°C, respectively. In addition, the large number of hosts allows its multiplication throughout the year, since diapause does not occur in *A. fraterculus* {Figure 42) [25].

The applied biological control of *A. fraterculus* and *C. capitata* has been carried out mainly with the parasitoid of larvae of the family Braconidae *Diachasmimorpha longicaudata* (Ashmead, 1905) (Hymenoptera: Braconidae). However, the natural parasitism of *A. fraterculus* by native species of braconids *Doryctobracon areolatus* (Szépligeti, 1911), *Doryctobracon brasiliensis* (Szépligeti, 1911), *Utetes anastrephae* (Viereck, 1913), *Opius bellus* (Gahan, 1930)], figitids *Aganaspis pelleranoi* (Brèthes, 1924) and peteromalids (*Pachycrepoideus vindemmiae)* in the different producing regions, with cases with up to 30% of control for the region of Pelotas (Figure 43) [25].

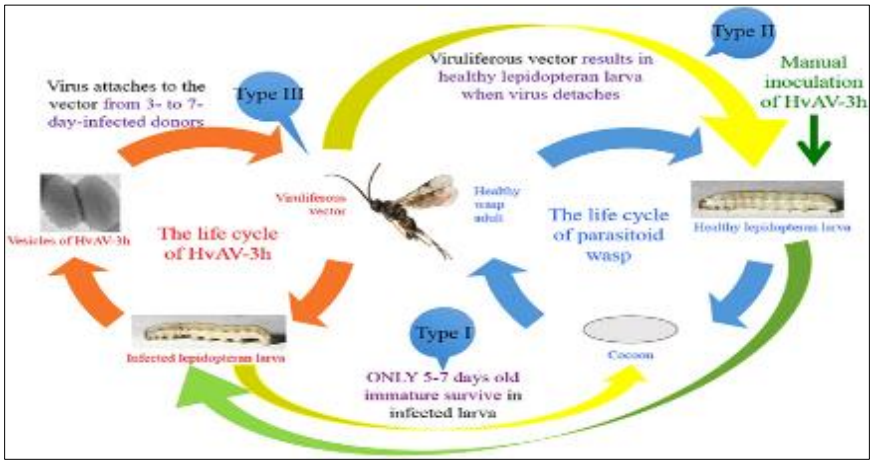

Figure 42 Parasitoid life cycle in *Anastrepha*. The system of parasitoid-host-virus contains two cycles: the life cycle of HvAV-3h and the life cycle of parasitoid wasp: The elements in both cycles are dependent to the other elements. Any changes of nature of any elements in the cycles result in disruption of the cycles. Parasitoid plays the most important role in both cycles, providing overlapping for both cycles. In the life cycle of parasitoid wasp (with blue arrows), the parasitoid wasp here is referred to healthy parasitoid wasp, which parasitizes lepidopteran larva, and the latter produces cocoon of parasitoid wasp, emerging as parasitoid wasp adult. In the life cycle of HvAV-3h (with blue, orange arrows), the parasitoid wasp here is referred to viruliferous vector. The virus (from donor) attaches to parasitoid wasp's (becomes viruliferous vector) ovipositor and be introduced into lepidopteran larva's cavity through parasitism of the viruliferous vector. The lepidopteran larva then becomes infected (donor) and provides virus for other parasitoid wasp since host-marking does not block viral transmission. The system containing both cycles is supposed to keep balance for itself by two scenarios (with yellow arrows): (a) viruliferous vector parasitism results in both infected and uninfected larvae; (b) larva parasitized by healthy parasitoid wasp then by viruliferous vector can produce healthy parasitoid wasp cocoon. The green arrow represents the experimental setting in our study. Purple words indicate the experimental data we got in this study. (All the photos taken by us).

Figure 43 Adult female *Diachasmimorpha longicaudata* (Ashmead), a braconid endoparasitic wasp that parasitizes the caribbean fruit fly, ovipositing into a fly larva; (Source: Photograph by Jeffery Lotz, Division of Plant Industry)

3.7. Study 7

This study aims to provide subsidies for the fruit fly control program in the area that encompasses the Luiz de Queiroz campus of the University of São Paulo. Thus, in this work, the specific composition of the genus *Anastrepha* and its association with host plants were studied (Figures 44, 45, 46, 47 and 48).

The occurrence of greater specific richness of *Anastrepha* - *A. barbiellinii* Lima, 1938*, A. bistrigata* Bezzi, 1919*, A. daciformis* Bezzi, 1909*, A. distincta* Greene, 1934*, A. fraterculus* (Wiedemann, 1830), *A. montei* Lima , 1934, *A. pseudoparallela* (Loew, 1873), *A. serpentina* (Wiedemann, 1830) and *A. sororcula* Zucchi, 1979 on the Luiz de Queiroz campus can be attributed to the great diversity of plant species cultivated in the area (at least 53), many of which are primary hosts of fruit flies, in addition to several species of native plants.

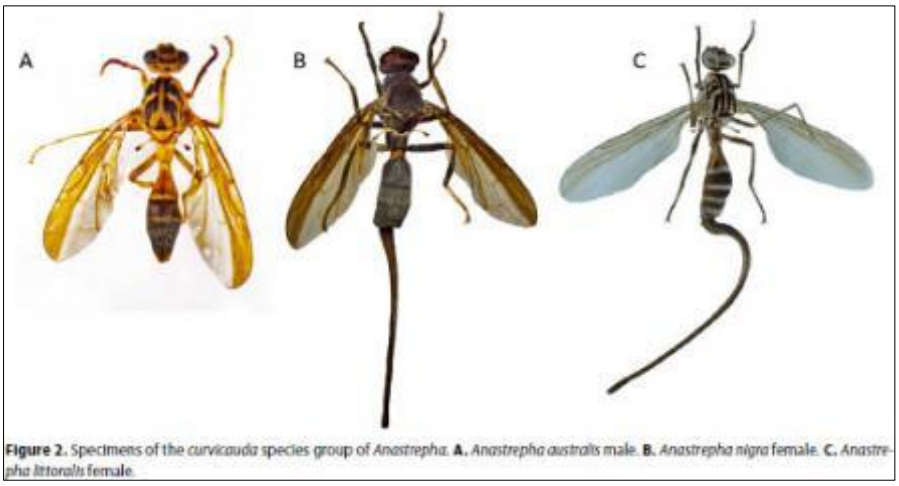

Figure 2. Specimens of the curvicauda species group of *Anastrepha*. **A.** *Anastrepha australis* male. **B.** *Anastrepha nigra* female. **C.** *Anastrepha littoralis* female.

Figure 44 The curvicauda species group of *Anastrepha* Schiner, 1868 (Diptera, Tephritidae, Trypetinae) in Uruguay; (Source: https://go.gale.com/ps/i.do?id=GALE%7CA628854168&sid=googleScholar&v=2.1&it=r&linkaccess=abs&issn=1809127X&p=AONE&sw=w&userGroupName=anon%7Ef7849e89)

10,243 females were identified. Of the 18 species of *Anastrepha* captured in traps, only six emerged from fruits: *A. bistrigata, A. fraterculus, A. obliqua, A. pseudoparallela, A. serpentina* and *A. sororcula*, although several species of fruits were collected. Probably, the other *Anastrepha* species develop in specific hosts on campus, which were not collected. *A. fraterculus* infested the greatest diversity of fruits (20 species), as observed in the surveys of fruit flies on fruit hosts in Brazil.

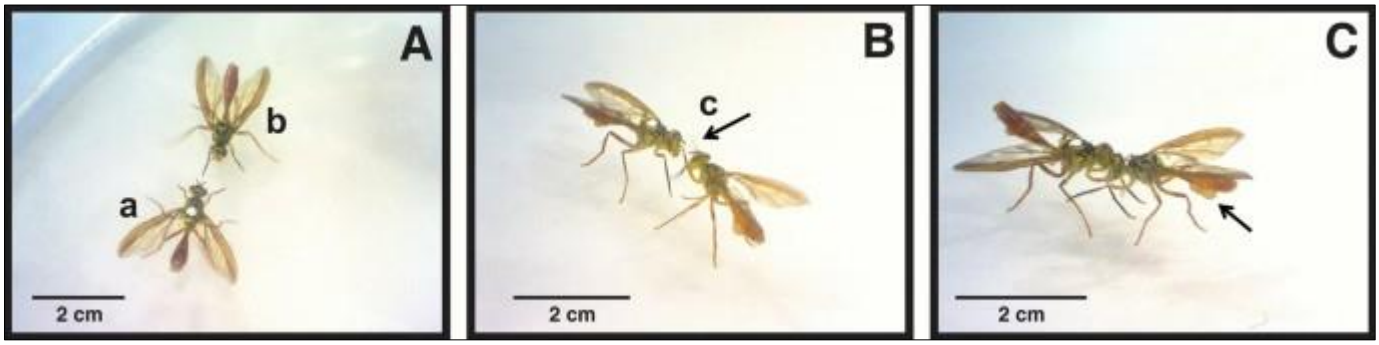

Figure 45 *Anastrepha* mate selection | Scientific Reports; (Source: https://www.nature.com/articles/s41598-021-85823-0)

In the present study, *A. fraterculus* infested species from nine families, including sapoti, *Manilkara zapota* L. (first record in Brazil) and *Pouteria caimito* L., both Sapotaceae, and *Passiflora edulis* Sims (Passifloraceae).

Specimens of *A. obliqua* emerged from nine plant species, mainly from Anacardiaceae. *A. bistrigata* was obtained from *Spondias dulcis* Forst. f. (Anacardiaceae) and *Psidium guajava* L. (Myrtaceae) and *A. sororcula, Eugenia uniflora* L. and *Psidium guajava* (Myrtaceae). *A. pseudoparallela* infested exclusively Passifloraceae and *A. serpentina* was restricted to Sapotaceae species. There is specificity between certain species and host plants, such as the *Pseudoparallela* group to Passiflora species (Passifloraceae) and the *Serpentine* group to Sapotaceae species.

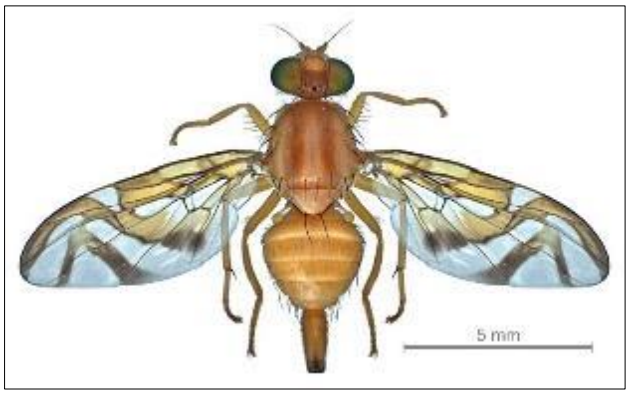

Figure 46 *Anastrepha obliqua* Macquar, 1868 (Diptera: Tephritidae) female, dorsal view; (Source: https://commons.wikimedia.org/wiki/File:Anastrepha_obliqua_female_dorsal.jpg)

Regarding the species of Anacardiaceae, there was a high infestation by *A. obliqua*. The cajá-manga (*Spondias dulcis*) was attacked by *A. bistrigata* and *A. fraterc*ulus and the mango (*Mangifera indica* L.) by *A. fraterculus*, however the infestations by these species were relatively minor. Star fruit (*Averrhoa carambola* L.) was predominantly infested by *A. obliqua* and in a small proportion by *A. fraterculus*. The preference of *A. obliqua* for star fruit (Oxalidaceae). From sweet passion fruit (*Passiflora alata* Dryander), it was obtained exclusively *A. pseudoparallela* and from sour passion fruit (*P. edulis*) it was also observed the predominant infestation by *A. pseudoparallela* and the emergence of only five specimens of *A. fraterculus*.

Figure 47 Phases of the biological cycle of *Anastrepha fraterculus* (Wiedemann, 1830) (A) adults – female on the left and male on the right; (B) egg; (C) larva; (D) puparia; (Source: hrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fcore.ac.uk%2Fdownload%2Fpdf%2F15435659.pdf&clen=852720&chunk=true)

Rosaceae species were exclusively infested by *A. fraterculus*. For the species of Rutaceae, *A. fraterculus* was predominantly obtained, except for two samples with three specimens of *A. obliqua*. The only species of Rubiaceae sampled, *Coffea arabica* L., was also predominantly infested by *A. fraterculus* and by only one specimen of *A. obliqua*. These associations with *A. obliqua* are accidental, considering the low proportion in relation to the total number of individuals that emerged.

Fruit flies emerged from guava samples collected from September to June, with an increase in infestation from December to March. The infested pitanga and uvaia samples were collected from September to November and from jambo only in December. Although citrus infestation was low, samples of these infested fruits were obtained throughout the year. This picture indicates the occurrence of a succession of hosts mainly for *A. fraterculus*.

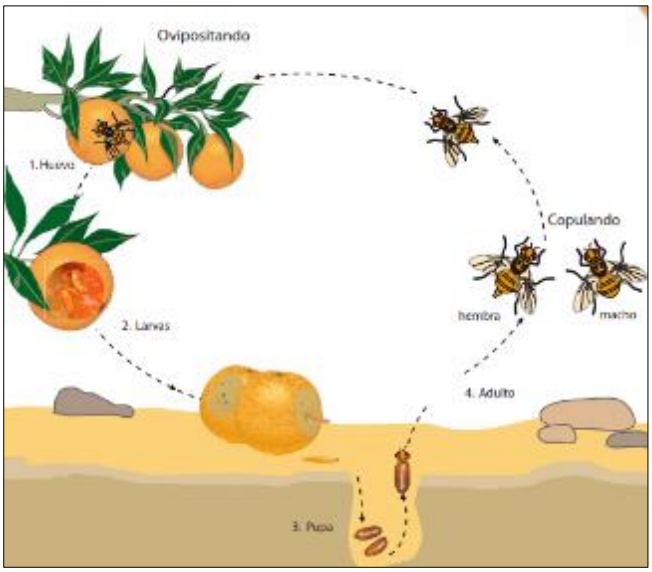

Figure 48 The female fly, once fertilized, places its huevos under the shell of the fruits in groups of 10 to 12 which will develop in a period of 2 to 7 days to emerge as larvae; (Source: https://www.librosymanualesdeagronomia.com/manual-de-mosca-de-la-fruta-agronomia-pdf-gratis/)

A similar scenario occurred with the preferred hosts of *A. obliqua,* with the following host succession: mango (November to February), cajá-manga (February to September, with greater infestations in (February and March), seriguela (January to March) and carambola (December to September) [26].

3.8. Study 8

Thus, in order to know the species of blemished-wing flies that are captured in flycatchers, as well as possible eating habits (Figure 49)

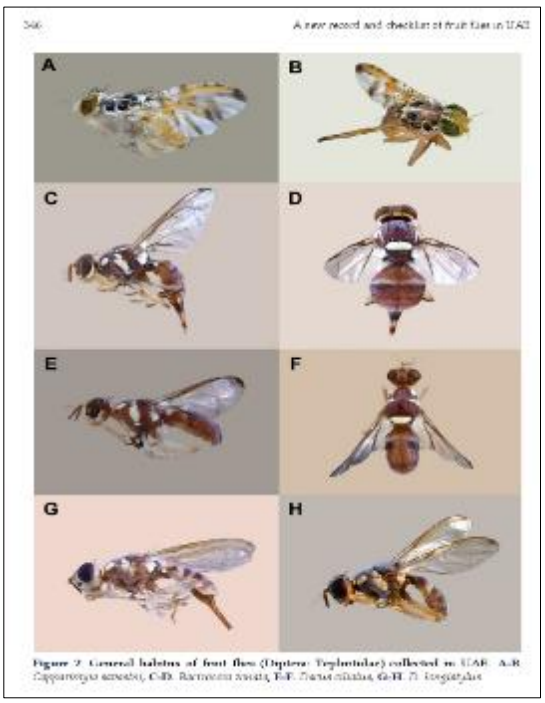

Figure 49 General habitus of fruit flies (Diptera: Tephritidae) collected in UAE. A-B. *Capparimyia savastni*, C-D. *Bactrocera zonata*, E-F. *Dacus ciliatus*, G-H. *D. longistylus*; (Source: https://jibs.modares.ac.ir/browse.php?a_code=A-10-56198-1&slc_lang=en&sid=36)

Figure 50 *Rhagoletis blanchardi* Aczel; (Source: https://bugguide.net/node/view/1629058)

Spotted wing flies may occur in some more characteristic families in the Tephritidae family, the true fruit flies, and in the Otitidae family (sensu latu), of false fruit flies The Otitidae family is being reexamined by taxonomists, who propose the division of the family into several others, as well as a better separation between the genera so that the species determinations are reliable. Among the species of the Tephritidae family found in the stored material, the following were determined: *Blepharoneura* sp., *Ceratitis capitata* (Wied.), *Dioxyna peregrina* (Loew), *Parastenopa elegans* (Blanchard), *Rhagoletis blanchardi* Aczel, *Rhagoletis ferruginea* Hendel, *Rhagoplaletotrymosa pastran* Hendel, *Tomoplagi*a sp. and *Trupanea* sp. for two other species, one being morphologically like *Trupanea* but larger in size, not enough specimens were obtained to identify it (Figure 50).

The records of *D. peregrina* and *T. reimoseri* are unpublished for the State of Santa Catarina. Species belonging to 7 Otitidae family (latu sensu) determined: *Neomyennis appendiculata* Hendel, *Neomyennis zebra* Hendel and Neomyennis sp., *Euxesta sororcula* Wied., *Euxesta* sp. *Robeluta* Loew, *Pterocerina* sp. prob *scalaris* Blanchard and two other species of *Pterocerin,* where the muscle pattern of one of them resembles that of Schiner *Tetrapleura picta*, both of which can be synonymous. Still with wing muscles, *Rhinotor*a sp., belonging to the Rhinotoridae family, was determined. *A. nerius* sp. was also determined. This one, despite not having macules on the wings, presents a long and sheathed ovipositor and that is why it was included [27].

3.9. Study 9

Figure 51 Trap models used in the sampling: (a) McPhail glass trap; (b) Multilure trap; and (c) blue polyethylene bottle. Source: https://www.researchgate.net/figure/Trap-models-used-in-the-sampling-a-McPhail-glass-trap-b-Multilure-trap-and-c_fig1_327200215

Figure 52 The Jackson trap has proven to be effective for the trapping of the Mediterranean fruit fly; (Source: http://www.biotrap.com.au/products?ty=0&kw=&pg=2)

The objective of this study is to know the monitoring of the fly population using traps, which allows knowing the species present, their abundance and distribution, enabling control programming.

McPhail Trap is the standard trap for collecting *Anastrepha adults*, however *C. capitata* adults and other insects are also collected. Jackson Trap is the standard trap for the collection of males of *Ceratitis capitata*, using the parapheromone trimedilure as attractant.

Interpretation of catch results After identification and quantification of the fruit flies, the number of captured flies per trap/day is calculated using the formula: M MAD index = MAD= fly/trap/day, where: M = number of captured flies; A= number of traps in the orchard D= number of days of exposure of the trap (Figures 51and 52) [28].

3.10.Study 10

The purpose of this work was to identify the species of *Anastrepha*, their natural and introduced hosts and the associated parasitoid species in 5 municipalities of the eastern zone of the Brazilian state of Amapá.

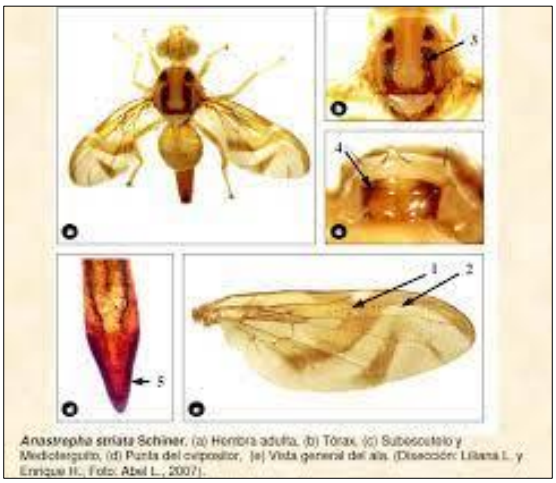

Figure 53 *Anastrepha striata* Schiner; (Source: Directorate General of Vegetable Health Directorate of Fruit Flies – Sarcapa)

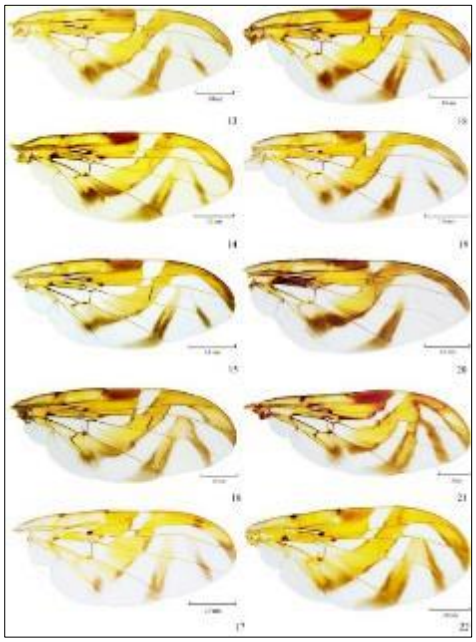

Figure 54 Wings: 13, *A. obliqua* (Paraguay: Cordillera, ICAM, 14, *A. pastranai* (Paraguay: Boquerón); 15, *A. pickeli* (Paraguay: Cordillera); 16, *A. pseudoparallela* (Paraguay: Cordillera); 17, *A. punctata* (Paraguay: Ñeembucú); 18, *A. rheediae* (Paraguay: Ñeembucú); 19, *A. sororcula* (Paraguay: Boquerón); 20, *A. striata* (Paraguay: Cordillera); 21, *A. undosa* (Paraguay: Misiones); 22, A. *xanthochaeta* (Paraguay: Itapúa); (Source: Clavijo, Pedro Alexander Rodriguez, Miret, Luz Maria, Norrbom, Allen L., Garay, Liz Carolina, Coronel, Blanca E. & Peñaranda, Emilio Arévalo, 2020, New records of *Anastrepha* (Diptera: Tephritidae) from Paraguay, Zootaxa 4809 (1), pp. 141-155: 145)

Table 1 Plant species sampled in the municipalities of Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb. 2006 to Aug. 2007

Family/Species	Origin*	Family/Species	Origin*
Anacardiaceae		**Malpighiaceae**	
Anacardium occidentale L.	N	*Byrsonima crassifolia* (L.) Kunth	N
Mangifera indica L.	SS	*Malpighia punicifolia* L.	N
Spondias mombin L.	N	**Lamiaceae**	
Spondias purpurea L.	E	*Gmelina arborea* Roxb. ex Sm.	N
Annonaceae		**Melastomataceae**	
Annona paludosa Aubl.	N	*Bellucia imperialis* Saldanha & Cogn.	N
Annona squamosa L.	E	*Bellucia grossularioides* (L.) Triana.	N
Annona muricata L.	E	*Mouriri acutiflora* Naud.	N
Annona mucosa (Jacq.) Bail.	N	**Fabaceae**	
Apocynaceae		*Inga edulis* Mart.	N
Ambelania acida Aubl.	N	*Inga fagifolia* G. Don	N
Couma utilis (Mart.) M. Arg.	N	*Inga heterophylla* Willd.	N
Parahancornia amapa (Huber) Ducke	N	*Inga velutina* Willd	N
Arecaceae		*Inga* sp. 1	SS
Astrocaryum vulgare L.	N	*Inga* sp. 2	N
Attalea maripa (Aubl.) Mart.	N	*Inga* sp. 3	N
Attalea phalerata Mart. ex Spring.	N	*Inga* sp. 4	N
Bactris maraja Mart.	N	*Inga* sp. 5	N
Bactris gasipaes Kunth.	N	*Inga* sp. 6	N
Oenocarpus bacaba Mart.	N	**Moraceae**	
Oenocarpus distichus Mart.	N	*Artocarpus heterophyllus* Lam.	SS
Bignoniaceae		*Ficus* sp.	N
Jacaranda copaia (Aubl.) D. Don	N	**Myrtaceae**	
Bromeliaceae		*Campomanesia xanthocarpa* O. Berg.	N
Ananas ananassoides (Baker) L.B. Sm.	N	*Eugenia cumini* (L.) Druce	SS
Ananas comosus (L.) Merr.	N	*Eugenia luschnathiana* Klotzsch ex O. Berg	SS
Burseraceae		*Eugenia malaccensis* L.	N
Protium heptaphyllum (Aubl.) March.	N	*Psidium guajava* L.	N
Trattinnickia burserifolia Mart.	N	*Psidium guineense* SW	N
Caricaceae		*Psidium* sp. 2	N
Carica papaya L.	SS	**Oxalidaceae**	
Caryocaraceae		*Averrhoa bilimbi* L.	SS
Caryocar glabrum Pers.	N	*Averrhoa carambola* L.	SS
Chrysobalanaceae		**Passifloraceae**	
Licania macrophylla Benth.	N	*Passiflora* sp. 1	N
Chrysobalanus icaco L.	N	*Passiflora* sp. 2	N
Dilleniaceae		**Rubiaceae**	
Doliocarpus sp.	N	*Coffea arabica* L.	SS
Dioscoreaceae		**Rutaceae**	
Dioscorea alata L.	N	*Citrus sinensis* (L.) Osbeck.	SS
Euphorbiaceae		*Citrus* sp.	N
Manihot sp.	N	**Sapotaceae**	
Celastraceae		*Pouteria caimito* (Ruiz & Pav.) Radlk.	N
Cheiloclinium cognatum (Miers) A.C. Sm.	N	*Pouteria* sp. 1	N
Humiriaceae		*Pouteria* sp. 2	N
Endopleura uchi (Huber) Cuatrec.	N	**Solanaceae**	
Lauraceae		*Solanum paniculatum* L.	N
Licaria mahuba (A. Samp.) Kostern.	N		
Persea americana Mill.	SS		

*N = native species, E = exotic species, SS = subspontaneous.

Table 2 *Anastrepha* species, hosts and period of occurrence in fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira Gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, Feb 2006 to Aug 2007

Host plant			Period and site of sampling*																	
			2006										2007							
Tephritidae	Family	Species	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
A. antunesi	Anacardiaceae	*S. mombin*												P							
	Melastomataceae	*B. imperialis*					C		C												
A. coronilli	Melastomataceae	*B. imperialis*					FT	CFT	T		T		T		T			F	F	CFT	CF
	Myrtaceae	*P. guajava*		T	CT		IT														
A. distincta	Fabaceae	*Inga* sp.1	T	T	T						T									F	C
		Inga sp. 4				T						F									
		Inga sp. 5												F							
		I. edulis				CFI	T	T	CI		FT	TP	CIT	CFIP	TP	FP	C				
		I. fagifolia												T							
	Myrtaceae	*P. guajava*										T	I				F				
	Oxalidaceae	*A. carambola*										I									
A. fraterculus	Anacardiaceae	*A. occidentale*											P								
		S. mombin	T	I										P		I	P				
	Malpighiaceae	*B. crassifolia*	C																		
	Melastomataceae	*M. acutiflora*													CT						
	Myrtaceae	*P. guajava*	T	T	T	CP									FPT	I	T	CIT			
A. leptozona	Sapotaceae	*Pouteria* sp. 1												F	F						
A. obliqua	Anacardiaceae	*S. mombin*	CT	CFIP	FP	CFIP								C	FPT	FIP	FP	FP			
		S. purpurea										T									
A. parishi	Melastomataceae	*B. imperialis*					T														
	Myrtaceae	*P. guajava*											P								
A. pickeli	Euphorbiaceae	*Manihot* sp.																			IT
A. serpentina	Sapotaceae	*Pouteria* sp. 2															P				
A. sororcula	Melastomataceae	*B. granulaioides*																			C
		M. acutiflora														C					
A. striata	Anacardiaceae	*A. occidentale*											P								
		S. mombin				C										P		P			
	Apocynaceae	*C. utilis*												F							
	Arecaceae	*O. bacaba*													I	P					
	Fabaceae	*Inga* sp.1		T																	
		Inga sp. 4				F															
		Inga edulis				C			I		P	P		CFT	T						
	Malpighiaceae	*B. crassifolia*												C							
	Melastomataceae	*B. granulaioides*																		F	
		B. imperialis					FT				T										
	Myrtaceae	*E. luschnathiana*										C									
		P. guajava	CFIT	CIPT	CFIT	CFIPT	CFIPT	IFP	FITP	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIPT	CFIT	CFIPT	CFIPT	CIP	CFIT
		P. guineense													P						
	Oxalidaceae	*A. carambola*						C				C									
A. zenildae	Myrtaceae	*P. guajava*							P												

*C = Cutias do Araguari, F = Ferreira Gomes, I = Itaubal do Piririm, T = Tartarugalzinho, P = Pracuúba.

Table 3 Number of parasitoids observed in *Anastrepha s*pecies found in fruits collected in Cutias do Araguari, Itaubal do Piririm, Ferreira gomes, Pracuúba, and Tartarugalzinho in Amapá, Brazil, feb 2006 to aug 2007

	Doryctobracon areolatus (n)	*Opius bellus* (n)	*Asobara anastrephae* (n)	*Utetes anastrephae* (n)
A. coronilli	136	0	0	0
A. distincta	7	0	0	0
A. fraterculus	78	0	2	0
A. obliqua	95	15	1	2
A. parishi	2	0	0	0
A. striata	307	3	4	0

A total of 817 samples (1,094.36 kg) of potential fruit fly hosts were collected from 70 plant species across 29 families (Tables 1, 2 and 3) Among the sampled plant species, *Psidium guajava* L.; Myrtales: Myrtaceae (guava) and *Anacardium occidentale* L; Sapindales: Anacardiaceae (cashew) are the most widely known and commonly grown in other regions of Brazil. Most other species were native (some of them found in a wild state), obtained from backyards or small rural properties where these plants are used for household consumption.

Among the sampled species, 22 were infested by *Anastrepha*, and Fabaceae was the family with the highest number of infested species, all of them in the genus *Inga*. Myrtaceae was second in number of collected and infested species, followed by Anacardiaceae. It should also be noted that all sampled species of Sapotaceae and Melastomataceae were infested. Other studies exploring wild fruits in Brazil Myrtaceae have emphasized as the plant family with the highest rates of infestation by Tephritidae. The tephritids obtained in this work all belonged to the genus *Anastrepha*.

We did not collect any *Bactrocera carambolae* Drew & Hancock and *Ceratitis capitata* (Wiedemann). *Bactrocera carambolae* is found only in the state of Amapá where an eradication program is underway. *Ceratitis capitata* has not been detected in the state. Twelve species of *Anastrepha* were identified.

Anastrepha striata Schiner (82.65*%), Anastrepha coronilli* Carrejo & González (6.63%), *Anastrepha obliqua* Macquar, *Anastrepha distincta* Greene (2.28%), *A. fratercuius* (2.10%), *Anastrepha parishi* Stone (0.30%), *Anastrepha leptozona* Hendel (0.22%), *Anastrepha pickeli* Lima (0.11%), *Anastrepha antunesi* Lima (0.07%), *Anastrepha serpentina* (Wiedemann) (0.07%), *Anastrepha sororcula* Zucchi (0.06%), and *Anastrepha zenildae* Zucchi (0.04%) *Anastrepha striata* had by far the highest number of hosts (14 species of fruit belonging to 8 families). *Anastrepha fraterculus* was observed in 5 host species (4 families).

The present work recorded a total of 652 specimens of parasitoids, all of them Braconidae: *Doryctobracon areolatus* (Szépligeti, 1911) (95.86%), *Opius bellus* Gahan, 1930 (2.76%), *Asobara anastrephae* (Muesebeck, 1958) (1.07%), and *Utetes anastrephae* (Viereck, 1913) (0.31%). *Doryctobracon areolatus* was most abundant and was present in all plant species where parasitoid emergence was observed (Figures 53 and 54 (Tables 1, 2 and 3) [29].

3.11.Study 11

The objective of this investigation was to determine the dynamics of population and the diversity of fruit flies (Tephritidae) in a mixed garden containing mango (*Mangifera indica*) cultivars Haden, Tommy Atkins, and Palmer, in the city of Presidente Prudente, SP, Brazil.

The populational dynamics of fruit flies was measured from November 2005 to December 2007 through weekly collections of adults using McPhail yellow-based traps with hydrolyzed protein solution (Figure 55).

Figure 55 McPhail trap used for monitoring, immature forms and symptoms of fruit fly (Diptera: Tephritidae) infestation on citrus; (Source: Photos: LT Galdino and A. Raga)

A total of 65,956 Tephritidae specimens was captured, comprising 63,168 specimens of *Ceratitis capitata* (95.77% of the total) and 2,788 specimens of *Anastrepha* spp. (4.23% of the total). *C. capitata* was represented by 46.74% of males

and 56.26% of females; for *Anastrepha* spp., 55.92% were males and 44.08% females. The highest capture of fruit flies took place in 2006 (93.6%), with 96.21% of that total consisting of *C. capitata* and 3.78% of *Anastrepha* spp.

A total of 229 female specimens of *Anastrepha* and 33,647 specimens of *C*. *capitata* were captured during the study period, in mixed orchard mango. The total number of captured *Anastrepha* specimens in traps was divided among *A. obliqua* (91.7%), *A. frater*culus (Wied.) (3.3%), *A. sororcula* Zucchi, 1979 (1.4%), *A. pseudoparalella (*Loew, 1873) (1.0%), *A. striata* Schiner, 1868 (0.7%), *A. barbiellinii* Lima, 1938 (0.2%), *A. daciformis* Bezzi, 1909 (0.08%), *A. haywardi* Blanchard 1961 (0.08%), *A. zenildae* Zucchi, 1979 (0.08%), *A. leptozona* Hendel, 1914 (0.6%) and *A. montei* Lima, 1934 (0.9%).

The specimens obtained in this work were generally monomorphic, following the pattern featured in the description of the species, except for *A. obliqua*, which showed variations in the aculeus apex (Tables 4 and 5) [30].

Table 4 Species of fruit flies (females) in a mixed orchard containing three cultivars of Mangifera indica at President Prudente, SP. November 2005to December 2007.

Species of fruit flies	Total number of individuals recovered	Number of individuals in mango cultivars		
		Haden	Tommy Atkins	Palmer
Ceratitis capitata Wiedemann, 1824	33,647	14,474	11,721	7,452
Anastrepha obliqua (Macquart, 1835)	1,127	360	351	416
A. fraterculus (Wiedemann, 1830)	41	19	13	9
A. *sororcula* Zucchi, 1979	17	8	7	2
A. pseudoparalella (Loew, 1873)	12	5	5	2
A. striata Schiner, 1868	8	4	0	4
A. barbiellinii Lima, 1938	3	1	2	0
A. daciformis Bezzi, 1909	1	0	0	1
A. haywardi Blanchard, 1961	1	1	0	0
A. leptozona Hendel, 1914	7	1	5	1
A. zenildae Zucchi, 1979	1	0	1	0
A. montei Lima, 1934	11	7	0	4

Source: Montes SMNM, Raga A, Souza-Filho MF. Presence of fruit flies (Diptera: Tephritidae) in a mixed mango orchard in the city of Presidente Prudente, SP, Brazil. Revista Colombiana de Entomología. 2012; 38 (2): 231237.

Table 5 Fauna analysis of fruit fly species captured using McPhail traps baited with hydrolyzed protein at President Prudente, SP. November 2005 to December 2007

Species	Haden				Tommy Atkins				Palmer			
	N	F	C	D	N	F	C	D	N	F	C	D
Ceratitis capitata	14,5	97.3	W	D	11,7	96.89	W	D	7,45	94.51	W	D
Anastrepha obliqua	360	2.42	Y	D	351	2.9	Y	D	416	5.28	Y	nd
Anastrepha fraterculus	19	0.13	Z	nd	13	0.11	Z	nd	9	0.11	Z	nd
Anastrepha sororcula	8	0.05	Z	nd	7	0.06	Z	nd	2	0.03	Z	nd
Anastrepha pseudoparalella	5	0.034	Z	nd	5	0.04	Z	nd	2	0.03	Z	nd
Anastrepha striata	4	0.027	Z	nd	0	0	.	.	4	0.05	Z	nd

Silveira et al. (1976) - W - constant species Y - acessory species Z - accidental species D - dominant species nd- not dominant species N - number F - frequency C - consta
D - dominant

Source: Montes SMNM, Raga A, Souza-Filho MF. Presence of fruit flies (Diptera: Tephritidae) in a mixed mango orchard in the city of Presidente Prudente, SP, Brazil. Revista Colombiana de Entomología. 2012; 38 (2): 231237.

Anastrepha is the most diverse genus in the American tropics and subtropics. Currently, it comprises more than 300 described species, including nine major pest species, such as the Mexican fruit fly (*A. ludens*), the South American fruit fly (*A. fraterculus* complex), the West Indian fruit fly (*A. obliqua*), the sapote fruit fly (*A. serpentina*), the Caribbean fruit fly (*A. suspensa*), the American guava fruit fly (*A. striata*), and the pumpkin fruit fly (*A. grandis*), as well as the papaya fruit fly (formerly *Toxotrypana curvicada* and *T. littoralis*). As some of their names suggest, these pest species cause damage in commercial fruits such as citrus, mango, guava, and papaya (Figures 56, 57 and 58).[30].

Figure 56 Fruit Fly Nets Tree insect net 2.4 X 2.8 meters. Used to protect Crops from insects, Formed to Drape over trees; (Source: http://www.biotrap.com.au/products?ty=0&kw=&pg=2)

Figure 57 Trap the Lynfield Trap consists of a disposable clear plastic cylindrical container measuring 115mm deep with a 100mm diameter base and 90mm diameter screw top. There are four evenly spaced entry holes around the wall of the trap; (Source: http://www.biotrap.com.au/products?ty=0&kw=&pg=2)

Figure 58 Sticky inserts Sticky insert for the Biotrap; (Source:

http://www.biotrap.com.au/products?ty=0&kw=&pg=2)

4. Conclusion

Fruit flies belong to the Tephritidae family that is one of the largest within the Order Diptera. This family is among the pests with the greatest economic expression in the world's fruit industry, as they attack the reproductive organs of plants, fruits with pulp and flowers. Therefore, to establish any fruit fly program, prior knowledge of the ecological aspects of tephritid populations and their parasitoids is necessary.

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