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Fruit Flies (Diptera: Tephritoidea): Biology, Host Plants, Natural Enemies, and the Implications to Their Natural Control

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1. Introduction

Brazil is the third world largest producer of fruits, surpassed only by China (94.4 millions of tons) and India (51.14 million tons) (Vitti, 2009). The fruit growing area in Brazil currently takes up 2.3 millions of hectares, with an annual production superior to 36.8 millions of tones. The horticulture generates six millions of direct jobs, totalizing about 27% of total labor force employed in agriculture in the Country, and makes a gross domestic product (GDP) of about US$ 11 billion. In the farms of fruit growing, in general, there are a demand for intensive and qualified labor, creating jobs and ensuring a rural Well-being of the farmers and their employees, both on small farms as on large farms. However, Brazil occupies the 17th position among world exporters of fruits (Ibraf, 2009; Vitti, 2009).

Part of Brazilian fruit production is lost in the field due the attack by larvae of different species of fruit flies (Diptera: Tephritoidea). Herein, fruit flies are referred as the guild of all specialized species with frugivorous larvae, that in South America, especially in Brazil, belong to two families: Tephritidae and Lonchaeidae (Diptera: Tephritoidea) (Uchoa & Nicácio, 2010). On the other hand, the fruit flies are interesting animals of the scientific point of view, because they have polytene chromosomes like those found in species of *Drosophila* (Drosophilidae), which are very important for genetics studies. Fruit Flies also can be easily reared in the laboratory to serve as experimental animals for research in several areas of the biological and environmental sciences (Uchoa et al., 2004).

The fruit flies belong to two families: Tephritidae and Lonchaeidae (Tephritoidea). They have great economic importance because they are considered the key pests that most adversely affect the production and marketing of fruits and vegetables around the world. The tephritids are able of inserting the ovipositor to drop their eggs into the living tissues of host plants, such as green fruit, fruit in process of maturation or ripe fruits. If females of Lonchaeidae lay their eggs inside or over the fruits, flowers, or inside terminal shoots of Euphorbiaceae is still unknown. According Lourenção et al. (1996), *Neosilba perezi* (Romero & Ruppel) is a key pest in shoots of cassava clones. Both families of fruit flies cause direct and indirect damages. The direct ones are because their eggs hatch and the larvae eat the underlying flesh of the fruits. The indirect damage is due to depreciation of the fruits in the market retailers; opening holes through which can penetrate pathogenic microorganisms or decomposers, or yet, causing the early fall of fruits attacked in the field. Some species of fruit flies are also the major bottleneck in the exports of fresh fruits and vegetables between nations. This is because the importing countries generally impose stringent quarantine barriers to the producing and exporting Countries where fruit flies do occur, fearing the entry exotic species inside the imported products in their territories (Uchoa & Nicácio, 2010; White & Elson-Harris, 1992).

Tephritidae is the most species rich family of fruit flies, with around 5,000 described species, in six subfamilies (Tachiniscinae, Blepharoneurinae, Phytalmyiinae, Trypetinae, Dacinae, and Tephritinae); about 500 genera, and probably many undescribed species worldwide. Tephritids are peculiars because they are among the few groups of dipterans strictly phytophagous, except the Tachiniscinae, which are thought be parasitoids of Lepidoptera, and at least, some species of Phytalmyiinae that feed on live or dead bamboos (Poaceae) or on trees recently fallen of other plant families. Blepharoneurinae feed in flowers, fruits, and make galls in Cucurbitaceae; Trypetinae and Dacinae feed in fruits or in seeds of a wide range of plant families, and Tephritinae eat in flowers, make gall, or are leaf-miners in a wide array of plant taxa: Aquifoliaceae, Scrophulariaceae, Verbenaceae, but mainly in flowerheads of Asteraceae (Norrbom, 2010; Uchoa & Nicácio, 2010).

The Lonchaeidae fruit flies have about 500 described species worldwide, in two subfamilies, and nine genera. Dasiopinae is represented only by *Dasiops* Rondani, and the Lonchaeinae, with the other eight remaining genera, being *Neosilba* the most studied and economically important genus in Neotropics, with 20 described species, from which 16 are reported in Brazil. The genus *Dasiops*, with about 120 described species worldwide, have few species reported in Brazil. The lonchaeids eat in flowers or fruits from different plant taxa (e. g. Asteraceae) or feed on organic matter, especially decaying plants (Macgowan & Freidberg, 2008; Uchoa & Nicácio, 2010).

The fruit fly species economically important in Brazil belong to six genera: *Anastrepha* Schiner, *Bactrocera* Macquart, *Ceratitis* McLeay, *Rhagoletis* (Loew) (Tephritidae), *Dasiops* Rondani, and *Neosilba* McAlpine (Lonchaeidae). The genera *Bactrocera* and *Ceratitis* in Brazil are represented by only one species each: *B. carambolae* Drew & Hancock, and the Mediterranean-Fruit fly, *C. capitata* (Wiedemann), both introduced in Brazil (Nicácio & Uchoa, 2011). The species of *Rhagoletis* have some economic importance in South of Brazil.

2. Fruit flies species with economic importance in South America

The genus *Anastrepha* is originally from the Neotropical Region, with a total of 252 species described worldwide to date, being 112 recorded in Brazil (Nicácio & Uchoa, 2011; Norrbom & Uchoa, 2011), where about 14 species of *Anastrepha* (Tab. 1), along with *Bactrecera carambolae*, *Ceratitis capitata* (Wiedemann) (Tephritidae), and some species of *Dasiops* and *Neosilba* (Lonchaeidae) are the main species of fruit flies with actual or potential economic importance to the Brazilian crop fruits or vegetables (Nicácio & Uchoa, 2011).

Bactrecera carambolae is native to the Indo-Australian region. It attacks at least 26 species of host fruits worldwide, most of them of commercial interest (e.g., Star Fruit, mango, sapodilla, cherry, guava, jabuticaba, rose apple, jackfruit, breadfruit, orange, tangerine, tomato, etc.). It was introduced in Northern Brazil (Oiapoque, Amapá) in 1996 from French Guiana, carried probably by airplane flights (aircraft) between Indonesia and Suriname (Oliveira et al., 2006). *B*. *carambolae* is a species in process of eradication from the Region North of Brazil.

The genus *Ceratitis* has 89 described species worldwide, occurring mainly in tropical Africa. In Brazil occurs only *Ceratitis capitata* which is distributed in almost all tropical and warm temperate areas in the world (Virgilio et al., 2008). *C. capitata* is originally from Africa, with abundant populations in the Mediterranean region which borders with Europe. It has been found in Brazil for the first time in 1901, in the state of São Paulo (Uchôa & Zucchi, 1999).

The genus *Rhagoletis*, with 70 described species occurs mainly in the Holarctic and Neotropical regions, being reported 21 species in the last one. *Rhagoletis* species infest mostly fruits of Juglandaceae, Rosaceae, Rutaceae, and Solanaceae. In the Brazilian territory are reported three species (*Ragoletis adusta* Foote, from the state of São Paulo, *R. ferruginea* Hendel, in Bahia, Paraná, and Santa Catarina, and *R. macquarti* (Loew), in Goiás, and Minas Gerais (Foote, 1981; Ramírez et al., 2008), but the species of *Rhagoletis* have not been considered as key pests in Brazil. On the other hand, some species in this genus are pest of fruits in Peru and Chile (Salazar et al., 2002).

Lonchaeidae is the second family of fruit flies with economic importance in South America, where some species of the genera *Dasiops* and *Neosilba* are primary pests in crop fruits. The species of *Dasiops* attack cultivated or wild passion fruit species: green or ripe fruits, or floral buds (Passifloraceae), depending on the *Dasiops* species (Norrbom & Mcalpine, 1997; Uchoa et al., 2002; Uchoa & Nicácio, 2010). The *Neosilba* species are generally polyphagous, attacking many species of fruit, native or exotic, cultivated or wild ones. The *Neosilba* species most commonly involved in the infestation of fruits and vegetables are: *N. zadolicha* Steyskal & McAlpine, *N. pendula* (Bezzi), *N. glaberrima* (Wiedemann), and *N. inesperata* Strikis & Prado. These four *Neosilba* species, plus *N. perezi,* are considered of greatest economic importance in South America because of their damage in crop fruits, vegetables, or in cassava plantations (Lourenção et al., 1996; Nicácio & Uchoa, 2011).

From the species of fruit flies pests that occurs in Central and South America, *Anastrepha obliqua* (Macquart), *Anastrepha fraterculus* (Wiedemann), and *Ceratitis capitata*, are the most polyphagous and with greater distribution in Brazil (Uchoa & Nicácio, 2010), Argentina Guillén & Sánchez (2007), Bolivia, Ovruski et al. (2009), Colombia, Canal (2010), Venezuela, Katiyar et al. (2000), and Peru, Harris & Olalquaiga (1991). Similar pattern is reported in Central America (Reyes et al., 2007), where *Anastrepha ludens* also occurs. Consequently, that that three first species are the most often involved in the colonization of fruits and vegetables sold in the market retailers. The status of these three species as pests of horticulture is motivated by three main factors: the existence of several host species, their wide distribution in the Neotropics (from Mexico to Argentina), and the direct damage that they can cause to fruits and vegetables (Uchoa & Nicácio, 2010). Populations of the Mexican fruit fly *Anastrepha ludens* occurs in North America: Mexico and USA (Florida); in Central America: Belize, Costa Rica, El Salvador, Guatemala, Honduras and Nicaragua, but it is not recorded in South America (Oliveira et al., 2006).

3. Why the control of the fruit flies is so difficult?

The control of fruit flies (including lance flies) in the South American orchards is still done mainly through of spray chemical pesticide. However, worldwide, the widespread use of chemical pesticides to protect agricultural products against insects and other arthropod pests is of increasing concern (Cancino et al., 2009), especially because of consequent environmental pollutants, and human food contamination by pesticides residues with disastrous consequences on our health and environments.

The adult female of the tephritid fruit flies (e.g. *Anastrepha* spp., *Bactrocera* spp., *Rhagoletis* spp., and *Ceratitis capitata*) are able to lay their eggs inside the fruit tissue, pouncing the skin and fruit pulp with their aculeus (ovipositor). After oviposition the wounds over the fruit surface become healed, and the eggs can mature and hatch inside the fruit tissue. The newly emerged larvae are now sheltered from the external environment, making difficult any effort with pesticides to control them.

4. Life history of *Anastrepha* species (Trypetinae: Tephritidae)

The complete life cycle of *Anastrepha fraterculus* in the field is still unknown, but under laboratory conditions (25ºC, and 70-80% RH), the life cycle from egg to the first female oviposition, occurred in about 80 days. The adult longevity in that condition was 161 days to both males and females. The eggs hatch in about 3 days, larvae is completed around 13 days, pupae emerged in about 14 days, and the female gained sexual maturation and started oviposition after 7 days from emergence (Salles, 2000). Differently from other phytophagous groups of Diptera, the adult females of several *Anastrepha* species need to feed on proteinaceous materials to maturing their eggs.

In nature or in laboratory, when the third-instar larvae of *Anastrepha* spp. are fully mature, they fall off from the fruit and dig in the soil to pupation, that occurs at depths between 2 and 5 cm (Hodgson et al. 1998). Nicácio & Uchoa (2011) found that depending on the climatic conditions (between 15-30ºC, and 60-90% RH) the emergence is faster. Under this condition, the adults can emerge, depending on the species, between 14 and 22 days after they have buried themselves in the soil to pupation.

The sexual behavior of *Anastrepha sororcula* Zucchi was studied in laboratory. This species is a key pest of guava (*Psidium guajava* L.) in Brazil. The age of sexual maturation to the males of *A. sororcula* in laboratory was completed between 7 and 18 days, at an average, 12 days after emergence. The males exhibited signaling behavior to the females, characterized by the distension of the pleural area of the abdomen, forming a small pouch on each side, and by the protrusion of a tiny membranous pouch of rectal cuticle that surrounds the anal area. During this display, the males produced rapid movements of wing vibrations, producing an audible sound. A droplet was liberated from the anal area during wing vibration movements. After attracting the females, the males accomplished a series of elaborated movements of courtship behavior (Fig. 1). On the other hand, females became sexually mature between 14 and 24 days, on average, at 19 days after emergence. The daily exhibition of sexual activities was confined almost exclusively to the period from 16:00 to 17:30h. *A. sororcula* presented a sharp protandry pattern (Facholi & Uchoa, 2006). These asynchronous developments between males and females of fruit flies may play an important evolutionary role. If males and females of the same progeny (offspring) reach sexual maturity at different times in nature, the chance of inbred mating decreases, which increases the genetic variability of the species (Nicácio & Uchoa, 2011).

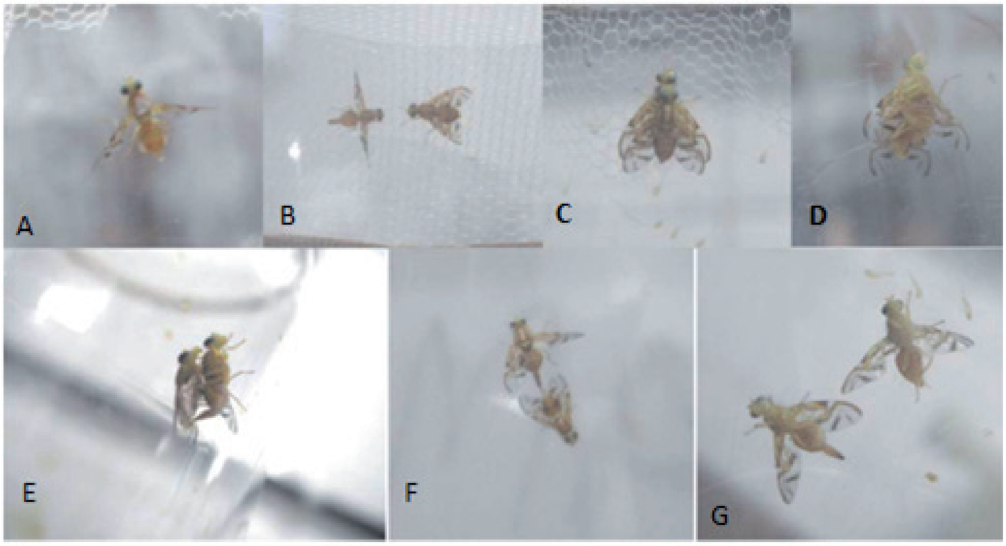

Fig. 1. Ethogram of the typical sequence of the mating behavior of *Anastrepha sororcula*: (A) Male signaling to the female with wing vibration, abdominal tip distension, and protrusion of their anal pouch; (B) the female attracted to the male approaches, and goes running to that chosen one, making alternating movements of rotation with their wings; (C) the male fly forward to mount the female, trying the copulation, or sometimes, he rises by the head of the female trying the copulation; (D) male with hind legs, raises the ovipositor of the female to connect their genitals for coupling; (E) regularly the male vibrates their body over the female's body; (F) the male goes down from female dorsum and both walk with their heads diametrically opposed for the separation of their genitals, and (G) after decoupling, both start rubbing hind legs on their terminalia (Facholi & Uchoa, 2006).

The longest fase on life cycle of *Anastrepha* species is, probably, adult. For some studied species (e. g. *A. fraterculus* and *A. sororcula*) in laboratory conditions (around 25-27 ^{o}C, 60-80% RH) they are able to live for about 180 days. Probably this trait enables the survival some species of *Anastrepha* in natural environment, enabling them to wait for the adequate stage of development of their host fruit in nature.

5. Host plants to fruit flies pests in South America

Although *Anastrepha* is the most biodiverse genus of Neotropical fruit flies, only 14 species are polyphagous, they are with a wide distribution in South America, and able to attack grown fruit and/or vegetables of commercial value. *Anastrepha pickeli* Lima has been recorded as polyphagous, because it is reported breeding in two species of different families (Uchoa et al., 2002; Zucchi, 2008). But, taking in account that the fruits of *Manihot esculenta* Crantz (Euphorbiaceae), and that of *Quararibea turbinata* (Swartz) (Bombacaceae), are not edible, *A. pickeli* is not considered a key pest (Tab. 1).

Ceratitis capitata is cosmopolitan, one of the most important key pest of fruit and vegetable crops worldwide, and certainly, the most widespread species of frugivorous tephritid around the world. This species feeds in more than 400 fruit species from 75 plant families. In Brazil, *C. capitata* is recorded in 60 species of host fruits from 22 families, of which 22 are native (Uchoa et al., 2002; Uchoa & Nicácio, 2010) (Tab. 1).

Species	Host Fruits	Plant Family	Distribution	References
**Anastrepha antunesi* Lima	*Spondias cf. macrocarpa* Engl. *Eugenia stipitata* McVaugh *Psidium guajava* L. *Spondias purpurea* L.	Anacardiaceae Myrtaceae Anacardiaceae	Brazil Peru Venezuela	Uramoto et al., 2008 Zucchi, 2008 White & Elson-Harris, 1994
**A. bahiensis* Lima	*Psidium guajava* L. *Myrciaria cauliflora* (Mart.) *Brosimum potabile* Ducke *Helicostylis tomentosa* (Poep. et Endl.) *Rollinia* aff. *sericea* (Fries) *Ampelocera edentula* Kuhlm.	Myrtaceae Moraceae Annonaceae Ulmaceae	Brazil Colombia Brazil	Zucchi, 2008 White & Elson-Harris, 1994 Uramoto et al., 2008 Costa et al., 2009
**A. bistrigata* Bezzi	*Pouteria gardneriana* (D.C.) *Psidium australe* Cambess. *Psidium guajava* L.	Sapotaceae Myrtaceae	Brazil	Zucchi, 2008
***A. fraterculus* (Wiedemann)	*Rollinia laurifolia* Schltdl. *Myrcianthes pungens* (Berg.) *Psidium guajava* L. *P. kenedianum* Morong *Syzygium jambos* (L.) + 81 Host fruits in Zucchi (2008)	Annonaceae Myrtaceae +18 Plant Families in Zucchi (2008)	Brazil Argentina Bolivia Colombia Ecuador Guyana Paraguay Peru Suriname Uruguay Venezuela	Uramoto et al., 2008 Ovruski et al., 2003 White & Elson-Harris, 1994 Zucchi, 2008 Uchoa & Nicácio, 2010 Castañeda et al., 2010
***A. grandis* (Mcquart)	*Citrullus lanatus* (Thunb.) *Cucumis sativus* L. *Cucurbita maxima* Duchesne *Cucurbita moschata* Duchesne *Cucurbita pepo* L.	Cucurbitaceae	Argentina Bolivia Brazil Colombia Ecuador Paraguay Peru Venezuela	White & Elson-Harris, 1994 Uchoa., 2002 Zucchi, 2008 Castañeda et al., 2010
**A. leptozona* Hendel	*Anacardium occidentale* L. *Alibertia* sp. *Pouteria torta* (Martius) *Pouteria cainito* Radlk.	Anacardiaceae Rubiaceae Sapotaceae	Bolivia Brazil Guyana Venezuela	White & Elson-Harris, 1994 Zucchi, 2008 Uchoa & Nicácio, 2010 Silva et al., 2010
**A. macrura* Hendel	*Ficus organensis* (Miq.) *Schoepfia* sp. *Pouteria lactescens* (Vell.)	Moraceae Olacaceae Sapotaceae	Argentina Brazil Ecuador Paraguay Peru Venezuela	White & Elson-Harris, 1994 Norrbom, 1998 Uchoa & Nicácio, 2010

Species	Host Fruits	Plant Family	Distribution	References
***A. obliqua* (Macquart)	*Anacardium humile* St.Hil. *Anacardium othonianum* Rizzini *Spondias cytherea* Sonn. *Psidium kennedianum* + 37 Host fruits in Zucchi (2008)	Anacardiaceae Myrtaceae + 5 Plant families in Zucchi (2008)	Argentina Brazil Bolivia Colombia Ecuador Paraguay Peru Venezuela	Zucchi, 2008 Uchoa & Nicácio, 2010 Silva et al., 2010 Castañeda et al., 2010 Katiyar et al., 2000
***A. pseudoparallela* (Loew)	*Mangifera indica* L. *Psidium guajava* *Passiflora alata* Curtis *Passiflora edulis* Sims. *Passiflora quadrangularis*	Anacardiaceae Myrtaceae Passifloraceae	Argentina Brazil Ecuador Peru	Zucchi, 2008 White & Elson-Harris, 1994
***A. serpentina* (Wiedemann)	*Spondias purpurea* L. *Mammea americana* L. *Salacia campestris* Walp. *Alibertia* sp. *Coffea canephora* L. *Ficus gomelleira* Kunth & Bouché *Achras sapota* L. *Chrysophyllum cainito* L. *Cotia* sp. *Manikara* spp. *Pouteria* spp. *Pouteria torta* *Pouteria ramiflora* (Martius) *Mimusops coriacea* (A. DC.) *Mimusopsis commersonii* (G. Don.)	Anacardiaceae Clusiaceae Hippocrateaceae Rubiaceae Moraceae Sapotaceae	Argentina Brazil Colombia Ecuador Guyana Peru Suriname Venezuel	Zucchi, 2008 White & Elson-Harris, 1994 Uramoto et al., 2008 Silva et al., 2010 Uchoa & Nicácio, 2010 Uchoa, M. A. – unpubl.
***A. sororcula* Zucchi	*Spondias purpurea* L. *Licania tomentosa* Fritsch *Terminalia catappa* L. *Casearia sylvestris* Swartz *Byrsonima orbignyana* A.Jussieu *Mouriri elliptica* Martius *Psidium cattleianum* Sabine *Psidium kennedyanum* Morong *Schoepfia* sp. *Physalis angulata* L. + 21 Host Fruits in Zucchi (2008)	Anacardiaceae Chrysobalanaceae Combretaceae Fabaceae Flacourtiaceae Oxalidaceae Malpighiaceae Melastomataceae Myrtaceae Olacaceae Oxalidaceae Rosaceae Rubiaceae Solanaceae	Brazil Colombia Ecuador Paraguay	Zucchi, 2008 Uchoa et al., 2002 Uchoa & Nicácio, 2010 Castañeda et al., 2010

Species	Host Fruits	Plant Family	Distribution	References
***A. striata* Schiner	*Spondias mombin* L. *Spondias purpurea* L. *Rolinia mucosa* Jacq. *Attalea excelsa* Martius *Chrysobalanacus icaco* *Persea americana* L. *Byrsonima crassifolia* L. Rich. *Artocarpus heterophyllus* Lam. *Campomanesia cambessedeana* O. Berg. *Eugenia stipitata* McVaugh *Psidium acutangulum* DC *Psidium australe* Cambess. *Psidium guajava* L. *Psidium guineense* SW *Citrus sinensis* L. *Passiflora edulis* *Pouteria cainito* L.	Anacardiaceae Annonaceae Araceae Chrysobalanaceae Lauraceae Malpighiaceae Moraceae Myrtaceae Rutaceae Passifloraceae Sapotaceae	Bolivia Brazil Colombia Ecuador Guyana Peru Suriname Venezuela	White & Elson-Harris, 1994 Uchoa et al., 2002 Zucchi, 2008 Uchoa & Nicácio, 2010
***A. turpiniae* Stone	*Andira cuyabensis* Benthan *Andira humilis* Martius *Psidium kennedyanum* *Psidium guajava* *Psidium guineense* *Eugenia dodoneifolia* Cambess. Syzygium jambos L. *Jacaratia heptaphylla* (Vell.) *Terminalia catappa* L. *Mangifera indica* L. *Spondias purpurea* L. *Prunus persicae* L. *Citrus sinensis*	Fabaceae Myrtaceae Caricacea Combretaceae Anacardiaceae Rosaceae Rutaceae	Brazil	Uchoa & Nicácio, 2010 Uchoa et al., 2002 Zucchi, 2008
***A. zenildae* Zucchi	*Licania tomentosa* *Terminalia catappa* *Andira cuyabensis* *Banara arguta* Briquel *Mouriri elleptica* *Sorocea sprucei saxicola* (Hassler) + 20 Host fruits in Zucchi (2008)	Chrysobalanaceae Combretaceae Fabaceae Flacourtiaceae Melastomataceae Moraceae + 6 Plant Families in Zucchi (2008)	Brazil	Uchoa & Nicácio, 2010 Uchoa et al., 2002 Zucchi, 2008

Species	Host Fruits	Plant Family	Distribution	References
***Bactrocera carambolae* Drew & Hancock	*Benincasa hispida* (Thunb.) *Cucumis sativus* L. *Cucurbita pepo* L. *Lagenaria siceraria* (Molina) *Luffa acutangula* (L.) *Luffa aegyptiaca* (Mill.) *Momordica charantia* L. *Trichosanthes cucumerina* L. *Psidium guajava* *Syzygium samarangense* (Blume) *Prunus persica* (L.) *Citrus aurantium* L. *Citrus maxima* Merr. *Manilkara zapota* (L.) *Capsicum annuum* L. *Lycopersicon esculentum* Mill.	Cucurbitaceae Myrtaceae Rosaceae Rutaceae Sapotaceae Solanaceae	Brazil Guyana Suriname	Oliveira et al., 2006
***Ceratitis capitata* (Wiedemann)	*Juglans australis* Grisebach *Hancornia speciosa* Gomez *Licania tomentosa* *Terminalia catappa* *Mouriri elliptica* *Inga laurina* *Syzygium jambos* *Chrysophyllum gonocarpum* Engler *Pouteria ramiflora* > 400 Host species worldwide (Uchoa & Nicácio 2010)	Juglandaceae Apocynaceae Chrysobalanaceae Combretaceae Melastomataceae Mimosaceae Myrtaceae Sapotaceae + 68 Plant families worldwide (Uchoa & Nicácio 2010)	Argentina Brazil Bolivia Chile Colombia Ecuador Paraguay Peru Uruguay Venezuela	Ovruski et al., 2003 White & Elson-Harris, 1994 Uchoa et al., 2002 Uchoa & Nicácio, 2010

Table 1. Species of Fruit Flies (Diptera: Tephritoidea: Tephritidae) with *potential or **real economic importance in South America.

Herein are considered species with **real economical importance those that have been historically reared from cultivated fruit species with economic value and, with *potential economical importance those that the adults are polyphagous and were reared from some genera of fruit trees in which occur species of fruit with commercial value.

The knowledge of trophic interactions between frugivorous Tephritoidea and their host plants is absolutely necessary to guide strategies for integrated management of fruit fly pests (polyphagous or oligophagous), and for the conservation of stenophagous and monophagous species in their natural environments. Currently in Brazil, from the total of 112 species of *Anastrepha* reported in our territory, are known the host plants for only 61 species (54.46%), being unknown where 51 *Anastrepha* species (45.54%) are breeding neither whom are their natural enemies (Nicácio & Uchoa, 2011).

6. Native parasitoids of *Anastrepha* species and *Ceratitis capitata*

Hymenoptera parasitoids are the most important natural enemies of pest tephritoid larvae throughout both the Neotropical and Nearctic Regions. These entomophagous insects help reduce naturally, sometimes substantially, populations of Tephritidae and Lonchaeidae pests in the field (Ovruski et al., 2009; Uchoa et al., 2003). Mass-rearing and augmentative releases of braconid parasitoids have been considered an important component of area-wide management programs for some species of fruit flies, including widespread polyphagous species of *Anastrepha* and *Ceratitis capitata* (Marinho et al., 2009; Palenchar et al., 2009).

Biological control of frugivorous tephritoid larvae with native parasitoids is a promising component of integrated pest management programs (IPM), because it is environmentally safe and works in synergy with sterile insect technique. Braconidae is the most abundant and species rich parasitoid family of fruit flies in the Neotropical Region. Species of this group also serve as bioindicators of the presence and absence of populations of their host insects (Nicácio et al. 2011).

Tritrophic interactions among wild tephritoids, their host plants and parasitoids, have been a largely neglected field of study in some regions. It could suggest possible applications for native parasitoid species upon frugivorous tephritoid key pests (Cancino et al., 2009). The autochthonous parasitoids are particularly interesting, because of their evolved interactions over extensive periods of time with their hosts (Nicácio et al., 2011), they can be effective in lowering pest populations in orchards (Cancino et al., 2009), keeping tephritoids outbreak in check without diminishing the local biodiversity, as may occur with the use of exotic natural enemies (Nicácio et al., 2011; Uchoa et al., 2003).

Nicácio et al. (2011) evaluated the incidence of parasitoids in larvae of fruit flies that infest several species of native and exotic fruit trees in the South Pantanal Region, Mato Grosso do Sul, Brazil. Ninety-two species of fruits from 36 families and 22 orders were sampled. From 11 species of host fruits, we obtained 11,197 larvae of fruit flies; being Braconidae and Figitidae the main recovered parasitoids. The Braconidae totaled 99.45%, represented by three species: *Doryctobracon areolatus* (Szépligeti), *Utetes anastrephae* (Viereck), and *Opius bellus* Gahan. The Figitidae were represented by *Lopheucoila anastrephae* (Rohwer) from puparia of *Neosilba* spp. (Lonchaeidae), infesting pods of *Inga laurina* (Swartz). *D. areolatus* was associated with two species of *Anastrepha*: *A. rhedia* Stone in *Rheedia brasilensis* Planchon & Triana, and *A. zenildae* Zucchi in *Sorocea sprucei saxicola* (Hassler) C.C. Berg. In *Ximenia americana* L., 14% of the larvae of *Anastrepha* spp. were parasitized and, *D. areolatus* reached more than 96% of total parasitism in this host fruit. The braconids were specific to Tephritidae (Tab. 2), and the Figitidae species were associated only with larvae of *Neosilba* spp. (Lonchaeidae) (Tab. 4).

Parasitism rates found in surveys in which the fruits were removed from the field and carried to laboratory condition, certainly are unreal, because the fruits were picked up from the natural environments, with possibly, some eggs, and larvae of first and second instars of the fruit flies. So, when this immature tephritoids have left the field and have arrived in the laboratory, they have had no more chance to be parasitized (Uchoa *et al*., 2003). Another mortality factor related of parasitoid attack that is not measured by percentage of parasitism is the damage caused by the scars left by the ovipositor of parasitoid, even when ovipositions failed, and the possibility of subsequent infections by viruses, bacteria, fungi, protozoa and nematodes (Nicácio et al., 2011) on the frugivorous larvae of tephritoids. There are still no methodologies available, however, to unambiguously to evaluate these causes of mortality to immature frugivorous flies, and this is an area that will require further research. In the future is important to look for oviposition scars by parasitoids upon the third-instar larvae or puparium of dead tephritoids to establish if they are correlated or not to death of flies (Nicácio et al., 2011).

Species of Parasitoids	Species of Fruit Flies	Species of Host Fruits	Host Family	Country	References
Alysiinae *Asobara anastrephae* (Muesebek)	*Anastrepha obliqua* (Macquart) *Anastrepha bahiensis* Lima	*Spondias lutea* L.	Anacardiacaee	Brazil	Uchoa et al., 2003 Silva et al., 2010 Costa et al., 2009
Idiasta delicata Papp	*Anastrepha* sp.	*Duckeodendron cestroides* Kuhlm.	Duckeodendraceae	Brazil	Costa et al., 2009
Phaenocarpa pericarpa Wharton & Carrejo	*A. distincta* Greene	*Inga* sp.	Fabaceae	Venezuela	Trostle et al., 1999
Opiinae *Doryctobracon areolatus* (Szépligeti)	*Anastrepha amita* Zucchi *Anastrepha fraterculus* (Wiedemann) *Anastrepha leptozona* Hendel *Anastrepha serpentina* (Wiedemann) *Anastrepha obliqua* (Macquart) *Anastrepha rheedia* Stone *Anastrepha zenildae* Zucchi *Ceratitis capitata* (Wiedemann)	*Citharexylum myrianthum* Cham. *Psidium guajava* L. *Pouteria ramiflora* (Martius) *Puoteria torta* (Martius) *Spondias purpurea* *Rheedia brasiliensis* Planchon & Triana *Sorocea sprucei saxicola* (Hassler) *Mouriri elliptica* Martius	Verbenaceae Myrtaceae Sapotaceae Anacardiaceae Clusiaceae Moraceae Melastomataceae	Brazil Argentina Bolivia Brazil Brazil Brazil Brazil Brazil	Marinho et al., 2009 Ovruski et al., 2009 Nicácio et al., 2011 Nicácio et al., 2011 Alvarenga et al., 2009 Nicácio et al., 2011 Nicácio et al., 2011

Species of Parasitoids	Species of Fruit Flies	Species of Host Fruits	Host Family	Country	References
Doryctobracon brasiliensis (Szépligeti)	*Anastrepha fraterculus*	*Psidium guajava* *Eugenia uniflora* L. *Feijoa sellowiana* O. Berg. *Prunus persicae* *Prunus salicina* Lindl.	Myrtaceae Rosaceae	Argentina Brazil Bolivia Brazil	Ovruski et al., 2009 Ovruski *et al.*, 2009 Marinho et al., 2009
Doryctobracon crawfordi (Viereck)	*Anastrepha fraterculus*	*Psidium guajava* *Prunus persicae* (L.)	Myrtaceae Rosaceae	Bolivia	Ovruski et al., 2009
Doryctobracon fluminensis (Lima)	*Anastrepha pickeli* Lima 1934 *Anastrepha montei* Lima	*Manihot esculenta* Crantz	Euphorbiaceae	Brazil	Uchoa et al., 2003 Alvarenga et al., 2009
Opius bellus Gahan	*Anastrepha alveatoides* Blanchard *Anastrepha pickeli* *A. fraterculus*	*Ximenia americana* L. *Manihot esculenta* *Psidium guajava* *Prunus persicae*	Olacaceae Euphorbiaceae Myrtaceae Rosaceae	Brazil Brazil Bolivia	Nicácio *et al.*, 2011 Alvarenga et al., 2009 Ovruski et al., 2009
Utetes anastrephae (Viereck)	*Anastrepha fraterculus* *Anastrepha obliqua*	*Eugenia uniflora* *Psidium guajava* *Spondias lutea* L. *Spondias purpurea* L. *Prunus persicae* *Manihot esculenta*	Myrtaceae Anacardiaceae Rosaceae Euphorbiaceae	Argentina Bolivia Brazil Bolivia Brazil	Ovruski et al., 2009 Uchoa et al., 2003 Ovruski et al., 2009 Alvarenga et al., 2009

Table 2. Trophic interactions between koinobiont braconid parasitoids, tephritid fruit flies, and host plants in South America.

Nine native species of braconid parasitoids have been recorded in several states of Brazil, and in other South American Countries. The most promising species to study with the view to apply in biocontrol programs against fruit fly pests are *Doryctobracon areolatus*, *Utetes* *anastrephae* and *Opius bellus* (Tab. 2), because they are ubiquitous, frequent and abundant in several regions of South America. Going forward is important to focus in studies on their biology and behavior, in order to multiply them in laboratory for use in programs of integrated pest management in horticulture.

7. Insect predators on *Anastrepha* species and *Ceratitis capitata*

The main predators for frugivorous larvae of tephritids worldwide has been the ants: *Solenopsis geminata* (Fabricius), *Solenopsis* spp., and *Pheidole* sp. (Hymenoptera: Formicidae) (Aluja et al., 2005); the myrmeleontid *Myrmeleon brasileiensis* (Navás) (Neuroptera) (Missirian *et al*., 2006); some species rove beetles, probably *Belonuchus* Nordmann (Coleoptera: Staphylinidae), and Carabidae (Coleoptera) (Uchoa, M. A., unpubl.). Galli & Rampazo (1996) listed the carabids *Calosoma granulatum* Perty, *Calleida* sp., and *Scarites* sp., and the staphylinids: *Belonuchus haemorrhoidalis* (Fabricius), and *Belonuchus rufipennis* (Fabricius), among the predators of *Anastrepha* spp. larvae in Brazil. Because all these predators are generalist upon larvae of *Anastrepha* species, they probably are also able of preying upon *Ceratitis capitata* larvae. Therefore, when these insects are present, it is important conserve their populations in the orchards to help in natural control of fruit flies.

8. Food attractants, parapheromones and pheromones to fruit flies

Three kinds of attractants have been proposed to catch fruit flies in traps: food lures, parapheromones, and sex pheromones. Although the McPhail traps baited with food lures are the most usually employed in the field to catch tephritids worldwide, they have low attractiveness to fruit flies, normally attracting adults only from a short distance, about 10 m far from the source, depending if the wind is blowing continuously. The most usual baits are hydrolyzed proteinaceous from soybean, corn or torula yeast. According to Aluja et al. (1989) only 30% of the flies that are attracted to near the traps with food baits are actually captured.

Some blends of synthetic dry food lures (ammonium acetate + trimethylamine hydrochloride + putrescine) have been prepared to catch *Ceratitis capitata*, *Anastrepha* and *Bactrocera* species (Leblanc et al., 2010), but like the hydrolysate proteinaceous baits, it has the inconvenient of catching nontarget insects from several Orders, such as Diptera (e.g. Calliphoridae, Tachinidae), Lepidoptera, Hymenoptera, Neuroptera, Orthoptera, and in some places, till small vertebrates such as amphibians (Uchoa, M. A., unpubl.).

The compounds called parapheromones, such as trimedlure, cuelure and methyl eugenol are efficient on capturing fruit flies. They have been applied in traps to capture species of *Ceratitis*, *Dacus* and *Bactrocera* in the field. Differently from the common food baits, like hydrolyzed proteinaceous (corn, soybean) or torula yeast, the parapheromones are considered more selective for catching fruit flies. This is an interesting trait of these chemicals due to avoid the capture of non-target insects. But, on other hand, due the fact they capture almost exclusively male specimens, they are a problem in cases when the aim of the research is to survey the diversity of fruit flies species. Because, in some taxa, the accurate identification is based mainly in females. Furthermore, they are comparatively more expensive and harder to find in the local markets than the food baits.

The pheromones are considered biochemically ideals to control fruit flies, because generally they are species-specific, environmentally safe, being non-toxic till to the target species. However, unlike other insects such as moths, beetles, and the true bugs; Tephritidae have a complex communication system, involving short range vision and acoustic signaling, beyond the chemical language (see **life history of** *Anastrepha* **species**). Although in Mexico has been reported the capture of *A. suspensa* females in traps baited with virgin males (Perdomo et al., 1975, 1976), in Brazil, Felix et al. (2009) found that Jackson and McPhail traps baited with food bait were significantly more attractive to females of *Anastrepha sororcula* that traps baited with fruit fly sexually mature conspecific males. The last authors did not found significant capture of *A. sororcula* females in the traps baited with conspecific virgin males releasing sex pheromone; conspecific female neither conspecific couples. So, probably, sex pheromone of *Anastrepha* fruit flies did not show high potential to be applied in field to control this group of horticultural pests. For Lonchaeidae, only food baits based on protein hydrolysates have been used. Lonchaeids are well captured into the same McPhail traps used for sampling of tephritids.

9. Life history of *Dasiops* and *Neosilba* species (Lonchaeidae)

The species of *Dasiops* (Dasiopinae) are probably stenophagous (see Aluja & Mangan, 2008), feeding mainly on flowers or fruits *Passiflora* spp. (Malpighiales: Passifloraceae) (Nicácio & Uchoa, 2011; Uchoa et al., 2002). On other hand, *Neosilba* species (Lonchaeinae) are mainly polyphagous, attacking a broad array of host plant groups in South America (Tab. 3). *Neosilba perezi* attacks the terminal buds of cassava (Euphorbiaceae), but this behavior of feeding on tissue different of fruits and flowers is uncommon for other Lonchaeidae species in South America, where the lance flies colonize fruits of both, native or exotic species (Tab. 3). Caires et al. (2009) found five species of *Neosilba* [*Neosilba bifida* Strikis & Prado, *N. certa* (Walker), *N. pendula* (Bezzi), *N. zadolicha* McAlpine & Steyskal, and *Neosilba* morphotype MSP1] feeding in fruits of a mistletoe plant, *Psittacanthus acinarius* (Martius) (as *Psittacanthus plagiophyllus* Eichler) (Santalales: Loranthaceae) in the Brazilian Pantanal.

10. Pest status of *Dasiops* and *Neosilba*

Up to date at least 34 species of Lonchaeidae that feed on live tissue of plants are reported in Americas. *Dasiops* species are probably stenophagous (Aluja & Mangan, 2008), feeding in flowers or fruits of *Passiflora* (Passifloraceae). Some of them (e.g. *D. inedulis*), are important pest in flower buds of passion fruits in South America (Peñaranda et al., 1986; Uchoa et al., 2002). By other hand, some species of the same genus have been proposed to be biocontrol agents for weed *Passiflora* introduced in Hawaii (Norrbom & McAlpine, 1997). In Brazil four *Dasiops* species are reported (*D. frieseni* Norrbom & McAlpine *D. inedulis* Stayskal, *D. longulus* Norrbom & McAlpine, and *D. ypezi* Norrbom & McAlpine). *D. inedulis* and *D. longulus* were reared from flower buds, but *D. frieseni* and *D. ypezi* were recovered from fruits (Tab. 3).

Currently 21 species of *Neosilba* McAlpine are recorded in the Neotropical Region. From this total, interestingly, only five species [*Neosilba dimidiata* (Curran) from Colombia and Trinidad, *N. fuscipennis* (Curran) from Panama, *N. longicerata* (Hennig) from Peru, *N. major* (Malloch) from Colombia, Peru and Mexico, and *N. oaxacana* McAlpine & Steyskal from Mexico], are not yet reported in Brazil. As far as we know the species of the genus *Neosilba* are highly polyphagous, attacking plant tissues, especially fruit (Tab. 3).

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Dasiopinae *Dasiops alveofrons* McAlpine	*Prunus armeniaca* L. (FRU)	Rosaceae	USA	McAlpine, 1961
Dasiops brevicornis (Williston)	?	?	Jamaica	Norrbom & McAlpine, 1997
Dasiops caustonae Norrbom & McAlpine	*Passiflora molissima* (H.B.K.) (FRU)	Passifloraceae	Venezuela	Norrbom & McAlpine, 1997
Dasiops curubae Steyskal	*Passiflora molissima* (H.B.K.) (FLB)	Passifloraceae	Colombia	Steyskal, 1980
Dasiops dentatus Norrbom & McAlpine	*Passiflora ligularis* Juss. (FRU)	Passifloraceae	Peru	Norrbom & Mcalpine, 1997
Dasiops frieseni Norrbom & McAlpine	*P. alata* W. Curtis (FRU)	Passifloraceae	Brazil	Aguiar-Menezes et al., 2004
Dasiops gracilis Norrbom & McAlpine	*P. edulis* Sims (FLB and FRU)	Passifloraceae	Venezuela	Norrbom & Mcalpine, 1997
	P. ligularis Juss. (FRU)	Passifloraceae	Colombia	Norrbom & Mcalpine, 1997
	P. ligularis Juss. (FRU)	Passifloraceae	Costa Rica	Norrbom & Mcalpine, 1997
	P. pinannatistipula (Cav.) (FRU)	Passifloraceae	Colombia	Norrbom & Mcalpine, 1997
Dasiops inedulis Steyskal	*Passiflora edulis* Sims (FLB)	Passifloraceae	Brazil	Uchoa et al., 2002
	P. edulis (FLB)		Brazil	Aguiar-Menezes et al., 2004
	P. edulis (FLB)		Colombia	Chacon & Rojas, 1984
	P. edulis (FLB)		Colombia	Peñaranda et al., 1986
	P. edulis (FLB)		Panama	Steyskal, 1980
	P. lindeniana Planch. (FRU)		Venezuela	Norrbom & Mcalpine, 1997
	P. rubra L. (FRU)		Venezuela	Norrbom & Mcalpine, 1997

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Dasiops longulus Norrbom & McAlpine	*Passiflora alata* (FLB)	Passifloraceae	Brazil	Aguiar-Menezes et al., 2004
	P. edulis (FRU)	Passifloraceae	Brazil	Norrbom & Mcalpine, 1997
Dasiops passifloris McAlpine	*Passiflora suberosa* L. (FRU)	Passifloraceae	USA	Steyskal, 1980
Dasiops rugifrons Hennig	*Passiflora alata* (FRU)	Passifloraceae	Venezuela	Norrbom & Mcalpine, 1997
	?	?	Peru	Korytkowski & Ojeda, 1971
Dasiops rugulosus Norrbom & McAlpine	?	?	Trinidad	Norrbom & Mcalpine, 1997
Dasiops ypezi Norrbom & McAlpine	*Passiflora ligularis* (FRU)	Passifloraceae	Colombia	Norrbom & Mcalpine, 1997
	P. edulis (FRU)	Passifloraceae	Brazil	Uchoa, M. A.- Unpubl.
Lonchaeinae *Neosilba batesi* (Curran)	*Mangifera indica* L. (FRU) *Carica papaya* L. (FRU) *Persea americana* Mill. (FRU) *Citrus sinensis* (L.) (FRU)	Anacardiaceae Caricaceae Lauraceae Rutaceae	Mexico Guatemala Colombia	McAlpine & Steyskal, 1982 Ahlmark & Steck, 1997
Neosilba bella Strikis & Prado	*Inga edulis* Martius (PO) *Inga velutina* Willd. (PO)	Fabaceae	Brazil	Strikis et al., 2011
Neosilba bifida Strikis & Prado	*Sorocea sprucei saxicola* (Hassler) (FRU)	Moraceae	Brazil	Uchoa & Nicácio, 2010
	Psittacanthus acinarius (Martius) (FRU)	Loranthaceae	Brazil	Caires et al., 2009

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba certa (Walker)	*Opercunina alata* (Hamilton) (FRU)	Convovulaceae	Brazil	Uchoa & Nicácio, 2010
	Terminalia catappa L. (FRU)	Combretaceae	Brazil	Uchôa & Nicácio, 2010
	Ficus insipida Willdenow (FRU)	Moraceae	Brazil	Uchoa & Nicácio, 2010
	Syzygium jambos L. (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria glomerata (Miquel) (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria torta (Martius) (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Physalis angualata L. (FRU)	Solanaceae	Brazil	Uchoa & Nicácio, 2010
	Psittacanthus acinarius (Martius) (FRU)	Loranthaceae	Brazil	Caires et al., 2009
	Inga velutina Willd. (PO)	Fabaceae	Brazil	Strikis et al., 2011
	Pouteria caimito (Ruiz & Pav.) (FRU)	Sapotaceae	Brazil	Strikis et al., 2011
	Coffea arabica L. (FRU)	Rubiaceae	Brazil	Souza et al., 2005
Neosilba dimidiata (Curran)	*Annona* spp. (FRU)	Annonaceae	Colombia Trinidad	Peña & Bennett, 1995 McAlpine & Steyskal, 1982
Neosilba flavipennis (Morge)	*Brassica rapa* L. (Roots)	Brassicaceae	Peru	Urrutia & Korytkowski, unpublished
Neosilba fuscipennis (Curran)	Unknown	Unknown	Panama	McAlpine & Steyskal, 1982

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba glaberrima (Wiedemann)	*Spondia dulcis* Parkinson (FRU)	Anacardiaceae	Brazil	Uchoa & Nicácio, 2010
	Annona crassiflora Martius (FRU)	Annonaceae	Brazil	Uchoa & Nicácio, 2010
	T. catappa (FRU)	Combretaceae	Brazil	Uchoa & Nicácio, 2010
	Ficus insipida (FRU)	Moraceae	Brazil	Uchoa & Nicácio, 2010
	Syzygium jambos (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Ximenia americana L. (FRU)	Olacaceae	Brazil	Uchoa & Nicácio, 2010
	Alibertia edulis A. Richard (FRU)	Rubiaceae	Brazil	Uchoa & Nicácio, 2010
	Genipa americana L. (FRU)	Rubiaceae	Brazil	Uchoa & Nicácio, 2010
	Coffea arabica L. (FRU)	Rubiaceae	Brazil	Souza *et al.*, 2005
	Pouteria ramiflora (Martius) (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria torta (Martius) (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
Neosilba inesperata Strikis & Prado	*T. catappa* (FRU)	Combretaceae	Brazil	Uchoa & Nicácio, 2010
	Opercunina alata (Hamilton) (FRU)	Convovulaceae	Brazil	Uchoa & Nicácio, 2010
	Strychnos pseudoquina St.Hilarie (FRU)	Loganiaceae	Brazil	Uchoa & Nicácio, 2010

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba inesperata Strikis & Prado	*Inga laurina* (Swartz) (PO)	Fabaceae	Brazil	Uchoa & Nicácio, 2010
	Psidium cattleianum Sabine (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Schoepfia sp. (FRU)	Olacaceae	Brazil	Uchoa & Nicácio, 2010
	Eryobotria japonica (Thunb.) (FRU)	Rosaceae	Brazil	Strikis & Prado, 2009
	Citrus jambhiri Lush (FRU)	Rutaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria ramiflora (Martius) (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Physalis angulata L. (FRU)	Solanaceae	Brazil	Uchoa & Nicácio, 2010
	Solanum sisymbriifolium Lamarck (FRU)	Solanaceae	Brazil	Uchoa & Nicácio, 2010
Neosilba longicerata (Hennig)	Unknown	Unknown	Peru	McAlpine & Steyskal, 1982
Neosilba major (Malloch)	*Capsicum annuum* L. (FRU)	Solanaceae	Colombia Peru Mexico	McAlpine & Steyskal, 1982
Neosilba morphotype MSP1	*Allogoptera leucocalyx* (Drude) (FRU)	Arecaceae	Brazil	Uchoa & Nicácio, 2010
Neosilba nicrocaeruela (Malloch)	*Carica papaya* L. (FRU) *Pouteria* sp. (FRU)	Caricaceae Sapotaceae	Brazil	McAlpine & Steyskal, 1982 Strikis et al., 2011
Neosilba oaxacana McAlpine & Steyskal	?	?	Mexico	McAlpine & Steyskal, 1982
Neosilba peltae McAlpine & Steyskal	? *Passiflora edulis* Sims	? Passifloraceae	Mexico Brazil	McAlpine & Steyskal, 1982 Strikis et al., 2011

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba parva (Hennig)	Unknown	Unknown	Brazil	Bittencourt et al., 2006
Neosilba pendula (Bezzi)	*Anacardium humile* Saint Hilaire (FRU) *Annona* spp. (FRU)	Anacardiaceae Annonaceae	Brazil Brazil Colombia Venezuela	Uchoa & Nicácio, 2010 Peña & Bennett , 1995
	T. catappa (FRU)	Combretaceae	Brazil	Uchoa & Nicácio, 2010
	Opercunina alata (FRU)	Convovulaceae	Brazil	Uchoa & Nicácio, 2010
	Andira cuyabensis Benthan (FRU)	Fabaceae	Brazil	Uchoa & Nicácio, 2010
	Banara arguta Briquel (FRU)	Flacourtiaceae	Brazil	Uchoa & Nicácio, 2010
	Inga laurina (Swartz) (PO)	Fabaceae	Brazil	Uchoa & Nicácio, 2010
	Ficus insipida (FRU)	Moraceae	Brazil	Uchoa & Nicácio, 2010
	Psidium cattleianum (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Schoepfia sp. (FRU)	Olacaceae	Brazil	Uchoa & Nicácio, 2010
	Citrus jambhiri (FRU)	Rutaceae	Brazil	Uchoa & Nicácio, 2010
	Chrysophyllum soboliferum Rizzini (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria ramiflora (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria torta (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Coffea arabica L. (FRU)	Rubiaceae	Brazil	Souza et al., 2005
	Psittacanthus acinarius (Martius) (FRU)	Loranthaceae	Brazil	Caires et al., 2009

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
*Neosilba pseudopendula (*Korytkowski & Ojeda)	*Coffea arabica* L. (FRU)	Rubiaceae	Brazil	Souza et al., 2005
Neosilba perezi (Romero & Ruppel)	*Manohot esculenta* Crantz (Apical Buds)	Euphorbiaceae	Brazil	Lourenção et al., 1996
Neosilba pradoi Strikis & Lerena	*Inga laurina* (Swartz) (PO)	Fabaceae	Brazil	Uchoa & Nicácio, 2010
Neosilba zadolicha McAlpine & Steyskal	*Anacardium humile* Saint Hilaire (FRU)	Anacardiaceae	Brazil Colombia	Uchoa & Nicácio, 2010 McAlpine & Steyskal, 1982
	Anacardium othonianum Rizzini (FRU)	Anacardiaceae	Brazil	Uchoa & Nicácio, 2010
	Spondia dulcis Parkinson (FRU)	Anacardiaceae	Brazil	Uchoa & Nicácio, 2010
	Annona crassiflora Martius (FRU)	Annonaceae	Brazil	Strikis et al., 2011
	Annona muricata L. (FRU)	Annonaceae	Brazil	Strikis et al., 2011
	Rollinia mucosa (Jacq.) (FRU)	Annonaceae	Brazil	Strikis et al., 2011
	Hancornia speciosa Gomez (FRU)	Apocynaceae	Brazil	Uchoa & Nicácio, 2010
	Licania tomentosa Fritsch (FRU)	Chrysobalanaceae	Brazil	Uchoa & Nicácio, 2010
	Buchenavia sp. (FRU)	Combretaceae	Brazil	Uchoa & Nicácio, 2010

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba zadolicha McAlpine & Steyskal	*T. catappa* (FRU)	Combretaceae	Brazil	Uchoa & Nicácio, 2010
	Operculina alata (FRU)	Convovulaceae	Brazil	Uchoa & Nicácio, 2010
	Strychnos pseudoquina (FRU)	Loganiaceae	Brazil	Uchoa & Nicácio, 2010
	Byrsonima orbignyana A. Jussieu (FRU)	Malpighiaceae	Brazil	Uchoa & Nicácio, 2010
	Mouriri elliptica Martius (FRU)	Melastomataceae	Brazil	Uchoa & Nicácio, 2010
	Inga laurina (PO)	Fabaceae	Brazil	Uchoa & Nicácio, 2010
	Ficus insipida (FRU)	Moraceae	Brazil	Uchoa & Nicácio, 2010
	Syzygium jambos (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Psidium kennedyanum Morong (FRU)	Myrtaceae	Brazil	Uchoa & Nicácio, 2010
	Schoepfia sp. (FRU)	Olacaceae	Brazil	Uchoa & Nicácio, 2010
	Ximenia americana (FRU)	Olacaceae	Brazil	Uchoa & Nicácio, 2010
	Passiflora coccinea Aublet (FRU)	Passifloraceae	Brazil	Uchoa & Nicácio, 2010
	Pasiflora edulis (FRU)	Passifloraceae	Brazil	Uchoa & Nicácio, 2010
	Alibertia edulis (FRU)	Rubiaceae	Brazil	Uchoa & Nicácio, 2010
	Genipa americana (FRU)	Rubiaceae	Brazil	Uchoa & Nicácio, 2010

Species	Host's Floral Buds (FLB), Apical Buds (AB), Fruits (FRU), or Pods (PO)	Plant Family	Country	References
Neosilba zadolicha McAlpine & Steyskal	*Tocoyena formosa* (Cham. & Schlencht.) (FRU)	Rubiaceae	Brazil	Uchoa & Nicácio, 2010
	Citrus jambhiri (FRU)	Rutaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria glomerata (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria ramiflora (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Pouteria torta (FRU)	Sapotaceae	Brazil	Uchoa & Nicácio, 2010
	Physalis angulata (FRU)	Solanaceae	Brazil	Uchoa & Nicácio, 2010
	Psittacanthus acinarius (Martius) (FRU)	Loranthaceae	Brazil	Caires et al., 2009
	Quararibea quianensis Aubl. (FRU)	Bombacaceae	Brazil	Strikis et al., 2011
	Duckeodendron cestroides Kuhlm. (FRU)	Duckeodendraceae	Brazil	Strikis et al., 2011

Table 3. Species list of Lance Flies (Diptera: Tephritoidea: Lonchaeidae) with economic importance, and their host plants in the Neotropical Region.

11. Native parasitoids of Lonchaeidae species

Eight species of Eucoilinae parasitoids (Figitidae: Cynipoidea) have been associated to frugivorous larvae of *Neosilba* in Brazil. However, up to date, only four of these parasitoid species were associated to their host larvae and host plant. *Aganaspis nordlanderi* Wharton was recovered from pupae of *N. pendula* (Bezzi) whose larvae were feeding in fruits of tangerine, *Citrus reticulata* Blanco (Rutaceae). *Lopheucoila anastrephae* (Rhower) was reared from pupae of *N. batesi* (Curran), obtained as larvae in *Passiflora* fruits (Passifloraceae), and from *N. pendula* attacking orange, *Citrus sinensis* (L.) (Rutaceae). *Odontosema anastrephae* Borgmeier was recovered from larvae of *N. pendula* in fruits of *Caryocar brasiliense* Camb. (Caryocaraceae), and *Trybliographa infuscata* Gallardo, Díaz & Uchoa was recovered from *N. pendula* in orange, *Citrus sinensis* and *Caryocar brasiliense*. In all the cases the species of *Neosilba* were collected in the larval third-instars, and only one specimen of Eucoilinae emerged from each pupa (Tab. 4).

Species of Parasitoids	Species of Lonchaeids	Species of Host Fruits	Family	Country	References
Aganaspis nordlanderi Wharton	*Neosilba pendula* (Bezzi)	*Citrus reticulata* Blanco	Rutaceae	Brazil	Gallardo et al., 2000
Aganaspis pelleranoi (Bréthes)	Not associated	Not associated	Not associated	Brazil	Guimarães et al., 2003
Lopheucoila anastrephae (Rhower)	*Neosilba bates*i (Curran)	*Passiflora* sp. *Citrus sinensis* (L.).	Passifloraceae Rutaceae	Argentina Brazil Peru Venezuela	Guimarães *et al.*, 2003 Uchôa et al., 2003
Odontosema albinerve Kieffer	Not associated	Not associated	Not associated	Brazil	Guimarães & Zucchi, 2011
Odontosema anastrephae Borgmeier	*Neosilba pendula*	*Caryocar brasiliense* Camb.	Caryocaraceae	Brazil	Uchôa, M. A. - unpublished Guimarães et al., 2003
Tropideucoila rufipes Ashmead	Not associated	Not associated	Not associated	Brazil	Guimarães & Zucchi, 2011
Tropideucoila weldi Lima	Not associated	Not associated	Not associated	Brazil	Guimarães et al., 2003
Trybliographa infuscata Gallardo, Díaz & Uchôa	*Neosilba pendula*	*Caryocar brasiliense* Camb. *Citrus sinensis*	Caryocaraceae Rutaceae	Brazil	Uchôa et al., 2003 Guimarães et al., 2003

Table 4. Trophic interactions between parasitoids, lonchaeid fruit flies, and host plants in South America.

12. Current status and future perspectives on the control of fruit flies

Currently the control of fruit fly is made with chemical pesticide spraying, a concerning reality because most tropical fruits are eaten raw, making the residue over them an environmental and human health problem. In Brazil, some farmers have reduced the impact of pesticides in orchards, spraying sugar solution on certain rows of fruit trees in the orchards, where fruit flies are attracted to the food source. So, they spray insecticides in this crowd of tephritids. This practice reduces the amount of insecticides in the environment, decreasing the risk of residues in the fruits.

Several researchers in the Americas (e.g. in Brazil) are looking for powerful and specific attractants to catch fruit flies in traps. These natural chemicals can be present in the host fruits of the fruit flies. If isolated, identified and synthesized these natural attractants can be important in both cases: surveys on species diversity in natural environments, and for the management of pest species in orchards, enabling the reduction in the use of chemical insecticides. This technique in association with biological control with native parasitoids, probably, will be possible in the near future. *Doryctobracon areolatus* and *Utetes anastrephae* are good candidates for keeping population of *Anastrepha* species and *Ceratitis capitata* in low levels, making possible to produce clean fruits and vegetables.

13. Conclusions

Anastrepha is the most biodiverse and economically important genus of Tephritidae in Brazil, but from the total of 112 species reported in the Country to date, only 14 species can be considered as pest or potential pests. In Brazil two very economically important tropical species of fruit flies: *Anastrepha ludens* (Loew) and *Anastrepha suspensa* (Loew) do not occur.

In South America occur at least eight species of Braconidae parasitoids. *Doryctobracon areolatus*, *Utetes anastrephae*, and *Opius bellus* are the most ubiquitous and with wide distribution, being *D. areolatus* the best candidate for biological control programs of *Anastrepha* species, and maybe also, for *Ceratitis capitata*. There are not enough studies to know how *Neosilba,* and *Dasiops* species lay their eggs in the host plants: if endophytic, like the tephritids, or if the eggs are scattered in the target part of the host plants and the newly hatched larvae are able to penetrate in the plant tissue by them. The Lonchaeidae can occupy the same ecological niche occupied by the tephritids. In some host plants, the lonchaeids can be more abundant and important as pest that the tephritids, including some fruit species with economic importance, such as *Citrus* spp. (Rutaceae), *Spondias dulcis* Parkison (Anacardiaceae), and species of *Passiflora* (Passifloraceae). The Lonchaeidae have, at least, eight species of Eucoilinae (Figitidae) parasitoids in Brazil, but the biology of both groups (lonchaeids and its parasitoids) is unknown. *Lopheucoila anastrephae*, *Trybliographa infuscata* and *Aganaspis nordlanderi*, have been the most abundant and frequent parasitoids in larvae of third-instars of *Neosilba* species in *Citrus* orchards in Brazil.

14. Research needs

For solving some bottlenecks to enable the monitoring and control of fruit flies with non-polluting methods, the following topics are specially in need of researches: regional surveys about species diversity; prospecting for more specific attractants to use in traps; developing of artificial diets to rearing larvae of Tephritoidea to multiply their parasitoids; improvement of mass rearing methods to both: fruit flies and their parasitoids; studies on tritrophic relationship with their host plants and parasitoids; basic biology, and behavior.

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