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## Dipteran flies in *Passiflora* L. (Passifloraceae): A comprehensive review

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### Abstract

Dipteran flies are among the most economically important pest species in the world, attacking a wide range of fruits and fleshy vegetables throughout tropical and sub-tropical areas. Passion fruit (*Passiflora edulis*) is an attractive, nutritionally rich fruit crop highly appreciated for fresh consumption and industrial purposes. *Passiflora* crops are evidenced to be affected by *Anastrepha* spp., *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), *Dasiops*, *Lonchaea*, *Hexachaeta*, *Neosilba*, *Protearomyia* spp. (Diptera: Lonchaeidae) and *Zaprionus salebrosus* Wheeler (Diptera: Drosophilidae). Despite its wide acceptance in world markets, passionfruit crops have been poorly researched in terms of biology, ecology and management of dipteran pests attacking passion fruit. Moreover, many of the fly species reported in passion fruit from various parts of the world are of quarantine importance, and its high time that researchers turn their attention to the population dynamics and extend of damage caused by these dipteran flies. More studies must be advanced to understand the biology, ecology and behavior of different fly species which could have important effects on passion fruit production worldwide. This manuscript is aimed to present a literature review on the various dipteran flies attacking passion fruit all over the world.

**Keywords:** Tephritidae, lonchaeidae, ulidiidae, passion fruit, passiflora

### 1. Introduction

Tropical fruits harbor a vast diversity of associated arthropods, far greater than in temperate crops [1]. The majority of *Passiflora* species are indigenous to the tropical and subtropical regions of South America, including Brazil [2]. The passion flowers belong to genus *Passiflora* L. and are the most representative and abundant of the family Passifloraceae [3]. Passion flowers include more than 500 defined species and are distributed in tropical and sub-tropical areas around the world [4]. Out of the 400 known species of *Passiflora*, about 50 bear edible fruits. Some species of this genus like *Passiflora edulis* f. *flavicarpa* Deneger (yellow passion fruit) and *Passiflora edulis* f. *edulis* Sims (purple passion fruit) are economically important worldwide [5]. Whereas, species as *Passiflora ligularis* Juss (sweet granadilla) and *Passiflora quadrangularis* L. (giant granadilla) are cultivated mainly in the Andean regions [6]. Several species of insects were listed as passion fruit pests around the world; the flies belonging to the superfamily Tephritoidea are major pests of this fruit crop. Some fly species feed on floral buds of *Passiflora* spp., and other infest the fruits [7].

The insect order Diptera is one of the most species rich, anatomically varied, and ecologically innovative groups of organisms, making up 10-15% of known animal species. An estimated 1,50,000 species of Diptera have been described [8, 9] although the actual total number of extant fly species is many times that number [10]. Tephritidae Newman, Lonchaeidae and Ulidiidae (formerly Otitidae) are important dipteran families reported as important pests in passionfruit [7]. Of this Tephritidae and Ulidiidae belong to Higher Tephritoidea [11].

The family Tephritidae (true fruit flies), consists of almost 4500 species dispersed throughout the tropical, sub-tropical and temperate regions of the world [12]. It is amongst the largest families of Diptera and are among the most economically important pest species in the world. The larvae of most of the tephritid species develop in the seedbearing organs of plants, and about 35% of the species attack soft fruits, including many commercial fruits. Besides attacking soft fruits, the larvae of about 40% of tephritid species develop in the flowers of Asteraceae and most of the remaining species are associated with the flowers of other families [13].

Tephritid fruit flies are key pests of a wide variety of fruit species and affects crop yield, quality of harvested produce, and (international) market access [14, 15].

About one-third of the known species of fruit flies are frugivorous. The remaining two-thirds of the known species infest and feed on other parts of plants, such as stems, roots, flowers, buds, seeds, ovaries and leaves. The economic importance of fruit flies is due to the fact that they cause direct loss in production and the producers loss marketing opportunities due to the presence of fruit flies. Consequently, trade restrictions will be imposed by the importing countries. In addition to this producer have to meet the expenses of field control of existing fruit fly species, eradication of outbreaks of exotic species and the costs for quarantine surveillance. Tephritid fruit flies are recognized as one of the most economically important group of insects which pose serious threat to the horticultural industry in the Sub Saharan Africa [13, 16, 17].

Lance flies are insects belonging to the family Lonchaeidae (Diptera: Tephritoidea) represented by the genera *Dasiops* Rondani, *Neosilba* McAlpine, and *Lonchaea* Fallén. Although this family has been considered of secondary importance [18], in the last decades, various species are reported as of economic importance due to the damage produced in fruits, flowers and fruit buds [19, 20, 21]. Moreover, they are being considered as key pest in several crops [22, 23, 24].

## 2. Dipteran flies in passion fruit

Passiflora crops are evidenced to be affected by *Anastrepha* spp., *Ceratitis capitata* (Wiedemann) (Diptera: Tephritidae), *Dasiops*, *Lonchaea*, *Hexachaeta*, *Neosilba*, *Protearomyia* spp. (Diptera: Lonchaeidae) and *Zapriothrica salebrosa* Wheeler (Diptera: Drosophilidae) [1, 25, 26, 27, 28]. Colombian reports indicate (presumed) presence of *Dasiops curubae* Steyskal, *D. inedulis*, *D. yepezi* Norrbom and McAlpine, *Lonchaea* sp., *Hexachaeta* sp., *Z. salebrosa* and up to 13 species of *Anastrepha* [29, 30, 31, 32].

In Brazil, three genera of flies that damage fruits of *Passiflora* spp. are commonly described: *Anastrepha* Schiner (Tephritidae), *Lonchaea* Fallén and *Dasiops* Rondani (Lonchaeidae). *Neosilba pendula* (Bezzi) and *Dasiops* spp. (Lonchaeidae) are the most common species attacking floral buds of passion fruits [33, 34, 35, 36, 37]. Five genera of Tephritoidea were associated to the genus *Passiflora*: *Anastrepha* (Tephritidae), *Dasiops*, *Neosilba* (both Lonchaeidae), *Euxesta* and *Notogramma* (both Otitidae (now Ulidiidae)). The lonchaeids and tephritids are reported to be most abundant, accounting for 48.5% and 48.1% respectively of all flies recovered from passion fruit [37]. Tephritidae are thought to exclusively affect the fruit, while Lonchaeidae attack flower buds, ovaries or young (immature) fruits [38, 39].

### 2.1 Family Tephritidae (Fruit flies)

#### A. Genus *Anastrepha* Schiner

In family Tephritidae, the genus *Anastrepha* Schiner is the most diverse and economically important fruit fly species in the Neotropical region, including a large number of major fruit pests [40, 41]. In Peru, the main species associated with damage on cultivated host plants are *Anastrepha fraterculus* (Wiedemann), *Anastrepha distincta* Greene, *Anastrepha obliqua* (Macquart), *Anastrepha serpentine* (Wiedemann), *Anastrepha striata* (Schiner) and *Anastrepha chichlayae* (Greene) [42]. *Anastrepha* adults are 6.5–8.0 mm in length, predominantly yellow in colour, with brown and yellow markings on the wings.

*Anastrepha curitis* Stone, *A. dissimilis* Stone, *A. fraterculus* (Wiedmann), *A. kuhlmanni* Lima, *A. lutzi* Lima, *A.*

*pseudoparallela* (Loew), *A. striata* Schiner, and *A. xanthochaeta* Hendel are the most common species associated with passion fruit [27, 33, 34]. In Brazil, [1] the following *Anastrepha* species associated with passionfruit: *A. consobrina* (Loew), *A. curitis* Stone, *A. dissimilis* Stone, *A. fraterculus*, *A. kuhlmanni* Lima, *A. lutzi* Lima, *A. pseudoparallela* Loew, *A. striata* and *A. xanthochaeta* Hendel. Additionally, [28] describe *A. mombinpraeoptans* Sein, *A. ethalea* Walker and *A. grandis* as passionfruit pests.

*Anastrepha pallidipennis* Greene (Diptera: Tephritidae) attacking Maracuya passionfruit (*Passiflora edulis* f. sp. *flavicarpa* Deneger) was observed for the first time in Venezuela [43]. Adults were obtained at the laboratory from naturally infected fruits. The identification was done based on the female and male morphological characteristics, mainly, those corresponding to the ovipositor, clypeal profile, costal and S stripes in the wing, and the lack of microtrichia on the male's scutellum. The attack of *A. pallidipennis* on passionfruit was associated with the elimination of giant granadilla (*P. quadrangularis* L.) plantation in the area.

The study conducted [44] in Iraceminha, Santa Catarina revealed that the population levels of *Anastrepha grandis* remained higher during the first five months in the passion fruit orchard. There were low infestation rates by flies of the genera *Ceratitis*, *Blepharoneura* and *Tomoplagia* when compared to flies of the genus *Anastrepha*. The results showed that the presence of flies in the orchards was associated with the availability of host fruit and not with climatic conditions.

*Anastrepha pseudoparallela* Loew is considered endemic to the South America Tropics [45] and was reported infesting *Passiflora alata* Dryand (sweet passion fruit) in the Southeastern of Brazil [7]. The first report of *A. pseudoparallela* infesting passion fruits in Peru [46] and it was the first time that a species of Tephritidae is associated to damage of passion flowers cultivated in Andean regions. In Peru, *Anastrepha pseudoparallela* (Diptera: Tephritidae) caused infestation in unripe (8♂, 13♀) and ripe (7♂, 13♀) *Passiflora ambigua* fruits and *P. quadrangularis* unripe fruits (7♂, 2♀). In both cases, the larvae damaged the fruit by feeding the pulp stimulating rot and contamination with microorganisms owing to their excrement. Unripe and ripe fruits of *P. ambigua* were also infested, while, these larvae bored until the mesocarp in high infestation. *Passiflora quadrangularis* evidenced damage caused by larvae only in unripe fruits; besides, the fruit skin showed oviposition puncture produced by female to lay eggs [46]. *A. pseudoparallela* lays eggs in unripe fruits of *P. alata*, and the larvae develop by feeding on the seeds. Cyanogenic compounds are present in all parts of *Passiflora* plants, including seeds, and these glycosides protect the plant by preventing feeding by herbivore species; therefore, the use of these resources by *A. pseudoparallela* for larval development is probably associated with its ability to tolerate these chemical defenses and suggests a high degree of specialization [47].

#### B. Genus *Bactrocera* Macquart

Tephritids in the genus of *Bactrocera* are of particular concern throughout much of Asia and Australia, where they constitute a significant threat to agricultural resources [48, 49, 50, 51, 52, 53, 54, 55]. In particular, the genus *Bactrocera* consists of over 460 described species [56, 57]. Nearly 440 species are distributed primarily in tropical Asia, the South Pacific, and

Australia [13, 58]. It is the most economically significant fruit fly genus with at least 50 species considered to be important pests, many of which are highly polyphagous [13].

Fijian fruit fly *Bactrocera passiflorae* Froggatt [59, 60] oriental fruit fly *Bactrocera dorsalis* Hendel [61, 62, 63], melon fruit fly *Bactrocera cucurbitae* Coquillett [61, 63], queensland fruit fly *Bactrocera tryoni* Froggatt [64] and *Bactrocera tau* Walker [65, 66] are some of the fruit flies of genera *Bactrocera* reported as pests of passion fruit. The oriental and melon fruit flies puncture the fruit while the rind is still tender [67]. A woody area termed callus develops around the puncture as the fruit enlarges. If the fruit is small and undeveloped, the damage may be sufficient to cause it to shrivel and fall from the plant and may continue to maturity if the fruit is well developed. At the time of ripening, the area around the puncture has the appearance of a small, woody crater, which disfigures the outer appearance of the fruit, but does not impair pulp quality. Although oviposition scars are present on ripening fruits, they generally do not contain living larvae. Larvae appear to be able to develop better in immature than in mature fruit.

Oviposition by queensland fruit fly, *B. tryoni* in immature green fruit also results in the formation of calluses in the skin of the fruit at the puncture site. Punctured fruits may persist on the plant to maturity but are not acceptable for fresh market sale because of the damage [64].

The fruit losses caused by the fruit fly, *Bactrocera tau* in passion fruit is estimated as high as 40% of the production [65]. In general, the yield loss due to fruit flies varies between 30-100% depending on the fruit species and season [68]. The seasonal fluctuation of trap catches of male *B. tau* in three passion fruit orchards in Alahan Panjang, West Sumatra, Indonesia [69] showed a similar pattern during the study period with a major peak in July.

### C. Genus *Ceratitis* Macleay

Mediterranean fruit fly, *Ceratitis capitata* Wiedmann had been listed as a potential pest of *P. edulis* [70] but provide no evidence of adult fly emergence from field-collected fruit. Other reports indicate *C. capitata* is an occasional pest of *Passiflora* sp., without specifying the exact crop species, botanical form or variety [71]. Yellow passionfruit (*P. edulis* f. *flavicarpa* Degener) is reported as a possible host of *C. capitata* in Hawaii [67], while many tephritids attack certain *Passiflora* species in Brazil [37]. In Colombia, national pest survey records for *C. capitata* maintained since 1986 have not detected this pest in the principal production regions of purple passionfruit [72]. As a note of caution, it is important to indicate that climate change could cause altitudinal range shifts of pest tephritids and may eventually bring *C. capitata* into those production regions in the future [73]. The Mediterranean fruit fly, *Ceratitis capitata* Wiedmann, are known to attack the passion fruit vines in Hawaii, USA [61]; however, the relative importance of each species appears to vary with respect to location of the vineyard [67].

Forced infestation trials under laboratory conditions at Horticulture Research Center CIAA (Chia, Colombia) with hand-picked fruit of different maturity levels (i.e., fruit harvested from vines) and fallen fruit, collected from the ground proved critical in delineating purple passionfruit host status to *C. capitata*. Even though *C. capitata* females oviposited in intact fruit (maturity degree 0) as in punctured fruit of different maturity degrees, larval development was very poor and no adults emerged. Hence, concluded that Colombia-grown purple passionfruit is a non-host under the

experimental conditions used in the tests and may be a non-host in the field [74].

### 2.2 Family Lonchaeidae (Lance flies)

Despite the presumed status of Lonchaeid flies as key pests of *Passiflora* spp., these insects have received comparatively little research attention in Latin America [7]. *Lonchea*, *Dasiops* Rondani and *Neosilba* are the three genera of Lonchaeidae found attacking floral buds and fruits of *passiflora*. A total of 8 Lonchaeid species, associated with *Passiflora* spp. in Colombia: five members of the genus *Dasiops* and three *Neosilba* species [75]. The adult *Dasiops curubae* is blackish blue. The wings are hyaline and slightly smoky yellowish, while the calypters and wing fringes are pale yellowish [25]. The adult *Dasiops inedulis* is bright metallic dark blue with hyaline wings; the calypters and wing fringes are yellowish to nearly white [25].

Floral buds of *Passiflora alata* collected from Seropédica [7] were infested by three species of Lonchaeidae: *Neosilba zadolicha* McAlpine and Steyskal, *Neosilba* n. sp. near *batesi* Curran, and *Dasiops longulus* Norrbom and McAlpine. Of the three, *N. zadolicha* was the most common species, representing 65.0% of all Lonchaeidae obtained from this host. These lonchaeids caused a mean infestation index of 2.1 puparia/bud, ranging from one to five puparia/bud [7]. *N. zadolicha* has been reared from fruits of several plants. Most *Neosilba* spp. are reported as secondary invaders of plant tissues damaged by other insects or otherwise injured [76]. Infestation by *N. zadolicha* in fruits of a wild species of *Passiflora* was also reported [77].

*Dasiops longulus* is a poorly known species, previously recorded from only two specimens reared from a *Passiflora* sp. in Brazil. This species is presumably a primary invader like its closest relatives within *Dasiops* [39]. Only *Dasiops inedulis* Steyskal was identified from *P. edulis* f. *flavicarpa* floral buds collected in Vila Valério, causing a high mean infestation index (6.0 puparia/bud, ranging from 1 to 15) and with high pupal viability (86.1%) [7].

One to three larvae of *Dasiops inedulis* per floral buds of *P. edulis* f. *flavicarpa* in the Cauca Valley (Colombia) was identified [26]. According to Norrbom and McAlpine (1997), *D. inedulis* is a primary invader in *Passiflora* spp. flowers. Larvae of this species bore into the anthers and the ovary and may cause intensive dropping of floral buds and young fruits [7, 78]. In Brazil, Uchoa-Fernandes *et al.*, (2002) reported that *D. inedulis* fed in floral buds of a wild passion fruit, causing an infestation index of approximately 0.7 larvae of 3rd instar per fruit with only 9.6% of larval viability. *D. inedulis* was reported in Panama as a serious pest of purple granadilla, *P. edulis* [25]. This species has been implicated in 21-65% loss of floral buds of *P. edulis* f. *flavicarpa* collected in the Cauca Valley (Colombia) [78]. It is also considered an important pest of *P. edulis* and *P. quadrangularis* in the USA [39].

*Dasiops friesenii* was originally described based on specimens collected from the municipality of Teresópolis, in 1939, and appeared to be a primary invader in *Passiflora* spp. fruits [39].

### 2.3 Family Ulidiidae (Picture winged flies)

*Euxesta* and *Notogramma* are the two genera under family Ulidiidae reported to attack passion fruits and represented 3.4% of all flies recovered from *P. alata* fruits [7]. *Notogramma cimiciforme* Loew, presents a wide geographical distribution in the New World, and is a saprophagous species reported from a broad range of plants [79]. Uchoa-Fernandes *et*

al. (2002) reported *N. cimiciforme* obtained from fruits of *P. edulis* and from wild passion fruit collected in Aquidauana and Terenos in the state of Mato Grosso do Sul, Brazil.

### 3. Conclusion

Passionfruit is a tropical fruit crop with global production levels of 680,000 metric tonnes/year. Despite its wide acceptance in world markets, passionfruit crops have been poorly researched in terms of pest biology, ecology and management. Species of Passifloraceae are commonly documented for having cyanogenic compounds, flavonoids and phenolics in various parts of the plant which are used as a mechanism of defense against the attack of herbivorous insects. The success in the larval development of fruit flies, inside the fruits showed the ability of these species to tolerate such chemical defenses and indicated a high degree of specialization in some passion flowers. Even though there are reports on passion fruits as host plants of frugivorous flies, natural field infestation data remains inconclusive with passion fruit host status. Moreover, many of the fly species reported in passion fruit from various parts of the world are of quarantine importance, and its high time that researchers turn their attention to the population dynamics and extend of damage caused by these dipteran flies. More studies must be developed to understand the biology, ecology and behavior of different fly species which could have important effects on passion fruit production worldwide.

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