

12 Passion Fruit

Elen L. Aguiar-Menezes,¹ Euripedes B. Menezes,²

Paulo Cesar R. Cassino² and Marco A. Soares²

¹*Empresa Brasileira de Pesquisa Agropecuária, Centro Nacional de Pesquisa de Agrobiologia, BR 465, Km 7, Caixa Postal 74505, Seropédica, RJ 23890-000 Brazil;*

²*Universidade Federal Rural do Rio de Janeiro, Centro Integrado de Manejo de Pragas 'Cincinnato Rory Gonçalves', BR 465, Km 7, Seropédica, RJ 23890-000 Brazil*

Introduction

Passion fruits belong to *Passiflora* L. (family *Passifloraceae*) which has a wide genetic base. While some species are undomesticated, others are cultivated as ornamental plants, for nourishment and for medical purposes. The majority of *Passiflora* species are indigenous to the tropical and subtropical regions of South America; Brazil is the centre of diversity of the *Passifloraceae* (Cunha, 1996; Manica, 1997). Of the 400 known species of *Passiflora*, about 50 or 60 bear edible fruits. The majority of these species are unknown outside their centre of origin (Martin and Nakasone, 1994). A few species are economically important e.g. *Passiflora edulis* botanical form *flavicarpa*, the yellow passion fruit, whose juice and pulp are used extensively as ingredients of beverages, salads, fruit cocktails and desserts (Donadio, 1983). *Passiflora edulis* f. *flavicarpa* Deneger, *P. edulis* Sims. (purple passion fruit) and *P. alata* Dryand (sweet passion fruit) are the main species cultivated in the world. The major producers of passion fruit are found in South America, mainly Brazil, Colombia, Peru and Ecuador (Ruggiero *et al.*, 1996). Commercial plantations of passion fruit are also found in Australia, Hawaii, USA, India, New Guinea, Kenya, South Africa, Sri Lanka and Costa Rica (Kluge, 1998). Other

important *Passifloraceae*, such as *Passiflora ligularis* Juss. (granadilla) and *P. quadrangularis* L. (badea, parcha granadina, tumbo) are cultivated in Central America and in the Andean regions of South America (Kluge, 1998).

Commercial production of passion fruits is currently increasing due to industrialization of the processed passion fruit products (Akamine *et al.*, 1954; Pires and São José, 1994). Although the passion fruit crop has great economic potential, its establishment and expansion have been hindered by various problems. For example, a wide host range of diseases, insects and mites attack passion fruit. Some pest species cause significant crop losses, reaching the status of key pests or secondary pests. Another limiting factor is the low sexual self-compatibility. Increased fruit set depends on effective cross-pollination. Therefore, hand cross-pollination is the second most expensive production cost of passion fruit culture. Knowledge of effective pollinating agents might be useful to secure maximum fruit production at lower cost.

Flowering and Fruit Setting

The period of flowering of passion fruit varies among species and among regions. For example, in Hawaii, USA, the passion fruit

flowers for 8–9 months a year with two distinct periods of flowering and fruit setting. The first period of flowering occurs in late winter or early spring (April and May), and the fruit matures in midsummer. The second period of flowering occurs in late summer (July and August), and the fruit matures in midwinter (Free, 1993).

According to Akamine *et al.* (1954), there is little or no overlapping of the functional periods of the flowers so that not much crossing takes place between the purple and yellow types. In Hawaii, USA, and Brazil, the flowers of the purple passion fruit open early in the morning, usually around dawn, and close before noon. The flowers of the yellow passion fruit open about noon and close about 2100 or 2200 h (Akamine *et al.*, 1954; Free, 1993; Teixeira, 1994).

In New South Wales, Australia, passion fruit flowers start to open in the night or early morning and start to close at about midday the following day, but the stigmas are fully receptive on the morning of the first day only. Anthers of the most flowers do not dehisce until the afternoon (Cox, 1957).

In Jaboticabal and Botucatu, SP (Brazil), the sweet passion fruit flowers for 12 months a year with two flowering peaks, one in January and February and the other in September and October. Its flowers open at about 0400 to 0500 h and close at 1800 to 2000 h (Vasconcellos, 1991; Ruggiero *et al.*, 1996).

Characteristics of Passion Fruit Flowers and Their Pollination

Recent interest in commercial production of passion fruit has prompted several studies on the pollination ecology. When the flowers first open, the stamens hang down, and the anthers dehisce on the undersides, exposing the pollen, the style remains erect, and there is no stickiness on the stigmatic surfaces. Eventually, the erect styles curve downwards and outwards, and when the process is completed, they are more likely to be touched by insects collecting nectar and pollen. However, for the first hour of flowering, a visiting insect is likely to receive pollen on its body

but is unlikely to deposit it on the stigma. When the flower begins to close, the styles return to an upright position. The process of recurvature requires about 1 h. However, the styles of some flowers do not curve downward as much as others, and because there is a greater distance between anther and stigma for a pollinator to bridge, they are less likely to be pollinated. This applies particularly to those flowers whose styles always remain upright, many of which are infertile as female flowers (Akamine *et al.*, 1954; Free, 1993). In Brazil, no fruit set is obtained on flowers of yellow passion fruit pollinated when their styles are upright. On flowers with styles partially curved and totally curved, 13% and 45% fruit set is obtained, respectively (Ruggiero *et al.*, 1976). Studies of Vasconcellos (1991) showed that the percentage of fruit set for sweet passion fruit was 0, 44.19 and 73.47% on flowers with styles upright, partially curved and totally curved, respectively. Under natural conditions, the stigma remains receptive only on the day of flower opening, and the pollen loses its viability after 24 h (Akamine and Girolami, 1959; Ruggiero *et al.*, 1976; Vasconcellos, 1991).

The flowers of passion fruit are fragrant when open. Nectar is secreted in a groove at the base of the gynophore, and the pollen is heavy and sticky. These features, in conjunction with the position of the anthers when the pollen is exposed and the functional position of the stigmas, indicate that flowers of passion fruit are adapted to pollination by insects rather than by wind. Wind is not important in cross-pollination (Akamine *et al.*, 1954; Akamine and Girolami, 1959; Nishida, 1963; Semir and Brown, 1975; Free, 1993), and this was confirmed in studies of caged plants that prevented access to insects; no fruit set occurred although plants flowered profusely (Akamine and Girolami, 1957).

Corbet and Willmer (1980) reported nectar sugar concentration of *P. edulis* f. *flavicarpa* to be about 45–50%, which varies little throughout the day. They calculated that the mean volume of the nectar chambers of yellow passion fruit is 180 μ l and that nectar secretion continues throughout the afternoon. The hypothesis in this study is that in order to support large bee pollinators, nectar sugar

concentrations will be low, and nectar production rates will be high.

In Hawaii, the principal insects visiting passion fruit flowers include honeybee, *Apis mellifera* L. (Apidae) and carpenter bee, *Xylocopa varipuncta* Patton (Anthophoridae) (Akamine *et al.*, 1954). It is doubtful whether the honeybee is effective for pollinating the flowers because of its small size. However, according to Hammer (1987), the foraging habits of honeybees, not their size, may cause less than expected fruit set. The carpenter bee, on the other hand, is large enough so that, in moving around the flower to obtain nectar, its body brushes along the anthers and stigmas, transferring pollen from one organ to the other (Plate 88).

Approximately, 700 species of bees belong to *Xylocopa* Latreille (Anthophoridae). They are found throughout the tropical regions of the world (Hurd and Moure, 1963; Hurd, 1978) with two generations and activity peaks during the periods of December to March and July to September (Camillo, 1978a; Camillo and Garófalo, 1982), coinciding with the flowering peaks of the passion fruit. Pope (1935) stated that carpenter bee, *X. varipuncta*, certain moths and hummingbirds were large enough to transfer pollen from the stamens to the stigmas of the passion flowers. Nishida (1958, 1963) reported insect species within Diptera, Hymenoptera, Coleoptera, Thysanoptera and Orthoptera visiting flowers of passion fruit in Hawaii, with *X. varipuncta* and hover fly, *Eristalis arvorum* (Syrphidae), being the most abundant species. Nishida (1958, 1963) stated that thrips and midges were too small to transfer the relatively large pollen grains of flowers of passion fruit.

The insects most commonly visiting passion flowers in El Salvador are *Bombus* spp., *Trigona* spp., and *Xylocopa* spp. (Free, 1993). In São Paulo (Brazil), the most common species visiting passion fruit flowers are *Xylocopa* spp., *Epicharis* spp. and *Apis mellifera scutellata* (Nishida, 1963; Ruggiero *et al.*, 1976).

Akamine and Girolami (1959) noticed that hover fly *E. arvorum* and long-horned grasshopper *Conocephalus saltator* (Tettigoniidae) feed on pollen of passion flowers, but considered that their value as potential pollinators outweighed their potential pest status.

In the West Indies, the successful pollinators of passion flowers included three species of hummingbird, and in higher numbers, *Xylocopa mordax* Smith (Corbet and Willmer, 1980). While collecting nectar, *X. mordax* moves around the flower while facing inward, often making at least one complete circuit. Only the tip of the galeae can be inserted past the operculum at the mouth of the nectary and into the nectar groove. Because of the depth of the nectar groove, at least 13 µl of nectar remained inaccessible to the bees. The collected nectar load has about 50–70 µl volume, and 45–49% sugar concentration. *Xylocopa mordax* spends about 8.5 s per flower visit. On sunny days each flower received a mean of four visits in the morning and two in the afternoon; overcast conditions reduced the visits. Besides nectar, *X. mordax* collected pollen on the dorsum when in contact with the fully recurved stigmas in different passion fruit species (Free, 1993). According to Corbet and Willmer (1980), most yellow passion flower pollination by *X. mordax* occurs between 1330 and 1500 h (Fig. 12.1) when the stigmas have curved downward. The daily percentage of flowers pollinated ranged from 25% on overcast days to 94% on bright sunny days. Flowers on lower branches were less likely to receive a visit by *X. mordax* and are less likely to set fruit than flowers on higher branches.

In Brazil, Ruggiero *et al.* (1975, 1976) observed that three species of *Xylocopa* and Africanized honeybees were the most abundant pollinators of passion fruit, but the pollinating efficiency of the honeybee was low compared with *Xylocopa* spp. (3% and 75% set, respectively). *Xylocopa* bees were more efficient pollinating flowers whose styles were totally and partially curved and less efficient on rainy days. Camillo (1978b, 1980) also found that *Xylocopa suspecta* Moure & Camargo is a more effective pollinator of yellow passion flowers than *X. frontalis* (Olivier) in Brazil. The author cited other insects, i.e. *Epicharis rustica* (Friesse) (Anthophoridae), *Bombus morio*, *B. atratus*, *Apis mellifera*, *Scaptotrigona postica*, *Geotrigona* sp. (Apidae), and *Oxaea flavescens* Klug (Oxaeidae) visiting flowers of yellow passion fruit. However, *S. postica* and *A. mellifera* usually collect pollen while

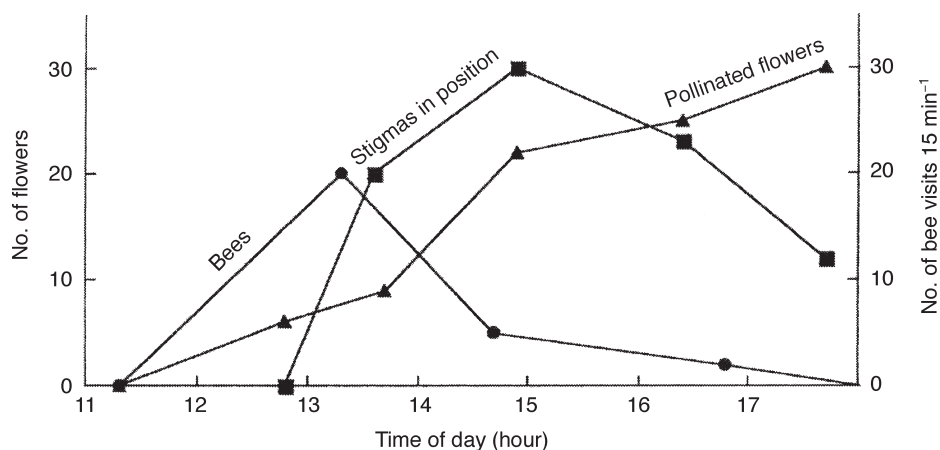


Fig. 12.1. Pollination of *Passiflora edulis flavicarpa*, yellow passion fruit. Changes throughout a day in the number of bee visits, number of flowers with at least one stigma curved downward to another level, and the number of pollinated flowers (those with pollen on at least one stigma) (after Corbet and Willmer, 1980).

E. rustica, *B. morio*, and *O. flavescens* collect nectar.

Sazima and Sazima (1989) also reported that *X. suspecta* and *X. frontalis* were effective pollinators of passion fruit in Ribeirão Preto, SP (Brazil), but *Trigona spinipes* (Fabricius) (Apidae) collected nectar and pollen without pollinating the flowers. When *T. spinipes* was numerous, their visits depleted the flowers of nectar, thereby diminishing foraging by *Xylocopa*. Moreover, *Trigona* attacked and repelled *Xylocopa* when the latter attempted to visit passion fruit flowers, resulting in 6–25% fruit set reduction. The deleterious effect of *Trigona* colonies is likely to be more serious in small plantations.

Hoffmann and Pereira (1996) found the following species of bees visiting flowers of yellow passion fruit in Campos dos Goytacazes, RJ (Brazil): *A. mellifera*, *Xylocopa ordinaria*, *X. frontalis*, *Eulaema nigrita*, and *E. cingulata* (Apidae). Most flower pollination by *Xylocopa* bees occurred between 1400 and 1700 h. Species of *Eulaema* were observed only during the morning.

In Malaysia, Mardan *et al.* (1991) observed that carpenter bee, *Platynopoda latipes*, was the most important pollinator of passion fruit. They suggested that honeybees (*Apis cerana* and *A. dorsata*) were detrimental to fruit set by removing pollen before effective pollination by *P. latipes* could occur.

Three carpenter bees, *Xylocopa mordax* Smith, *X. scutellata* Moure, and *X. (Megaxylocopa) fimbriata* Fabricius, were the most important pollinators of passion fruit in east and southeast of Lake Maracaibo (Venezuela). *Xylocopa* nests were observed in wooden trellis supporting passion fruit plants. Most flower visits occurred between 1500 and 1800 h (Dominguez-Gil and McPherson, 1992).

Ways of facilitating pollination by *Xylocopa* have been advocated. Nishida (1958) advised that either the area of passion fruit should not exceed the pollinating capacity of the insects present, or the number of pollinators on the crop should be increased. Different ways to increase the population of pollinators have been suggested (Nishida, 1954; Akamine and Girolami, 1959; Cobert and Willmer, 1980). The carpenter bee builds its nest in wood or plant stems, and thus its presence as a pollinating agent can be encouraged by placing wooden posts throughout the passion fruit plantation. The post may be redwood, kukui, or some other suitable soft wood. Abundance of nesting sites might reduce time spent searching for nests and diminish competition between adult females (Akamine *et al.*, 1954; Free, 1993). Studies of Camillo and Garófalo (1982) showed that eucalyptus was the wood preferred by *Xylocopa* bees given a choice between nine types of wood. Hoffmann (1997)

recommended the use of posts about 20 cm diameter have been 60–70 cm length in which two holes of 1.5 cm diameter have been made. The first hole is longitudinal, 20 cm deep, and the second one is perpendicular to the first at 15 cm high, allowing them to meet. The first hole is closed by a woody piece or a cork, and the second is used as the nest entrance.

Camillo (1996) increased the pollination of passion fruit by introducing into plantations *Xylocopa* spp. in Holambra, São Paulo (Brazil). Before the placement of *Xylocopa* nests, the natural pollination resulted in 3.2% fruit set. With the introduction of 49 nests of *X. frontalis* and *X. grisescens* into 1.5 ha of passion fruit, the percentage of fruit set increased to 25%.

Carpenter bee populations can be increased by providing seasonal spreads of nectar and pollen sources, thereby reducing competition with other nectar sources while passion fruit is flowering (Akamine *et al.*, 1954). In Brazil, *Hibiscus* spp., *Cassia* spp., *Ipomoea purpurea*, and *Crotalaria juncea* have flowers that are very attractive to carpenter bees (Ruggiero *et al.*, 1996).

Evaluation of the need to either increase numbers of carpenter bees or perform hand pollination is by counting the number of flowers dropped, because this may be caused by lack of fertilization, indicating low population density of insect pollinators. To evaluate whether the pollinators occur in the crop at a suitable level, Ruggiero *et al.* (1996) recommended that three opening flowers per plant should be labelled on a sunny day. For 2–3 ha, this operation must be repeated with > 34 plants, labelling 100 flowers in total. If the area is greater, the quantity of labelled flowers should be increased proportionally. Four days later, the fruit set on the labelled flowers is counted. Of the 100 labelled flowers, Ruggiero *et al.* (1996) observed that 40–50% developed into fruit, meaning that the population density of carpenter bees was adequate. However, values < 30% indicated there was a lack of pollinators and, in this case, flowers must be hand pollinated.

According to Akamine *et al.* (1954), Akamine and Girolami (1957, 1959), and Nishida (1958), honeybees may actually cause unfruitfulness of passion fruit. In areas where

honeybees are plentiful, it has been observed that they visit the flowers as soon as flowers have opened. The bees remove the pollen from the anthers and carry it back to the hive. By the time the styles have moved into position where their stigmas can be pollinated by carpenter bees, the pollen may be entirely gone. Unless the carpenter bees have some pollen remaining on their bodies from early visits to the flowers, pollination is entirely precluded and fruit setting fails to occur.

In Hawaii, Nishida (1958) found that in two localities, flowers bagged and pollinated by hand had about the same percentage set as unbagged flowers. However, in two other localities, bagged and hand pollinated flowers had a greater fruit set, indicating that the local insect pollinators were too few in these sites (Fig. 12.2). His results also showed that the fruit set from cross-pollinating, bagged flowers varied from 50 to 100%, depending on the locality. So the maximum fruit set in some localities was limited by factors other than pollinators. The percentage of fruit set from hand pollination and the difference in set between hand and natural pollination also varied within a season. Akamine and Girolami (1959) reported that natural fruit set was less than that achieved by hand pollination. Corbet and Willmer (1980) confirmed that bagged flowers only set fruit following cross-pollination (mean of 77% fruit set). Furthermore, manually cross-pollinating flowers exposed to insect pollinators increased fruit set from 27 to 73%, indicating that natural pollination was inadequate.

Nishida (1963) found that the abundance of honeybees on the crop and the proportion of pollen gathered varied greatly from one month to the next and was probably associated with the presence of competing sources of forage. He observed that sometimes honeybees were so abundant that nearly all pollen was removed soon after the flowers opened. A few honeybees were present on the crop when it was not flowering and in the mornings before the flowers opened; these bees were collecting from the extrafloral nectaries on the leaf petioles. He found that when the density of honeybees present increased to a certain level there was a tendency for the fruit set to decrease. However, there was a positive

correlation between the increase in fruit set and the increase in the population of *X. varipuncta* that was present (Fig. 12.3). Nishida (1963) suggested that *X. varipuncta* is a more efficient pollinator than the honeybee, because it is larger, works faster and carries

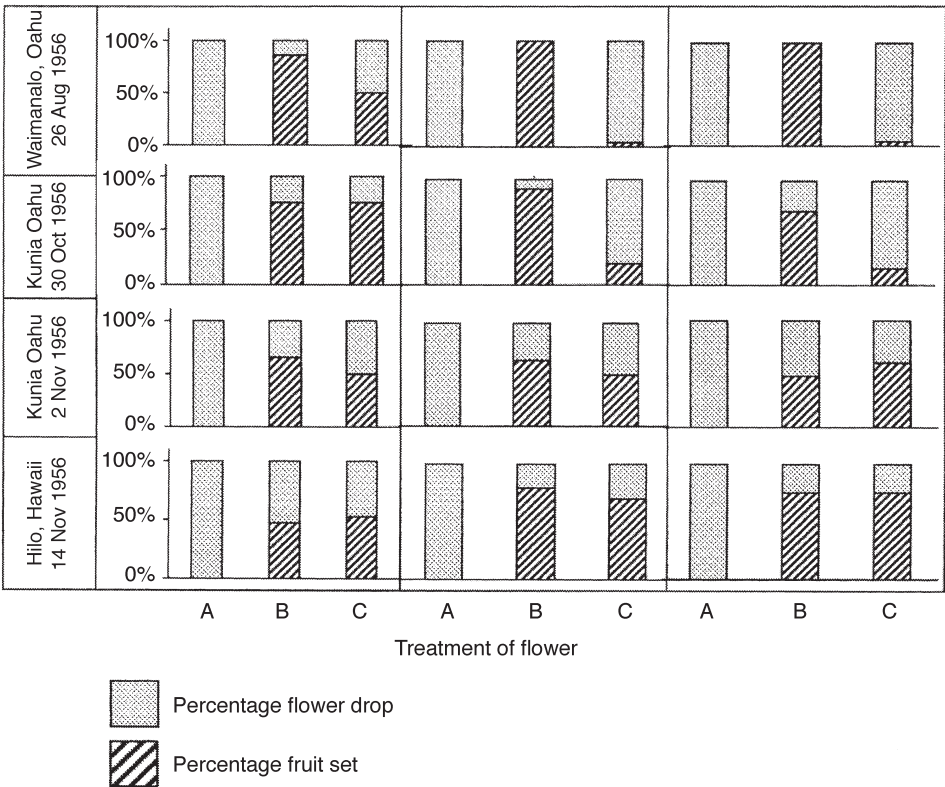


Fig. 12.2. An experiment to determine the efficiency of natural pollination of *Passiflora edulis*, passion fruit, in three sites in each of four localities: A, flowers bagged; B, flowers bagged and hand pollinated; C, flowers not bagged nor hand pollinated (after Nishida, 1958).

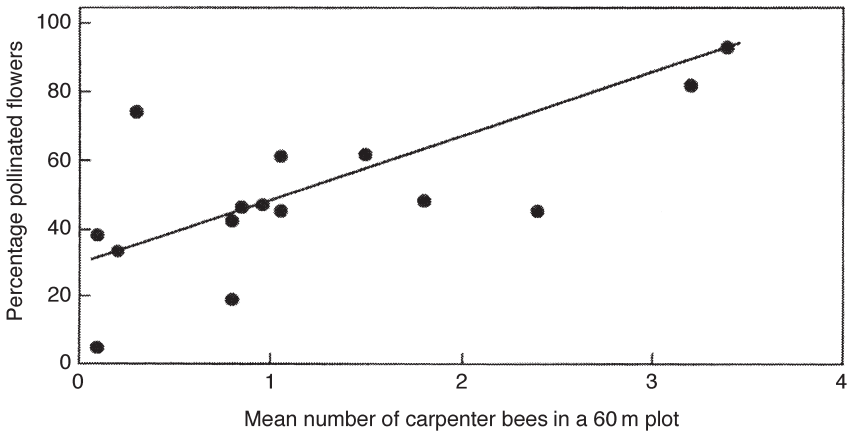


Fig. 12.3. Relationship between the number of *Xylocopa varipuncta*, carpenter bees, in *Passiflora edulis*, passion fruit, fields and percentage of flowers pollinated (after Nishida, 1963).

larger loads. Ruggiero *et al.* (1976) confirmed this by experiments in which caged plants resulted in better fruit set when confined with *Xylocopa* spp. than with honeybees (75% and 45% fruit set, respectively).

On the other hand, Free (1993) suggested that honeybees as pollinators are important because they forage in the lowlands and in the humid uplands, and may be easily manipulated. Cox (1957) reported that honeybees are abundant and effective pollinators of passion fruit in Australia. In Florida, USA, where honeybees are the sole pollinators of *P. edulis*, up to 25% of its flowers produce fruit (Hardin, 1986).

As pointed out by Gilmartin (1958), it has not been determined that cross-pollination between flowers of different clones or varieties is necessary for maximum fruit setting. It is advisable to plant several selected varieties in an orchard to enhance the possibility of cross-pollination and to minimize crop losses which might occur from planting with a variety strain that proved to be highly self-incompatible. Akamine and Girolami (1959) found that any cross that involved variety 'C 39' (Table 12.1) was compatible, but crosses between other varieties were nearly completely incompatible. They suggested that plants of compatible clones, which flower at the same time, should be distributed in the field to ensure the maximum possibility of cross-pollination.

Conclusions

Plants of the *Passifloraceae* depend on cross-pollination to set fruit because their flowers present characteristics that make it difficult for self-pollination, such as presence of stigmas above the level of the anthers and stigma receptivity and low self-fertility. Thus, the passion fruit depends largely on mutualistic relationships, with insects as pollinators. In fact, the flowers of passion fruit are large, attractive, colourful, fragrant, and produce plentiful nectar and pollen that facilitate insect cross-pollination. Most of the studies dealing with pollination of the *Passifloraceae* support the theory that carpenter bees, mainly *Xylocopa* spp., are the most effective

Table 12.1. Reciprocal crosses between varieties of passion fruit, and the percentage of fruit set following cross-pollination. (From Akamine and Girolami, 1959.)

Reciprocal crosses	No. flowers pollinated	Percentage of fruit set
C 39 and C 37	258	92
C 39 and C 77	250	97
C 39 and C 80	167	97
C 37 and C 77	83	2
C 37 and C 80	106	2
C 77 and C 80	80	4

pollinators. However, other hymenopterans (e.g. *Apis*, *Bombus*, *Epicharis*, *Oxaea*) and orthopterans, dipterans, etc., visit the flowers of passion fruit, and may pollinate, even though they may be less effective than *Xylocopa*. Thus, as stated by Price (1997) studies of pollination ecology, co-evolution between plant and pollinator, energetic relationships, demographics of plant and pollinator, reproductive strategies, population dynamics and community ecology, are still warranted and needed for *Passifloraceae*.

Pests

Although passion fruit is attacked by several pest species of insects and mites that feed upon all parts of the plant, a limited number of species are clearly of major economic importance. Few have key pest status, while some species are secondary pests because they are sporadic or occur at low population levels, and therefore do not require control strategies. Insect and mite pests that are frequently associated with passion fruit are described below, including their description, life history, behaviour, hosts, damage and control (Santo, 1931; Lordello, 1952b; Correa *et al.*, 1977; ICA, 1987; Dominguez-Gil *et al.*, 1989; Figueiro, 1995; Lima and Veiga, 1995).

Lepidopterous defoliators

Three heliconiine species, *Dione juno juno* Cramer, *Agraulis vanillae vanillae* Linnaeus,

and *Eueides isabella huebneri* Ménétries (Nymphalidae), are the most common lepidopterans feeding upon foliage of passion fruit (Dominguez-Gil and McPheron, 1992). *Dione juno juno* is the key pest of passion fruit in Brazil and causes severe damage to the plants (De Bortoli and Busoli, 1987; Gravena, 1987). *D. juno* is distributed in the southern USA, the Antilles, Guyana, Surinam, French Guiana, Trinidad, and from Colombia to Argentina (Toledo, 1991), while *A. vanillae* occurs in South America and over a large part of the southeastern USA (Carter, 1992). *Eueides isabella* is found in Venezuela and south of Brazil (Silva *et al.*, 1968; Brown Júnior and Mielke, 1972; Dominguez-Gil and McPheron, 1992; Boiça Júnior *et al.*, 1993).

DESCRIPTION AND LIFE HISTORY Adults of *D. juno* have orange wings with black borders and venation. The wingspan is about 60 mm. Eggs are laid in groups of 40–70 on the leaf underside, near the border. The 0.9×0.6 mm egg is light yellow when first laid, and darkens just before hatching. Eggs hatch in 6–7 days. The larvae pass through four or five instars, requiring 19–27 days to reach full growth. When fully grown, the larva is about 29–35 mm in length, 3–5 mm in width, dark brown, with small yellow spots, and covered with black setae arranged in rows. The larvae are gregarious and, when disturbed, raise their head and thorax, and stand on their pseudolegs. The chrysalis is suspended by the cremaster, is obiect, cream in colour, and about 16–25 mm in length. The pupal stage requires 7–9 days (D’Almeida, 1944; Lordello, 1954; Silva, 1979; Chacón and Rojas, 1984; De Bortoli and Busoli, 1987; Toledo, 1991; Dominguez-Gil and McPheron, 1992; Dominguez-Gil, 1998).

The *A. vanillae* butterfly has red-orange wings, with black markings and venation, and silver spots on the underside (Plate 89). Wingspan varies from 60 to 75 mm (Carter, 1992). The female lays eggs singly on leaves or stems. The eggs are light yellow when recently oviposited, spindle shaped, and about 1 mm in length. The eggs hatch in 3 days (Lordello, 1952a). The newly hatched larva, approximately 3 mm long, is creamy white. The

full-grown larva is about 35–40 mm in length, the dorsum has orange, blue and white stripes and six longitudinal lines of branched black spines (Plate 90). The larvae has five instars, and lasts about 17 days (Lordello, 1952a). The chrysalis is suspended by the cremaster, which is usually attached to a branch of the host plant. The chrysalis is about 25 mm in length, sharply angled, and creamy white and lasts about 7 days.

Two-thirds of the forewing of *Eueides isabella huebneri* is dark brown, almost black, with irregular yellow spots, and one-third is orange with black stripes. The hindwings are orange with black borders and a central stripe. The wingspan is 70–80 mm. Females oviposit single eggs on leaves or stems. The eggs are whitish yellow when recently laid, and are darker close to hatching, which occurs 4–7 days after oviposition. The newly hatched larva is 1–3 mm long, white with black head and body hairs. The full-grown larva is 30 mm long. The dorsal surface of its body is black with transversal narrow white stripes, and the dorsal surface of the eighth and ninth abdominal segments is orange. The larvae require five instars. The chrysalis has spines on the thorax and abdomen, differing from the other heliconiines.

HOST PLANTS Caterpillars of *D. juno* feed on all *Passiflora* species, except *P. foetida* (Echeverri *et al.*, 1991; Carter, 1992). According to Boiça Júnior *et al.* (1993), *P. alata*, *P. setacea* and the hybrid *P. alata* \times *P. macrocarpa* are more resistant to attack by *D. juno* than *P. edulis*, *P. cincinnata*, *P. caerulea* and the hybrid *P. edulis* \times *P. alata*.

INJURY The three species of heliconiine defoliators reduce leaf area, thereby indirectly reducing yield. *Dione juno* usually causes damage that is more serious because of its gregarious behaviour (Fancelli and Mesquita, 1998). During the first instar, the caterpillars scrape the leaf epidermis of young leaves, leaving small holes in the leaves, while older larvae devour both young and older leaves (Lordello, 1954; Chacón and Rojas, 1984). Besides defoliation, the caterpillars may feed on the apical buds, flowers or stems (De Bortoli and Busoli, 1987).

NATURAL ENEMIES Several predators and parasitoids have been reported from these heliconiids. However, these natural enemies are not considered to be effective. For instance, Silva *et al.* (1968) reported *Alcaeorrhynchus grandis* (Dallas) and *Apateticus mellipes* Bergroth (Pentatomidae) as predators of *D. juno*. In Argentina, *A. vanillae* was recorded to be parasitized by *Pteromalus caridei* Brèthes (Pteromalidae). Silva (1979) reported *Spilochalcis* spp. (Chalcididae) parasitizing *D. juno*. In the state of Pernambuco (Brazil), Lima and Veiga (1995) found *Spilochalcis* spp., *Polistes* sp. (Vespidae), *Paratrechina longicornis*, *Crematogaster* sp., *Pseudomyrmex gracilis* (Formicidae), and *Forcipomuaia* sp. (Ceratopogonidae) as natural enemies of *D. juno*. Ruggiero *et al.* (1996) recorded the hymenopteran wasps, *Polistes* spp. and *Polybia* spp. (Vespidae), as predators of passion fruit heliconiids in Brazil. In Lake Maracaibo (Venezuela), Dominguez-Gil and McPherson (1992) reared two specimens of *Spilochalcis* sp. from field-collected larvae and chrysalis of *A. vanillae* and *E. isabella*.

Lima and Veiga (1993) verified the occurrence of nuclear polyhedrosis virus (NPV) infesting *D. juno* caterpillars in Pernambuco. In Lake Maracaibo, larvae of *D. juno* were also infected by NPV. Once infected, larvae became sluggish, and their cuticles become discoloured and fragile. Chacón and Rojas (1984) estimated that NPV kills 100% of the *D. juno* population in Colombia. A NPV epizootic occasionally reduced populations of *A. vanillae* in plantations located east of Lake Maracaibo where NPV was very abundant during January and February for 3 consecutive years (Dominguez-Gil *et al.*, 1989).

CONTROL In small areas, cultural control during periodic crop inspection includes hand picking and destruction of eggs and caterpillars (Rossetto *et al.*, 1974). However, these methods require considerable time and labour and are often impractical for a large-scale cultivation. In this case, injurious populations of defoliating caterpillars infesting passion fruit must be controlled with insecticidal sprays. Action thresholds have not been defined. Growers spray the foliage, often starting with appearance of the pest, and continue at

regular intervals until the crop is harvested. In passion fruit it is very important to protect pollinating insects by timing insecticidal treatments when pollinators are not present in the field. Choosing an insecticide that is selective for the pest and less toxic to pollinators, predators and parasitoids is important in these agroecosystems. *Bacillus thuringiensis* (Bt) Berliner, which effectively controls a variety of caterpillars and has little or no effect on natural enemies, is commonly recommended. Menezes *et al.* (1989) performed a laboratory experiment with different strains of Bt to control *D. juno*. Figueiro (1995) demonstrated that suspensions of *Baculovirus dione* at concentrations of 10, 20, 40 and 80 g of larvae per 500 l of water, were highly pathogenic and efficient at controlling larvae of *D. juno* under laboratory conditions. Studies of Moura *et al.* (2000) on selectivity of insecticides to vespids predators of *D. juno*, showed that the deltamethrin was highly selective to *Polybia scutellaris* and *Polybia fastidiosuscula*, and showed intermediate selectivity to *Protoneectarina sylveirae*. Cartap was moderately selective to all three species of predatory wasps. Malathion was selective to *P. sylveirae* and showed intermediate selectivity to *P. fastidiosuscula*.

Coreid bugs

Many species of bugs attack passion fruit and the majority belongs to the Coreidae (leaf-footed bugs). In passion fruit producing areas, three main species of coreids are reported: *Diactor bilineatus* Fabricius, *Leptoglossus* spp. and *Holhymenia* spp. *D. bilineatus* is the most common species, and is known as the passion fruit bug because it feeds only on fruit of *Passiflora* spp. Among the *Holhymenia*, *H. clavigera* (Herbst.) and *H. histrio* (Fabricius) are the most common species attacking passion fruit. The bugs *Leptoglossus*, *L. gonagra* Fabricius and *L. australis* Fabricius, usually cause damage to passion fruit.

D. bilineatus is considered the most important pest of passion fruit in Brazil by Mariconi (1952) and Fancelli and Mesquita (1998). However, Dominguez-Gil and McPherson (1992) consider that *Diactor*

bilineatus Fabricius, *Leptoglossus* spp. and *Holhymenia* spp. are the second most significant phytophagous group of pests in passion fruit plantations in the Lake Maracaibo region (Venezuela).

DESCRIPTION AND LIFE HISTORY Adults of *D. bilineatus* are orange on the ventral face of the head, and the dorsal face is dark metallic green with two orange longitudinal lines that continue on the prothoracic tergum and the scutellum, both of which are dark metallic green. The hind legs have the tibia expanded and leaf-like, dark green in colour with some orange markings. Males are about 20 mm in length, and females, 21.5 mm. When disturbed, they walk or make short flights, mainly in cold periods. A female lays a batch of six to nine eggs on the underside of the leaves. They are about 3 mm long, light yellow, bright, ellipsoid and flattened in the base. The incubation period for eggs is 13–16 days. The nymphs, which pass through five instars, require about 43–46 days to reach the adult stage (Mariconi, 1952). The first instar nymph has an orange head that turns dark blue in the following instars. The thorax is orange, and a white stripe surrounds the femurs and tibiae. The hind legs are characterized by the expanded leaf-shaped tibia. The abdomen is orange with six pairs of lateral, dark blue expansions from the third to the eighth abdominal segments (Dominguez-Gil, 1998).

The adult body of *Holhymenia* spp. is black with orange spots. The legs are reddish orange. The head, the prothoracic tergum and the scutellum are black with white spots (De Bortoli and Busoli, 1987; Brandão *et al.*, 1991; Dominguez-Gil, 1998).

The adult *L. gonagra* (Plate 91) is about 15–19 mm in length and dark brown in colour. The head colour ranges from dark brown to almost black, with two yellow longitudinal lines. The prothoracic tergum is brown with a yellow transverse line. The antennae are brown with the second, third and distal two-thirds of the fourth segments light yellow in colour. The hind tibiae are expanded and leaf-like. The longevity of adults is about 37 days. Eggs are 1.4 mm in length, dark brown with triangular cross-section. The eggs hatch in 8 days. Newly hatched nymphs are reddish

with black legs and antennae. The bugs pass through five nymphal instars in about 55 days (Chiavegato, 1963; De Bortoli and Busoli, 1987). The adult passion vine bug, *L. australis*, is elongate, approx. 20 mm in length, and dull black in colour with orange spots on the underside of the body. In Hawaii, passion vine bugs migrate from surrounding scrub to infest passion fruit plantations. Neglect of vines may allow populations of the bug to build up. Feeding usually occurs on flowers or green-mature fruit. Nymphs often cluster on fruit when feeding. Damage to mature fruit is not pronounced; however, young fruit develops dimple-like surface blemishes at the feeding sites (Murray, 1976).

HOST PLANTS Silva *et al.* (1968) listed several species of *Passiflora* as being hosts of *D. bilineatus*. Mariconi (1952) verified that *P. quadrangularis* is seriously damaged by this pest. Besides passion fruit, *H. clavigera* feed on guava (Fancelli and Mesquita, 1998). Silva *et al.* (1968) mentioned *P. edulis* as host of this species. *L. gonagra* feeds on a large number of host plants, including passion fruit, chayote, citrus, tobacco, guava, sunflower, cucumber, grape, pomegranate, São Caetano melon (*Cayaponia esvelina*), bixa (*Bixa orellana*), araçazeiro (*Psidium araca*), and *Anisoperma passiflora* (Chiavegato, 1963).

NATURAL ENEMIES Silva *et al.* (1968) reported that *D. bilineatus* eggs were parasitized by *Hadronotus barbiellini* Lima (Scelionidae). Eggs of *H. clavigera* were reported to be parasitized by *Hexacladia smithii* Ashmead (Encyrtidae) (Silva *et al.*, 1968).

INJURY Both immature and adult bugs injure the crop, piercing stems, leaves, fruits and flowering buds, and sucking plant juices. However, the nymphs prefer to feed on flowering buds and young fruits, usually resulting in excessive dropping. The adults may also attack leaves, stems and fruits at any stage of ripening. If larger fruits are fed upon, they wilt and show a wrinkled surface. Fruits may also develop dimple-like blemishes at the feeding sites on the fruit surface (Murray, 1976). *Leptoglossus gonagra* often causes misshaping or dropping of young fruits (Chiavegato, 1963).

CONTROL In small passion fruit producing areas, hand picking and destruction of eggs, nymphs and adults is recommended (Mariconi, 1952). Chiavegato (1963) suggests the removal of the alternative cucurbit host, 'São Caetano melon', a preferred host of *L. gonagra*, or to avoid the cultivation of chayote and *Anisosperma passiflora* in adjacent areas as tactics to reduce pest densities. In southeast Queensland, Australia, regular inspections are recommended during the summer months to detect any build-up of *L. australis* (Murray, 1976).

Stem weevil

In Brazil, the stem weevil *Philonis* spp. (Curculionidae) was first reported in Alagoas in 1972. Currently, the infestation has expanded to several states in Brazil (Warumbi and Veiga, 1978; Leão, 1980; Torres Filho and Araújo, 1981; Oliveira and Busoli, 1983; Cruz *et al.*, 1993; Racca Filho *et al.*, 1993; Boaretto *et al.*, 1994). It is commonly found on borders of young plantations (Fancelli, 1992a). Severe outbreaks of this pest have caused the eradication of 250 ha in Brazil (Rossetto *et al.*, 1978). Racca Filho *et al.* (1993) reported the occurrence of *P. passiflorae* O'Brien and *P. obesus* Champion in Rio de Janeiro. The species that occurs in São Paulo was identified as *P. crucifer* (Piza Júnior and Kavati, 1995).

DESCRIPTION AND LIFE HISTORY Adults of *P. passiflorae* are about 7 mm in length, brown with whitish elytra with two brown stripes. Adults of *P. crucifer* are 4 mm in length, brown with black markings. They are nocturnal (Piza Júnior and Kavati, 1995). According to Santos and Costa (1983) and Boaretto *et al.* (1994), females lay eggs on young or old stems. The eggs hatch in 8–9 days. The larvae are white and legless. The full-grown larva is about 8 mm long. The larval stage is 53–64 days, and the pupal period is 14–35 days (Costa *et al.*, 1979). All stages of development of this species occur inside the stem. Pupae and recently emerged adults are frequently found in cocoons spun by the full-grown larva (De Bortoli and Busoli, 1987).

HOST PLANTS In Brazil, yellow passion fruit is susceptible to attack by *Philonis* spp. while *Passiflora alata*, *P. maliformis*, *P. serrato digitata* and *P. caerulea* are not infested by this pest (Oliveira and Busoli, 1983). Cruz *et al.* (1993) observed that yellow passion fruit is very susceptible to *Philonis obesus* attack, but *P. alata* and *P. giberti* show some plant resistance.

INJURY Larvae of *Philonis* spp. feed within the stems, opening longitudinal galleries inside stems that prevent plant development. The attacked stems are easily identified by the presence of excrement and sawdust (Santos and Costa, 1983). As the larva develops, infested stems become weak and frail, and die (Fancelli, 1992a). According to De Bortoli and Busoli (1987), the simultaneous attack of several larvae is characteristic of weevil infestations, which causes hypertrophy in stems where the pupal cell will be constructed (Rossetto *et al.*, 1978; Oliveira and Busoli, 1983; Racca Filho *et al.*, 1993). Attack by the stem weevil also causes fruit drop before maturation (Costa *et al.*, 1979).

CONTROL Periodic inspections of the crop are essential for an early detection of weevil-infested stems (Fancelli, 1992a). When infestation symptoms are detected on the crop, affected stems should be pruned and burned (De Bortoli and Busoli, 1987). According to Leão (1980) and Costa *et al.* (1979), a contact insecticide (e.g. decamethrin at 25% (5–10 g a.i. ha⁻¹)) should be applied during early afternoon hours for stem weevil control, at the time of adult emergence. After 4–5 days, systemic insecticides for control of future stem infestations should be used.

Flies

Some fly species feed upon the fruits of *Passiflora* spp., and others attack flowering buds. In Brazil, Lordello (1954), Santos and Costa (1983) and Teixeira (1994) reported the following genera of flies damaging passion fruits: *Anastrepha* Schiner (Tephritidae) and *Lonchaea* Fallén (Lonchaeidae). *A. consobrina* (Loew), *A. 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 reported as being the most common species associated with passion fruit in Brazil (Santos and Costa, 1983; Teixeira, 1994; Zucchi, 1988, 2000). *Anastrepha pallidipennis* Guerne was reported on yellow passion fruit in Colombia (Chacón and Rojas, 1984). The oriental fruit fly, *Bactrocera dorsalis* (Hendel), melon fly, *Bactrocera cucurbitae* Coquillett, and the Mediterranean fruit fly, *Ceratitis capitata* Wiedmann, are known to attack the passion fruit vines in Hawaii, USA (Back and Pemberton, 1918); however, the relative importance of each species appears to vary with respect to location of the vineyard (Akamine *et al.*, 1954). The Queensland fruit fly, *Bactrocera tryoni* (Froggatt), is the most important insect pest of passion fruit in Australia (Murray, 1976).

Neosilba pendula (Bezzi) and *Dasiops* sp. (Lonchaeidae) are the most common species attacking flowering buds of passion fruit (Rossetto *et al.*, 1974; Silva, 1982; Fancelli and Mesquita, 1998). *Dasiops* sp. attacking flowering buds was reported in Rio de Janeiro, Brazil (Silva *et al.*, 1968; Vasconcellos *et al.*, 1995). The species of *Dasiops* known to attack flowering buds or fruits of *Passiflora* spp. in the Americas are *D. curubae* Steyskal, *D. inedulis* Steyskal, and *D. passifloris* McAlpine (Steyskal, 1980).

Other flies may also feed upon flowering buds, such as *Lonchaea cristula* McAlpine (Lonchaeidae) and *Zapriothrica salebrosa* Wheeler (Drosophilidae) (Chacón and Rojas, 1984). Hernández *et al.* (1985) observed that *L. cristula* is more common in curuba (*Passiflora molissima*) when this crop is cultivated near areas where other host fruits grow. The larvae of these fly species destroy pollen by boring into anthers, and may cause intensive dropping of infested buds (Chacón and Rojas, 1984).

DESCRIPTION AND LIFE HISTORY *Anastrepha* adults are 6.5–8.0 mm in length, predominantly yellow in colour, with brown and yellow markings on the wings. The adult Medfly is a smaller colourful insect with yellow and black markings on the body and black and orange markings on the wings. Adult flies emerge

from puparia buried up to 2–5 cm deep in the soil, and crawl to the surface. They feed on juice of ripening fruits (Plate 92) and on honeydew excreted by aphids, mealybugs, and soft scale insects. Females deposit their eggs mainly in ripening fruit, depositing two to six eggs in the cavity beneath the skin. After 2 or 3 days, the whitish eggs hatch. The cream coloured larvae bore into the fruit pulp and contaminate it with bacteria and fungi, which cause the fruit to decay. Large fruits may contain as many as 100 larvae. Under favourable conditions, larvae complete development in about 9–13 days. They exit the fruit while it is hanging on the tree or after it has fallen to the ground. In the tropical areas, the pupae complete development in 10–14 days. In temperate areas, the pupae complete development in 7–11 days during the summer, but in winter may remain dormant for several months. Flies of the genus *Anastrepha* produce a variable number of generations depending on the inhabited region (Orlando and Sampaio, 1973; Morgante, 1991).

The adult of *Bactrocera tryoni* is wasp-like in appearance, about the size of a house fly, with transparent wings bearing a dark band on the front margin. Bright yellow patches interrupt the general reddish brown body colour. The female lays several pale cream, elongate eggs beneath the skin surface of the fruit. Creamy coloured maggots may emerge from the eggs in 2 or 3 days and tunnel within the fruit while feeding. During the warmer weather the larval stage is completed in about 2 weeks. The mature larvae then leave the fruit to burrow into soil to pupariate for an additional 2 weeks, after which adults emerge from puparia. Very few eggs laid in immature passion fruit produce adult flies. The development of woody tissue around eggs in the rind of the fruit prevents some eggs from hatching, or when hatching occurs, causes high mortality of young larvae. Egg hatching in ripe fruit is mostly unaffected since the fruit has ceased growing and does not form the woody tissue around the eggs (Murray, 1976). In Queensland (Australia), *B. tryoni* invades passion fruit vines from alternative host plants and is most active from September to April (Swaine *et al.*, 1985).

The adult *Dasiops curubae* is blackish blue. The wings are hyaline and slightly smoky yellowish, while the calypters and wing fringes are pale yellowish (Steyskal, 1980).

The adult *Dasiops inedulius* is bright metallic dark blue with hyaline wings; the calypters and wing fringes are yellowish to nearly white (Steyskal, 1980). Peñaranda *et al.* (1986) reported that the length of the life cycle of this species takes 22.8 days under laboratory conditions. The period of incubation requires 2–3 days; the larval stage, 4–9 days; and the pupal stage, 10–17 days (Peñaranda *et al.*, 1986).

Dasiops passifloris was described by McAlpine (1964), who recorded its distribution in Florida. Adults are metallic blue-black, and females have a long ovipositor resembling those species in the Otitidae and Tephritidae. They oviposit one to four eggs in the pulp of immature fruit. After hatching, larvae bore through the immature fruit and feed on developing seeds. The maturing larvae then begin feeding on the fruit pulp immediately beneath the skin. In about 12 days the larvae mature and drop to the ground, where they pupariate within the soil or possibly beneath some refuse. The pupal stage lasts 14 days (Stegmaier, 1973).

The adult *Neosilba pendula* is about 4 mm long, bright metallic dark blue, with hyaline wings (Rossetto *et al.*, 1974).

HOST PLANTS The highly polyphagous *Anastrepha* spp. infest approximately 270 plant species in 41 families, and are considered to be the major fruit pests of tropical and subtropical America. *Passiflora* has been reported as a host of the larvae of two groups of *Anastrepha* (*chiclayae* and *pseudoparallela*) (Norrbom and Kim, 1988; Stefani and Morgante, 1996). *Anastrepha chiclayae* Greene has been found associated with *Passiflora* spp. in Mexico (Hernández-Ortiz, 1992). Larvae of *A. limae* Stone feed upon fruits of *P. quadrangularis* (Stone, 1942; Caraballo, 1981). Lordello (1954) observed infestations by *Anastrepha* and *Lonchaea* species on *Passiflora quadrangularis* and *P. macrocarpa*. The Medfly attacks 253 kinds of fruits, nuts, and vegetables; many of which are tropical plants. *Neosilba pendula* is known as the key pest of cassava, and is a

secondary pest of several fruits, especially tangerine (Rossetto *et al.*, 1974). *Dasiops curubae* damages flowers of curuba (*P. mollissima*) (Steyskal, 1980; Causton, 1993). *Dasiops inedulius* is reported in Panama to be a serious pest of purple granadilla, *P. edulis* (Steyskal, 1980). This species has been implicated in 21–65% loss of flowering buds of passion fruit in the Cauca Valley (Colombia) (Peñaranda *et al.*, 1986). *Dasiops passifloris* attacks fruits of *P. suberosa* (syn., *P. pallida*) (Steykal, 1980).

INJURY Fruit fly adult damage is caused by oviposition in green fruits, causing disfigurements of the fruit surface. The larvae damage the fruit by feeding on its pulp, contaminating it with bacteria and fungi (Plate 93), and causing premature fruit drop (Medina *et al.*, 1980; Santos and Costa, 1983; Morgante, 1991). According to Akamine *et al.* (1954), the oriental, melon, and Mediterranean fruit flies puncture the fruit while the rind is still tender. As the fruit enlarges, a woody area (callus) develops around the puncture. If the fruit is small and undeveloped, the damage may be sufficient to cause it to shrivel and fall from the plant. If the fruit is well developed, it may continue to maturity. 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 *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 (May, 1953; Hargreaves, 1979).

According to Murray (1976), passion fruit increase rapidly in size during the first 10–15 days after fruit set. During this period the skin of the fruit is turgid and easily punctured by the ovipositor. Infested immature fruit shows characteristic skin blemishes. The woody tissue, which forms around the eggs, develops a hard raised area around the puncture mark. Egg laying or puncture often cause young

fruit to shrivel and drop. Puncture marks are difficult to detect on ripe fruit. A few days after larval infestation, mature fruit will show wrinkling and breakdown.

Anastrepha 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 of unripe fruits. These glycosides protect the plant by preventing feeding by herbivore species. Thus, the use of these resources by *A. pseudoparallela* for larval breeding is probably associated with its ability to tolerate these chemical defences and suggests a high degree of specialization (Stefani and Morgante, 1996).

The larvae of flies that attack the flowering buds and immature fruits cause premature fruit drop (Brandão *et al.*, 1991). Immature fruits infested by *D. passifloris* become dirty, whitish green in colour, while infested ripe fruits become bluish white (Stegmaier, 1973). *Dasiops inedulius* larvae bore into the anthers, and the ovary, causing flowering bud drop (Peñaranda *et al.*, 1986).

NATURAL ENEMIES Most species of tephritid fruit flies are attacked by a complex of larval parasitoids while egg and pupal parasitoids are much less common (Bateman, 1972). *Doryctobracon* Enderlein, *Diachasmimorpha* Viereck, *Opius* Wesmael, *Psytalia* Walker and *Utetes* Foerster (Braconidae) are the most common larval parasitoids of tephritid fruit flies (Wharton, 1996). *Pachycrepoideus vindemiae* (Rondani) and *Spalangia endius* Walker (Pteromalidae) are pupal parasitoids of Medfly (Back and Pemberton, 1918). In Colombia, *Opius* sp., *Zelus rubidus* (Reduviidae), and spiders of Thomisidae were reported as natural enemies of *D. inedulius* (Peñaranda *et al.*, 1986).

According to Silva *et al.* (1968), larvae of *N. pendula* are parasitized by *Alysia lonchaeae* Lima, *Ganaspis carvalhoi* Dettmer, *Tropideucoila weldi* Lima (Cynipidae), and *Opius* sp. and preyed upon by *Belonuchus rufipennis* (Fabricius) (Staphylinidae).

CONTROL Akamine *et al.* (1954) argued that one of the most important steps in controlling fruit flies is the elimination of over-ripe

papaya, tomato, and other fruits in which the flies breed and on which the adults feed. Santos and Costa (1983) recommended that passion fruit must be planted far away from coffee plantations and wild host plants that grow adjacent to the passion fruit crop should be removed. Fruit flies may be controlled using bait sprays composed of molasses (7%) or protein hydrolysate (1%), and an insecticide. The bait is sprayed over 1 m² of the plant canopy, using 100–200 ml of bait per plant (Santos and Costa, 1983). The bait should be applied during the night (Rossetto *et al.*, 1974). Boaretto *et al.* (1994) reported that bud flies may be controlled by insecticide baits composed of fenthion, molasses and water. The bait is applied at the beginning of the flowering peak, and usually three applications spaced at 8–10 days are necessary. The authors also suggested burying the attacked buds and planting trap crops, such as sweet pepper.

Mites

Several species of mites have been reported from passion fruit (Sanches, 1996). *Brevipalpus phoenicis* (Geijskes) (Tenuipalpidae), the red spider mites *Tetranychus mexicanus* (McGregor) and *T. desertorum* Banks (Tetranychidae) are known to infest passion fruit plants. Warm temperature and low precipitation favour development of these species (Haddad and Millán, 1975; Oliveira, 1987; Brandão *et al.*, 1991). On the other hand, *Polyphagotarsonemus latus* (Banks) (Tarsonemidae) prefers high temperatures and > 80% relative humidity (Oliveira, 1987; Brandão *et al.*, 1991).

DESCRIPTION AND LIFE HISTORY *Brevipalpus phoenicis* mites are quite small, e.g. 0.3 mm in length, and pass through five stages in their life cycle: egg, larva, protonymph, deutonymph, and adult. Adults are bright red, depositing bright red, oval eggs of about 0.1 mm long, on the underside of leaves or in crevices on the stems (Swaine *et al.*, 1985). The length of the cycle from egg to adult varies from as little as 18 days (30°C) to as long as 49 days (20°C) (Oliveira, 1987). In Queensland (Australia), the life cycle takes about 6 weeks. According

to Flechtmann (1989), this mite develops on both upper and lower leaf surface, but prefers the lower leaf surface. Large numbers congregate in leaf axils, along grooves in the terminal shoots and leaf stalks, and along the main veins of leaves (Swaine *et al.*, 1985). Severely infested leaves are completely webbed by spider mites (Oliveira, 1987).

Female spider mites are < 0.5 mm long, and red. Males are slightly smaller than females, and greenish yellow. The life cycle of spider mites comprises five stages: egg, larva, protonymph, deutonymph, and adult. The length of female and male life cycles is about 18 and 20 days, respectively (Oliveira, 1987). The period of incubation is 5–6 days. The larva of *T. mexicanus* is light yellow with three pair of legs, and the larval stage requires 4–7 days. Its protonymph is reddish yellow with four legs and develops in 4–5 days. The deutonymph completes its development in 2–4 days (Dominguez-Gil, 1998).

Polyphagotarsonemus latus females are about 0.2 mm in length. The body varies in colour from white to yellowish. Males are smaller than females, and hyaline (Brandão *et al.*, 1991). The entire cycle from egg to adult takes about 3–5 days. The species develops rapidly through four stages: egg, larva, pupa, and adult. This mite attacks young leaves, and its colonies are localized on the lower leaf surface (Oliveira, 1987).

HOST PLANTS A wide variety of host plants are attacked by the mites. *Brevipalpus phoenicis* feeds on citrus, coffee, cashew, papaya, banana, guava, pomegranate, apple, loquat, peach, pear, grape, grevillea, and various weeds (Oliveira, 1987). *Tetranychus desertorum* occurs on cotton, sweet potato, bean, papaya, passion fruit, strawberry, peach, tomato, grape, and certain ornamentals. *Tetranychus mexicanus* feeds upon cotton, citrus, apple, papaya, passion fruit, pear, peach, cacao, walnut, and ornamentals (Flechtmann, 1989). Hosts of *P. latus* are bean, potato, cotton, coffee, citrus, apple, pumpkin, walnut, grape, peach, pepper, rubber plantation, and various weeds (Oliveira, 1987).

INJURY *Brevipalpus phoenicis* is responsible for general discoloration of the leaves, and

necrosis, culminating in leaf drop. Attacked young stems dry from the extremity to the base and eventually die (Flechtmann, 1989). In Queensland, Australia, *B. phoenicis* infestations are usually most damaging during the summer and autumn. Heavy infestation may result in defoliation (Swaine *et al.*, 1985). In Hawaii, *B. papayensis*, known as red mite, is one of the most troublesome pests of passion fruit, but it is usually most damaging in areas of low rainfall and during prolonged dry weather. Its effects are yellowing, shriveling, and falling of the leaves. With heavy and prolonged infestation, leaf fall increases and the vine has the appearance of dying back. At the same time, developing fruit may begin to shrivel and fall prematurely from the plant. Close examination reveals the presence of mites as scattered reddish patches on the surface of the fruit, particularly around the stem end, along the midrib and veins of the leaf, especially on the under-surface. If red spider mites are left uncontrolled, the plant may eventually die (Akamine *et al.*, 1954).

Red spider mites cause a general weakening of the plants. Initial damage to foliage appears as fine silver speckling on the lower surface of the leaves, which turn brownish on the upper side as mites continue to feed. If a large number of mites are present, entire leaves or plants turn yellow and necrotic (Oliveira, 1987). Photosynthesis and transpiration of the plants are suppressed. Dense populations of spider mites produce silken webs that cover the leaves. Heavy infestations cause leaves to drop and plants to lose vigour (Oliveira, 1987).

P. latus induces malformations in developing leaves, which later dry and drop. It may attack flowering buds, causing a reduction in the number of flowers, and in turn, of fruits produced per plant (Oliveira, 1987; Flechtmann, 1989).

NATURAL ENEMIES Important natural enemies of spider mites are predacious mites belonging to Phytoseiidae. The life history of these predators is closely related to that of their host. Larvae and adults of *Stethorus* sp. (Coccinellidae) were also observed as predators of *T. mexicanus* in passion fruit plantations in Lake Maracaibo (Venezuela) when spider

mites reached high population densities (Dominguez-Gil and McPherson, 1992).

CONTROL Periodic inspections of the orchard and other adjacent hosts, including weeds, are essential to verify the occurrence and first symptoms of mite attacks (Oliveira, 1987; Brandão *et al.*, 1991). Mites have also become resistant to many of the organophosphate miticides. Selective miticides, dosages, timing, and refining application techniques may be useful in an integrated mite management system. The four principal requirements for a practical operation are: (i) presence of predacious mites in the orchard; (ii) knowledge of the appearance and habits of plant-feeding and predacious mites; (iii) careful examination of relative numbers of predators and plant-feeding mites, particularly during a period when rapid population changes are occurring; and (iv) knowledge of pesticides to use, how to use them, and what pesticides to avoid, in order to conserve predators.

Flechtmann (1989) recommended the use of sulphur that is not toxic to pollinating insects. According to Piza Júnior (1992), fenthion, propargite, chlorfentezine, and avermectin are effective miticides.

Secondary Pests

Secondary pests include various species of insects that may become abundant, and occasionally damage the passion fruit crop. The insects in this group are either associated frequently with a particular environmental condition, or else occur within limited geographical areas.

Aphids

Aphids (Aphidae) are known to attack passion fruit vines, although they seldom cause serious damage. Nevertheless, at least three species of aphids, *Myzus persicae* (Sulzer), *Aphis gossypii* (Glover), and *Macrosiphum solanifolii* Ashmead (= *M. euphorbiae* (Thomas)), must be regarded as potentially important pests of passion fruit.

DESCRIPTION AND LIFE HISTORY The characteristic of *Myzus* is the presence on the head of tubercles at the base of the inner side of antennae. Because of this, the frons shows an outline that is scooped out in the middle. The apterous form of *M. persicae* is 1.2–2.3 mm long, and frequently pale green in colour, but populations also occur that are yellowish or tending to reddish. The cornicles are long and cylindrical, sometimes with a slight swelling of the distal part, which is often blackish. The cauda is subtriangular, shorter than the cornicles. The length of the antennae is a little less than that of the body. The alate form is about 1.2–2.2 mm in length and green in colour; head, antennae and thorax are brown or blackish (Barbagallo *et al.*, 1997).

The apterous form of the cotton aphid, *A. gossypii*, has an ovoid body shape, and is medium to small in size (1.0–1.8 mm in length). Colour is variable, from ochreous brown to mottled, more or less dark green or even bluish tinged. Antennae are brown with the middle part cream coloured; cornicles and cauda are blackish brown. The alate form has head and thorax blackish, as are the antennae, cornicles and cauda; the abdomen has the same variation in colour as does the apterous form. Length of body is 1.2–2.0 mm. The cotton aphid has a nearly cosmopolitan world distribution. This species is of greater seriousness in warm-temperate regions and in the intertropical zone. It is typically anholocyclic, remaining active during the whole year with uninterrupted generations of parthenogenetic females. However, there are recorded cases of the appearance of sexual forms, with the subsequent deposition of resistant eggs on various plants (Barbagallo *et al.*, 1997).

M. solanifolii is about 2.6–4.0 mm in length, green, with wax secretions on the body of immature forms (Barbagallo *et al.*, 1997).

HOST PLANTS Peach is the preferred primary host of *M. persicae*. It may infest other *Prunus* species, in particular almond and plum. Its secondary host plants include numerous wild and cultivated plants, such as passion fruit (Barbagallo *et al.*, 1997). *Aphis gossypii* infests numerous species of dicotyledonous plants, including passion fruit. Favoured hosts are in the *Malvaceae* (cotton, hibiscus, etc.) and

Cucurbitaceae (pumpkin, cucumber, watermelon, melon) (Barbagallo *et al.*, 1997). *M. solanifolii* is a very polyphagous species, showing preference for the *Solanaceae*, i.e. potato, tomato, etc. (Barbagallo *et al.*, 1997).

INJURY Although these aphids cause malformation in foliage, they are more important as disease vectors. *Myzus persicae* and *A. gossypii* transmit a virus disease that causes a disease associated with hardening of fruits (Brandão *et al.*, 1991; Piza Júnior and Resende, 1993). *Myzus persicae* and *M. solanifolii* are vectors of the passion fruit woodiness virus in Australia. In Hawaii, however, where these two species are present, this virus does not occur (Akamine *et al.*, 1954).

NATURAL ENEMIES Naturally occurring predators and parasites are effective against aphids. The Coccinellidae are effective against cotton aphids, and in particular the larval stage of *Scymnus*. Other predators include the Chrysopidae (*Chrysoperla*), Cecidomyiidae (*Aphidoletes*) and Syrphidae (*Syrphus*). Parasitism by *Lysiphlebus* sp. (Aphidiidae) has been reported (Barbagallo *et al.*, 1997). According to Grasswitz and Paine (1993), *Lysiphlebus testaceipes* (Cresson) parasitizes *Myzus*, *Aphis*, and *Macrosiphum*. Silva *et al.* (1968) reported parasitism of *M. solanifolii* by *Aphidius platensis* Brèthes, *A. brasiliensis* Brèthes, *Diaeretiella rapae* (McIntosh) (Aphidiidae), and predation by *Bacha clavata* (F.) (Syrphidae), *Coccinella ancoralis* Germar, *Cycloneda sanguinea* (L.), and *Eriopis connexa* (Germar) (Coccinellidae). They also reported parasitism of *M. persicae* by *Aphelinus mali* (Hald.) (Aphelinidae), *A. platensis*, and *D. rapae* in Argentina and Uruguay. Cabbage aphid is the primary host of *D. rapae* which is commercially available for release against a wide range of aphids, especially *Myzus* and *Brachycaudus* spp. (Hsieh and Allen, 1986).

Caterpillars

Caterpillars of *Azamora penicillana* (Walker) (Pylalidae) are defoliators of passion fruit (Santos and Costa, 1983; Fancelli, 1992b;

Fancelli, 1993). *Peridroma saucia* (Hübner) (Noctuidae) attacks the floral structure, and may reduce fruit production (Chacón and Rojas, 1981). *Pyrausta nereidiformis* (Hampson) (Pylalidae) is also associated with passion fruit flowers. In Colombia, this species is one of the most important pests of curuba, and may infest 70% of the crop. Caterpillars of *Aepytus (Pseudodalaca) sarta* (Schaus) (Hepialidae) and *Odonna passiflorae* Clarke (Oecophoridae) are passion fruit stem borers (Chacón and Rojas, 1984).

DESCRIPTION AND LIFE HISTORY Caterpillars of *A. penicillana* lodge in flowering buds or in a nest made from leaves, which are joined by silk webs produced by the insect. The caterpillar is whitish, and when fully grown, 25 mm long. The adult is a small pale greyish moth (Santos and Costa, 1983; Fancelli, 1992b; Fancelli, 1993). *P. saucia* is a moth with a 39 mm wingspan. Forewings are crimson red, hindwings are whitish. Females lay their eggs on the underside of leaves, usually in clusters of 60–244. Eggs are about 0.7 mm in diameter. Eggs are creamy white when first laid, but turn reddish blue when close to hatching, after 8–10 days, depending on temperature. The newly hatched larva, approximately 0.97 mm long, is reddish brown; full-grown larvae are about 40 mm, and brownish grey. The larva has six instars and becomes fully grown in 31–38 days. The pupa is about 18.1 mm in length and dark brown. The pupal stage lasts from 18 to 22 days (Chacón and Rojas, 1981).

Moths of *A. sarta* are pale brown and have a wingspan of about 45 mm. Eggs, each about 0.65 mm in diameter, are light yellow and laid on the bark of stems near the ground. The larva is cream in colour with a dark brown head. The full-grown larva is about 38 mm. Pupae are light brown and about 39 mm long, and 34 mm in length for females and males, respectively (Chacón and Rojas, 1984).

The adult moth of *O. passiflorae* has a wingspan of 24–30 mm. The head and thorax are greyish, and the dorsal of the abdomen is olive-green anteriorly, and greyish posteriorly. The full-grown larva is 18–21 mm long with a light brown head and cream coloured body, with several setae. The pupa is dark yellow and about 9.5–13.0 mm long. The pupal

stage occurs inside galleries constructed by the larvae (Chacón and Rojas, 1984).

The adult *P. perelegans* is a pale coloured microlepidopteran with a wingspan of about 35 mm. The wings are yellow semi-hyaline. The borders of the forewings are dark rose. The young larva is about 1.95 mm long and green. The full-grown larva is about 23.8 mm long, and the pupa is dark brown and about 13.24 mm long (Chacón and Rojas, 1984).

HOST PLANTS *A. penicillana* was reported damaging a wild species of passion fruit (*Passiflora cincinnata*) in Brazil (Fancelli, 1993). *P. saucia* damages and causes reduction in fruit production of curuba (*Passiflora mollissima*). It is a polyphagous insect, feeding on potato (*Solanum tuberosum*), oak (*Quercus suber*), *Calendula officinalis*, cotton, tobacco, bean, tomato, lucerne, soybean, and beet (Chacón and Rojas, 1981).

INJURY Although the caterpillars of *A. penicillana* cause defoliation, the most serious damage is caused by the phytotoxic effects of the fluid secreted by the caterpillar on the leaves and young stems. Heavy infestations cause leaves to dry and drop, and passion fruit plants lose vigour and bear fewer flowers. In Bahia, Brazil, the population peak of this pest occurs during the rainy season (April to June) (Santos and Costa, 1983; Fancelli, 1992b, 1996).

P. saucia larvae feed upon floral structures of *P. mollissima*. Young larvae migrate from leaves to the flowers where they feed on the floral tube, nectary and gynophore, causing flower dropping. The sixth instar larvae may occasionally continue feeding on the young fruit, or drop onto the soil to pupate. In Colombia, *P. saucia* infested 64% of the flowers during the summer (July to September) (Chacón and Rojas, 1981).

Larvae of *A. sertá* bore into roots located near the surface, and occasionally bore into stems. Stem injury is characterized by the presence of sawdust. A single larva is regularly found in 1-year-old plants, while in 6–8-year-old plants, up to five larvae may develop (Chacón and Rojas, 1984).

The damage of *O. passiflorae* caterpillars is characterized by the presence of sawdust

outside the principal and lateral stems. Several larvae in different stages of development attack simultaneously at the same point of the stem, and cause cellular hypertrophy. They form galleries in different directions, resulting in total destruction of the stem.

The caterpillars of *P. perelegans* infest 6-month-old plants, and remain during the whole vegetative period. They attack the buds and developing flowers, feeding on nectaries, gynophores, and young fruits (Chacón and Rojas, 1984).

NATURAL ENEMIES Naturally occurring predators and parasites are particularly effective against *P. saucia* in Colombia. A tachinid fly, *Incamiya* sp., is an important factor for reducing the population of *P. saucia* caterpillars. Another dipterous parasitoid is *Megaselia scalaris* (Phoridae). Adults of the predator *Anisotarus* sp. (Carabidae) feed on caterpillars and prepupae. Some caterpillars may also be infected by bacteria (*Bacillus cereus*, *Pseudomonas aeruginosa* and *Streptococcus* spp.) and nematodes (Pseudodiplogasteridae). The larval stage of *O. passiflorae* is infected with the fungus *Beauveria bassiana* and is parasitized by the hymenopteran *Neotheronia* sp. (Ichneumonidae). *Sathon* sp. (Braconidae) and *Enytus* sp. (Ichneumonidae) parasitize larvae of *P. perelegans*. The former has gregarious behaviour, and on average 11 adult wasps may emerge from one larva (Chacón and Rojas, 1984).

CONTROL According to Chacón and Rojas (1984), the infestation of *A. sertá* depends on the wood used to made the trellises. The authors suggest the use of resistant wood such as mangrove (*Rhizophora mangle*). Wood of Barbados cherry (*Malpighia glabra*) and *Cassia tomentosa* are susceptible to attack by *A. sertá*, and are not recommend for trellises.

Mealybugs

Citrus mealybug, *Planococcus citri* Risso, and the passion vine mealybug, *Planococcus pacificus* Cox (Pseudococcidae), are pests of lesser importance on passion fruit.

DESCRIPTION AND LIFE HISTORY Citrus mealybug, *P. citri*, is a small, oval-shaped sucking insect commonly found on passion fruit in Hawaii, USA. A white, mealy powder covers the upper surface of the insect body. Wax strands radiate from the body with slightly longer strands posteriorly. Females are wingless and vary in length from 3 to 4 mm. The males are fragile, with two wings, and 2 mm in length with two long white filaments extending from the end of the abdomen. The female is active and feeds throughout its life. The male feeds only during the first stage (Murray, 1976). After mating, the female deposits up to 500 yellowish eggs in a loose cottony mass or ovisac and then dies. Crawlers emerge from the eggs in 3–9 days and moult several times until the adult stage is reached. There are three moults in the female and four in the male. Approximately 4 weeks are required for completion of the cycle during warm weather (Murray, 1976).

The females of passion vine mealybug, *P. pacificus*, are white, oval and about 3–4 mm long. Eggs are laid in a loose, cottony mass and hatch to produce crawlers 3–9 days later. Development from egg to adult takes about 4 weeks during summer. In Queensland (Australia), these species are most common in late summer and autumn (Swaine *et al.*, 1985).

HOST PLANTS Citrus mealybug infests citrus and many greenhouse and indoor plants. Other plants recorded as its hosts include avocado, pineapple, pumpkin, cotton, rice, sweet potato, potato, cacao, coffee, sugarcane, chayote, tobacco, guava, mango, rose, pomegranate, etc. (Silva *et al.*, 1968).

INJURY Mealybugs characteristically aggregate on the plant, especially at leaf nodes and under dead leaves and trash. Aggregation may also occur under dried flower bracts. Secretion of a sugary solution from the mealybugs promotes growth of a black fungal mould on the fruits and leaves. Ants are often found tending mealybugs for this secretion and interfere with the natural control of the mealybugs by parasites and predators. If a severe infestation occurs, loss of vigour, leaf drop, and fruit malformation may occur. Unchecked, an infestation may cause

death of the plant (Murray, 1976; Swaine *et al.*, 1985).

NATURAL ENEMIES Lady beetles (Coccinellidae), especially mealybug lady beetle, *Cryptolaemus montrouzieri* Mulsant, and maculate lady beetle, *Harmonia octomaculata* (Fabricius), substantially reduce mealybug numbers. Of secondary importance are small wasp parasitoids such as *Leptomastidea abnormis* (Girault) (Encyrtidae) and *Ophelosia* sp., and lacewing larvae (*Oligochrysa lutea* (Walker)) (Murray, 1978; Swaine *et al.*, 1985).

Silva *et al.* (1968) reported several species of parasitoids and predators of *P. citri* in Argentina. It is parasitized by *Apanteles paraguayensis* Brèthes (Braconidae), *Coccophagus caridei* (Brèthes) (Aphelinidae), *Anagyrus coccidivorus* Dozier, *A. pseudococci* (Girault), *Leptomastidea abnormis* (Girault), *Leptomatrix dactylopii* Howard (Encyrtidae), and *Pachyneuron* sp. (Pteromalidae). *Leptomastix dactylopii* is commercially available. It is a yellowish brown wasp that lays its eggs in late instar nymphs and adult mealybugs. *Leptomastix* prefers hosts in warm, sunny, humid environments. It may complete one generation in 2 weeks at 30°C or in 1 month at 21°C (Fisher, 1963).

CONTROL Clusters of mealybugs under dead leaves are well protected from the insecticide sprays, and little control can be achieved unless vines are cleaned thoroughly to allow spray penetration. Pruning may enhance the effectiveness of the spray; however, this is often impractical, as laterals to be pruned are generally bearing fruits (Murray, 1976).

According to Murray (1976), occasional outbreaks of this pest are best controlled by two sprays of 1 : 60 oil or methidathion 0.05% combined with 1 : 100 oil, 2 weeks to 1 month apart. The 1 : 60 oil is preferred, as methidathion is highly toxic to the mealybug's natural enemies. For good control, thorough coverage is essential.

Scales

Soft brown scale (*Coccus hesperidum* Linnaeus) (Coccidae) may occasionally infest

leaves and stems of passion fruit. California red scale, *Aonidiella aurantii* (Maskell) (Diaspididae), is most common on older passion fruit vines (Swaine *et al.*, 1985).

DESCRIPTION AND LIFE HISTORY Adults of soft brown scale are approximately 3 mm long, and covered by a brown, oval, dome shaped scale. A sweet, sticky secretion produced by this insect promotes growth of sooty mould on the fruit and leaves. Ants also tend the scale for this secretion (Murray, 1976).

California red scale is a small, flattened, reddish orange scale. The dull-red female produces living young or crawlers that shelter under the parent scale for some time. After leaving the protection of the parent scale, the crawlers quickly settle on the vine or fruit and then moult – twice if a female, three times if a male – before reaching the adult stage. The life cycle from egg to adult takes about 6 weeks in summer (Swaine *et al.*, 1985).

HOST PLANTS California red scale infests citrus and many ornamental plants (Forster *et al.*, 1995). Silva *et al.* (1968) cited several other host plants of this species such as pumpkin, coconut, papaya, rose, mulberry, etc.

Soft brown scale uses various plants as host, such as avocado, sapodilla, plum, mulberry, coconut, gladiolus, papaya, laurel, salvia, maté, pear, rose, grape, etc. (Silva *et al.*, 1968).

INJURY Soft scales and diaspidids injure plants by sucking sap, and when numerous can kill the plant. They sometimes heavily encrust the leaves, fruits, twigs or branches. Mealybugs may be found on almost any part of the host plant from which they suck the sap (Murray, 1976; Swaine *et al.*, 1985).

NATURAL ENEMIES Parasitic wasps are important to control *A. aurantii*, mainly *Comperiella bifasciata* (Howard), and *Aphytis chrysomphali* (Mercet) (Aphelinidae) (Murray, 1976; Swaine *et al.*, 1985). In Argentina, this species was reported to be parasitized by the aphelinids, *A. chrysomphali*, *A. maculicornis* Masi, and *Aspidiotiphagus citrinus* (Crawford) (Silva *et al.*, 1968).

Azya luteipes Mulsant, *Coccidophilus citricola* Brèthes, and *Pentilia egena* Mulsant have been recorded as predators of California red scale. Two species recorded as pathogenic fungi of this scale are *Nectria coccophila* and *Myriangium duriaei* (Silva *et al.*, 1968).

According to Forster *et al.* (1995), *Aphytis melinus* is the most important parasitoid attacking California red scale. The adult is a tiny yellow wasp. The female *A. melinus* feeds on and oviposits in immature scales, preferring the virgin adult female scale. The solitary, ectoparasitic larva leaves a flat and dehydrated scale body beneath the scale cover, where the parasitoid's cast skin and faecal pellets (meconia) may be observed. The parasitoid's short life cycle (10–20 days) results in two or three parasitoid generations for each scale generation. *Comperiella bifasciata* is an important encyrtid that parasitizes California red scale. Adult parasitoids are black, with two white stripes on the female's head. One parasitoid generation requires about 3–6 weeks to develop, with faster development occurring on larger (later instar) hosts and at warmer temperatures.

Parasitoids of *C. hesperidum* in Argentina are *Aneristus coccidis* Blanchard, *Coccophagus caridei* (Brèthes), *Ablerus ciliatus* De Santis (secondary parasitoid) (Aphenilidae), *Aphycus flavus* Howard, *A. luteolus* (Timberlake), and *Cheiloneurus longisetaceus* De Santis (Encyrtidae). Among the predators is *Azya luteipes* Mulsant (Coccinellidae) (Silva *et al.*, 1968).

CONTROL Chemical control is often not required since parasitization by small wasps substantially reduces populations. Should chemical control be necessary, a 1:60 oil spray is satisfactory (Murray, 1976).

Termites

Termites are increasingly common in passion fruit plantations, but losses attributable to them have not been quantified. Three termite species, *Heterotermes convexinotatus* (Snyder), *Amitermes foreli* Wasmann, and *Microcerotermes arboreus* Emerson, were observed to feed on roots and stems of 2–4-year-old passion

fruit plants in Venezuela (Dominguez-Gil and McPheron, 1992).

DESCRIPTION AND LIFE HISTORY *Heterotermes* (Rhinotermitidae) is a widespread genus. It is characterized by the soldier which has a long and rectangular head. It does not have teeth on the interior curvature of the mandibles. The pronotum is wide and flat (Hadlington, 1987). It has subterranean habits, and does not construct an exposed nest. The colony always remains in contact with the soil through the galleries (Dominguez-Gil, 1998).

Amitermes (Termitidae) is cosmopolitan in distribution and especially conspicuous in the tropics and in the warmer areas of the temperate zones (Krishna and Weesner, 1970). The members of this genus are essentially subterranean in habit. The nest is usually situated in the soil (Krishna and Weesner, 1970). Its soldiers have the mandibles curved, thin, not too long, and with a prominent tooth and not clearly rectangular (Hadlington, 1987).

Subterranean soldiers of *Microcerotermes* (Termitidae) have long, rectangular mandibles, which are serrated on the interior face (Hadlington, 1987). A queen of *M. arboreus*, measuring 21 mm in length, may deposit 1680 eggs in 24 hours (Krishna and Weesner, 1970).

INJURY Termites penetrate and excavate the roots and continue upwards within the stems. The plant often dies, and death may be associated with the presence of soil pathogens, which usually cause rotting, including *Fusarium* spp. and *Phytophthora* spp. (Dominguez-Gil and McPheron, 1992; Piza Júnior, 1992).

CONTROL The use of tillage operations to reduce populations of soil-inhabiting insects may work in several ways. In the case of termites, it may change the physical condition of soil and expose the colony to the sun. Piza Júnior (1992) recommended that after tillage, the soil should be treated with Thiodan 350 CE (endosulfan) at 100–500 cm³ per 100 l of water. The soil must be treated when it is wet to allow the penetration of the insecticidal solution. When the crop is already established, the insecticidal solution must be applied to the soil around the plants in large quantities to reach a depth of 35 cm.

Bees

In some passion fruit growing areas, the honeybee *Apis mellifera* L. (Apidae) is considered a pest since it robs the pollen from the carpenter bees, thereby causing a reduction of fruit set (Akamine *et al.*, 1954). Adults of *Trigona spinipes* Fabricius (Apidae), known as irapuá or arapuá in Brazil, attack leaves, stems, trunk, developing buds, developing fruits, and fruit peduncles of several plant species (Puzzi, 1966; Bastos, 1985; Teixeira *et al.*, 1996). It may be found from northern to southern Brazil (Silva *et al.*, 1968; Bleicher and Melo, 1993). Carvalho *et al.* (1994) reported serious damage caused by *T. amazonensis* to yellow passion fruit in Acre (Brazil).

DESCRIPTION AND LIFE HISTORY *Trigona spinipes* is about 5–6.5 mm in length, black with transparent wings and without an ovipositor (Santos and Costa, 1983). It constructs its nests on trees, usually between their branches, or in abandoned termite nests. It uses fibrous filaments of plant material and agglutinative elements, mainly resin. Like honeybees, they exist in large colonies with a queen, without corbiculae, and with thousands of workers (Riek, 1979).

INJURY *Trigona spinipes* causes malformation of foliage and dropping of flowers, resulting in a reduction in the number of fruits produced per plant. It also attacks developing flowering buds (Fancelli and Mesquita, 1998).

HOST PLANTS *Trigona spinipes* damages various plant species, especially flowering buds and leaves, of sapodilla, mulberry, banana, citrus, coconut, mango, rose, pine, and fig (Silva *et al.*, 1968).

NATURAL ENEMIES Silva *et al.* (1968) reported the parasitism of larvae of *T. spinipes* by *Pseudohypocera nigrofascipes* Borgn. & Schn. (Phoridae).

CONTROL Recommendations to prevent honeybees from robbing passion fruit flowers of their pollen have been made. One of them is to plant more attractive plant species such as eucalyptus and basil in adjacent areas to

Table 12.2. Phytophagous arthropods associated with passion fruit (*Passiflora* spp.) around the world.

Class/Order	Family	Scientific name	Feeding habits	Damaging stage	References
ARACHNIDA					
Acari	Tarsonemidae	<i>Tarsonemus stammeri</i> Schaarschmidt	Fruit sucker	Larva, nymph and adult	Dominguez-Gil and McPheron, 1992; Teixeira, 1994
		<i>Polyphagotarsonemus latus</i> (Banks)	Leaf sucker	Larva, nymph and adult	
	Tetranychidae	<i>Tetranychus mexicanus</i> (McGregor)	Leaf sucker	Larva, nymph and adult	Brandão <i>et al.</i> , 1991;
		<i>Tetranychus desertorum</i> (Banks)	Leaf sucker	Larva, nymph and adult	Dominguez-Gil and McPheron, 1992; Teixeira, 1994
		<i>Tetranychus urticae</i> (Koch)	Leaf sucker	Larva, nymph and adult	
	Tenuipalpidae	<i>Brevipalpus phoenicis</i> (Geijsks)	Leaf sucker	Larva, nymph and adult	Teixeira, 1994
INSECTA					
Thysanoptera	Thripidae	<i>Frankliniella auripes</i> Hood	Feed on pollen	Adult	Chacón and Rojas, 1984
Coleoptera	Chrysomelidae	<i>Trichaltica bogotana</i> Harold	Leaf chewer	Adult	Lordello, 1952b; Silva <i>et al.</i> , 1968; Corrêa <i>et al.</i> , 1977; Chacón and Rojas, 1984; Dominguez-Gil and McPheron, 1992; Teixeira, 1994
		<i>Euryscopa cingulata</i> Latreille	Leaf chewer	Adult	
		<i>Cacoscelis marginata</i> (F.)	Leaf chewer	Adult	
		<i>Cacoscelis famelica</i> (F.)	Leaf chewer	Adult	
		<i>Cacoscelis melanoptera</i> (Germar)	Leaf chewer	Adult	
		<i>Cacoscelis orphelia</i> Bechyné	Leaf chewer	Adult	
		<i>Cacoscelis walteriana</i> Bechyné	Leaf chewer	Adult	
		<i>Diabrotica</i> poss. <i>undecimpunctata</i> M.	Leaf and flower chewer	Adult	
		<i>Maecolaspis</i> sp.	Leaf chewer	Adult	
		<i>Monomarca</i> sp.	Flower-bud chewer	Adult	
		<i>Acalymma</i> sp.	Seedling chewer	Adult	
	Curculionidae	<i>Litostylus diadema</i> (F.)	Leaf chewer	Adult	Dominguez-Gil and McPheron, 1992; Racca Filho <i>et al.</i> , 1993; Piza Júnior and Kavati, 1995
		<i>Philonis passiflorae</i> O'Brien	Stem borer	Larva	
		<i>Philonis obesus</i> Champion	Stem borer	Larva	
		<i>Philonis crucifer</i>	Stem borer	Larva	
	Scolytidae	<i>Chramesus bispinus</i> Wood	Stem borer	Larva and adult	Chacón and Rojas, 1984
	Cerambycidae	<i>Stenygra conspicua</i> (F.)	Stem borer	Larva	Chacón and Rojas, 1984; Teixeira, 1994
		<i>Lepturges</i> sp.	Stem borer	Larva	
		<i>Stizocera</i> sp.	Stem borer	Larva	
			Stem borer	Larva	
	Meloidae	<i>Epicauta atomaria</i> Germ.	Leaf chewer	Adult	Teixeira, 1994
	Scarabaeidae	<i>Cyclocephala melanocephala</i> (F.)	Flower and leaf chewer	Adult	Rossetto <i>et al.</i> , 1974; Chacón and Rojas, 1984; De Bortoli and Busoli, 1987
		<i>Leucothyreus</i> sp.	Flower and leaf chewer	Adult	
	Anthribidae	<i>Araecerus fasciculatus</i> Degeer	Calyx and fruit chewer	Larva and adult	Chacón and Rojas, 1984

Hymenoptera	Apidae	<i>Trigona amalthaea</i> (Olivier)	Flower chewer	Adult	Carvalho <i>et al.</i> , 1994; Sazima and Sazima, 1989; Dominguez-Gil, 1998
		<i>Trigona spinipes</i> F.	Flower chewer	Adult	
		<i>Trigona amazonensis</i>	Flower chewer	Adult	
	Formicidae	<i>Crematogaster</i> sp.	Feed on stem	Adult	
		<i>Solenopsis</i> sp.	Feed on stem	Adult	
Isoptera	Rhinotermitidae	<i>Heterotermes conexinotatus</i> (Snyder)	Feed on root and stem	Adult (workers)	Dominguez-Gil, 1998
	Termitidae	<i>Microcerotermes arboreus</i> Emerson	Feed on root and stem	Adult (workers)	Dominguez-Gil and McPheron, 1992
		<i>Amitermes foreli</i> Wasmann	Feed on root and stem	Adult (workers)	
Lepidoptera	Nymphalidae	<i>Eueides isabella huebneri</i> Ménétries	Leaf chewer	Larva	Santo, 1931; Lordello, 1952a, 1954; Silva <i>et al.</i> , 1968; Brown Júnior and Mielke, 1972; Chacón and Rojas, 1984; De Bortoli and Busoli, 1987; Carter, 1992; Dominguez-Gil and McPheron, 1992
		<i>Eueides isabella dianosa</i> (Hübner)	Leaf chewer	Larva	
		<i>Eueides aliphera aliphera</i> (Godart)	Leaf chewer	Larva	
		<i>Dione juno juno</i> (L.)	Leaf chewer	Larva	
		<i>Dione glycera</i> (C. & R. Felder)	Leaf chewer	Larva	
		<i>Agraulis vanillae vanillae</i> (L.)	Leaf chewer	Larva	
		<i>Agraulis vanillae maculosa</i> S.	Leaf chewer	Larva	
		<i>Dryadula phaetusa</i> (L.)	Leaf chewer	Larva	
		<i>Philaethria dido</i> (L.)	Leaf chewer	Larva	
		<i>Philaethria wernickei wernickei</i> (R)	Leaf chewer	Larva	
		<i>Heliconius silvana robigus</i> (Weymer)	Leaf chewer	Larva	
		<i>Heliconius sara apseudes</i> (Hübner)	Leaf chewer	Larva	
		<i>Heliconius ethilla narcaea</i> (Godart)	Leaf chewer	Larva	
		<i>Heliconius erato phyllis</i> (F.)	Leaf chewer	Larva	Chacón and Rojas, 1984
	Geometridae	<i>Sabulodes</i> sp. poss. <i>matrica</i> Druce	Leaf chewer	Larva	
	Hepialidae	<i>Aepytus</i> (P.) <i>serta</i> (Schaus)	Stem borer	Larva	Silva <i>et al.</i> , 1968; Chacón and Rojas, 1984
	Noctuidae	<i>Peridroma saucia</i> (Hübner)	Flower chewer	Larva	
		<i>Copitarsia consueta</i> (Walker)	Flower chewer	Larva	Chacón and Rojas, 1984
		<i>Spodoptera ornithogalli</i> (Guenée)	Flower chewer	Larva	
		<i>Odonna passiflorae</i> Clarke	Stem borer	Larva	
		<i>Pyrausta perelegans</i> (Hampson)	Bud, flower, fruit borer	Larva	Chacón and Rojas, 1984; Fancelli, 1992b
	Pyrilidae	<i>Azamora penicillana</i> (Walker)	Leaf chewer	Larva	
		<i>Pococera</i> sp.	Calyx and fruit chewer	Larva	
	Cossidae	<i>Langsdorfia</i> sp.	Stem borer	Larva	Chacón and Rojas, 1984
Homoptera	Coccidae	<i>Coccus hesperidum</i> L.	Stem sucker	Nymph and adult	Murray, 1976; Chacón and Rojas, 1984
		<i>Ceroplastes</i> sp.	Stem sucker	Nymph and adult	
	Aleyrodidae	<i>Hexaleurodicus</i> sp.	Leaf, stem sucker	Nymph and adult	Chacón and Rojas, 1984

continued

Table 12.2. *Continued.*

Class/Order	Family	Scientific name	Feeding habits	Damaging stage	References
	Diaspididae	<i>Selenaspidus articulatus</i> (Morgan)	Leaf, fruit, stem suckers	Nymph and adult	Murray, 1976; Swaine <i>et al.</i> , 1985; ICA, 1987
		<i>Aonidiella auranti</i> (Maskell)		Nymph and adult	
	Aphididae	<i>Myzus persicae</i> (Sulzer)	Leaf sucker	Nymph and adult	Akamine <i>et al.</i> , 1954; Brandão <i>et al.</i> , 1991; Piza Júnior and Resende, 1993
		<i>Aphis gossypii</i> (Glover)	Leaf sucker	Nymph and adult	
		<i>Macrosiphum solanifolii</i> Ashmead	Leaf sucker	Nymph and adult	
	Pseudococcidae	<i>Planococcus citri</i> Risso	Leaf sucker	Nymph and adult	Murray, 1976; Swaine <i>et al.</i> , 1985
		<i>Planococcus pacificus</i> Cox	Leaf sucker	Nymph and adult	
Hemiptera	Coreidae	<i>Holhymenia histro</i> (F.)	Leaf, fruit sucker	Nymph and adult	Mariconi, 1952; Chiavegato, 1963; Silva <i>et al.</i> , 1968;
		<i>Holhymenia clavigera</i> (Herbest.)	Leaf, fruit sucker	Nymph and adult	
		<i>Veneza zonatus</i> (Dallas)	Leaf, fruit sucker	Nymph and adult	Murray, 1976; Dominguez-Gil, 1998; Chacón and Rojas, 1984; De Bortoli and Busoli, 1987; ICA, 1987; Dominguez-Gil and McPheron, 1992
		<i>Leptoglossus gonagra</i> (F.)	Leaf, fruit sucker	Nymph and adult	
		<i>Leptoglossus conspersus</i> (Stal)	Leaf, fruit sucker	Nymph and adult	
		<i>Anisoscelis foliacea</i> (F.) <i>marginella</i>	Leaf, fruit sucker	Nymph and adult	
		<i>Anisoscelis flavolineata</i> (F.)	Leaf, fruit sucker	Nymph and adult	
		<i>Diactor bilineatus</i> (F.)	Leaf, fruit sucker	Nymph and adult	
Diptera	Tephritidae	<i>Anastrepha pallidipennis</i> Guerne	Feed on fruit	Larva	Akamine <i>et al.</i> , 1954; Lordello, 1954; Murray, 1976; Santos and Costa, 1983; Chacón and Rojas, 1984; Zucchi, 1988; Teixeira, 1994
		<i>Anastrepha consobrina</i> (Loew)	Feed on fruit	Larva	
		<i>Anastrepha ethalea</i> (Walker)	Feed on fruit	Larva	
		<i>Anastrepha grandis</i> (Macquart)	Feed on fruit	Larva	
		<i>Anastrepha kuhlmanni</i> Lima	Feed on fruit	Larva	
		<i>Anastrepha lutzi</i> Lima	Feed on fruit	Larva	
		<i>Anastrepha pseudoparallela</i> (Loew)	Feed on fruit	Larva	
		<i>Ceratitis capita</i> (Wiedemann)	Feed on fruit	Larva	
		<i>Dacus curcubitae</i> Coquillett	Feed on fruit	Larva	
		<i>Bactrocera dorsalis</i> (Hendel)	Feed on fruit	Larva	
		<i>Dacus tryoni</i> (Froggatt)	Feed on fruit	Larva	
	Drosophilidae	<i>Zapriothrica salebrosa</i> Wheeler	Flower-bud chewer	Larva	Chacón and Rojas, 1984
	Lonchaeidae	<i>Lonchaea cristula</i> McAlpine	Feed on flower bud	Larva	Rossetto <i>et al.</i> , 1974;
		<i>Silba pendula</i> Bezzi	Feed on flower bud	Larva	Steyskal, 1980; Chacón and Rojas, 1984
		<i>Dasiops curubae</i> Steykal	Feed on flower bud	Larva	
		<i>Dasiops inedulis</i> Steykal	Feed on flower bud	Larva	
		<i>Dasiops passifloris</i> McAlpine	Feed on fruit	Larva	

passion fruit. Collection of wild swarms is also recommended (Boaretto *et al.*, 1994). The control strategies recommended for *T. spinipes* include the destruction of nests near the crop, and weekly inspections to verify the occurrence of this pest on flowers. In exceptional cases, chemical control is recommended.

Conclusions

Several different species of arthropods have been reported in passion fruit. Other pests doubtless occur, and new ones will appear in the future. Fortunately the majority of these species are not injurious. The species listed in Table 12.2 are generally accepted as being responsible for most of the insect and mite damage wherever passion fruit grows.

For control of insect and mite pests which attack passion fruit, we must consider two basic problems: (i) creation and preservation of conditions favourable to carpenter bees, whose function in pollination is of vital importance for fruit set; (ii) suitable control of insects and mites that damage the plant. Additionally, a latent problem is the conservation of natural enemies, which is complicated because beneficial and noxious insects and mites are closely associated with the plant. The timing of spraying is critical, so that applications are not made when passion fruit flowers are open and the carpenter bees are active. The choice of a selective pesticide, with low toxicity to predators and parasites, is important to maintain not only natural control but also pollinators.

References

- Akamine, E.K. and Girolami, D.G. (1957) Problems in fruit set in yellow passion fruit. *Hawaii Farm Science* 5, 3–5.
- Akamine, E.K. and Girolami, D.G. (1959) *Pollination and Fruit Set in Yellow Passion Fruit*. Hawaii Agricultural Experiment Station, Honolulu, Technical Bulletin 39, 32 pp.
- Akamine, E.K., Hamilton, R.A., Nishida, T., Sherman, G.D. and Storey, W.B. (1954) *Passion Fruit Culture*. University of Hawaii, Extension Circular 345, 23 pp.
- Back, E.A. and Pemberton, C.E. (1918) The Mediterranean fruit fly in Hawaii. *United States Department of Agricultural Bulletin* 536, 1–118.
- Barbagallo, S., Cravedi, P., Pasqualini, E. and Patti, I. (1997) *Aphids of the Principal Fruit-Bearing Crops*. Bayer, Milan, 123 pp.
- Bastos, J.A.M. (1985) *Principais Pragas das Culturas e Seus Controles*, 3rd edn. Nobel, São Paulo, 329 pp.
- Bateman, M.A. (1972) The ecology of fruit flies. *Annual Review of Entomology* 17, 493–518.
- Bleicher, E. and Melo, Q.M.S. (1993) *Artrópodes Associados ao Cajueiro no Brasil*. EMBRAPA/CNPAT, Fortaleza, Documentos 9, 33 pp.
- Boaretto, M.A.C., Brandão, A.L.S. and São José, A.R. (1994) Pragas do maracujazeiro. In: São José, A.R. (ed.) *Maracujá, Produção e Mercado*. DFZ/UESB; Vitória da Conquista, pp. 99–107.
- Boiça Júnior, A.L., Lara, F.M. and Oliveira, J.C. (1993) Resistência de genótipos de maracujazeiro ao ataque de *Dione juno juno* Cramer, 1779 (Lepidoptera: Nymphalidae). In: *Resumos do 14 Congresso Brasileiro de Entomologia*. SEB, Piracicaba, p. 143.
- Brandão, A.L.S., São José, A.R. and Boaretto, M.A.C. (1991) Pragas do maracujazeiro. In: São José, A.R., Ferreira, F.R. and Vaz, R.L. (eds) *A Cultura do Maracujá no Brasil*. FUNEP, Jaboticabal, pp. 136–168.
- Brown Júnior, K.S. and Mielke, O.H.H. (1972) The heliconians of Brazil (Lepidoptera: Nymphalidae). Part II. Introduction and general comments, with a supplementary revision of the tribe. *Zoologia* 57, 1–40.
- Camillo, E. (1978a) Aspectos reprodutivos de algumas espécies de *Xylocopa* (Hymenoptera: Anthophoridae). *Ciência e Cultura* 30, 594–595.
- Camillo, E. (1978b) Polinização do maracujazeiro. In: *Anais do 2 Simpósio Sobre a Cultura do Maracujazeiro*, Jaboticabal, pp. 32–39.
- Camillo, E. (1980) Polinização do maracujazeiro. In: Ruggiero, C. (ed.) *Cultura do Maracujazeiro*. FCAN, Jaboticabal, pp. 47–53.
- Camillo, E. (1996) Utilização de espécies de *Xylocopa* (Hymenoptera: Anthophoridae) na polinização do maracujá amarelo. In: *Anais do 2 Encontro Sobre Abelhas*. Ribeirão Preto, pp. 141–146.
- Camillo, E. and Garófalo, C.A. (1982) On the bionomics of *Xylocopa frontalis* (Olivier) and *Xylocopa grisescens* (Lepeletier) in southern Brazil. I. Nest construction and biological cycle. *Revista Brasileira de Entomologia* 42, 571–582.
- Caraballo, J. (1981) Las moscas de las frutas del género *Anastrepha* Schiner, 1868 (Diptera: Tephritidae) de Venezuela. MSc thesis, University Central de Venezuela, 210 pp.

- Carter, D. (1992) *Butterflies and Moths*. Dorling Kindersley, London, 304 pp.
- Carvalho, E.F., Calixto, A.R.Y., Silva Filho, J.R. and Morato, E.F. (1994) Avaliação da polinização artificial na redução dos danos causados por *Trigona amazonensis* na cultura do maracujá amarelo. In: *Anais do 13 Congresso Brasileiro de Fruticultura*. SBF, Salvador, pp. 798–799.
- Causton, C.E. (1993) Una mosca del genero *Dasiops* (Diptera: Lonchaeidae) atacando la curuba (*Passiflora mollissima*) en el Edo. Merida, Venezuela. *Boletín de Entomología Venezolana* 8, 146.
- Chacón, P. and Rojas, M. (1981) Biología y control natural de *Peridroma saucia*, plaga de la flor de la curuba. *Revista Colombiana de Entomología* 7, 47–53.
- Chacón, P. and Rojas, M. (1984) Entomofauna asociada a *Passiflora mollissima*, *P. edulis* f. *flavicarpa* y *P. quadrangularis* en el Departamento del Valle del Cauca. *Turrialba* 34, 297–311.
- Chiavegato, L.G. (1963) *Leptoglossus gonagra* – praga do maracujá. *O Agrônomo*, 15, 31–36.
- Corbet, S.A. and Willmer, P.G. (1980) Pollination of the yellow passionfruit: nectar, pollen and carpenter bees. *Journal of Agricultural Science* 95, 655–666.
- Corrêa, L.S., Ruggiero, C. and Oliveira, J.C. (1977) Ocorrência de *Acalymma* sp. (Coleoptera: Chrysomelidae) sobre mudas de maracujá-amarelo (*Passiflora edulis* f. *flavicarpa* Deg.). *Científica* 5, 229–230.
- Costa, J.M., Correa, J.S., Santos, Z.F.A.F. and Ferraz, M.C.V.D. (1979) *Estudos da Broca do Maracujazeiro na Bahia e Meios de Controle*. EPABA, Salvador, Comunicado Técnico 37, 10 pp.
- Cox, I.E. (1957) Flowering and pollination of passion fruit. *Agricultural Gazette of New South Wales* 68, 573–576.
- Cruz, C.A., Graça, D. and Lima, A.F. (1993) Ocorrência de *Philonis obesus* em maracujazeiro no Estado do Rio de Janeiro. In: *Resumos do 14 Congresso Brasileiro de Entomologia*. SEB, Piracicaba, p. 16.
- Cunha, M.A.P. (1996) Recursos genéticos e modificações em métodos de seleção para produtividade em maracujá. *Revista Brasileira de Fruticultura* 18, 413–423.
- D’Almeida, R.F. (1944) Estudos biológicos sobre alguns lepidópteros do Brasil. *Archivos de Zoologia do Estado de São Paulo* 4, 44.
- De Bortoli, S.A. and Busoli, A.C. (1987) Pragas. In: Ruggiero, C. (ed.) *Cultura do Maracujazeiro*. Legis Summa, Ribeirão Preto, pp. 111–123.
- Dominguez-Gil, O.E. (1998) Fauna fitófaga de parchita maracujá (*Passiflora edulis* f. *flavicarpa*) en las regiones oriental y suroriental de la cuenca del Lago de Maracaibo, Venezuela: características morfológicas. *Boletín del Centro de Investigaciones Biológicas* 32, 1–66.
- Dominguez-Gil, O.E. and McPherson, B.A. (1992) Arthropods associated with passion fruit in western Venezuela. *Florida Entomologist* 75, 607–612.
- Dominguez-Gil, O.E., Vera, H., Socarras, G. and Carvajal, R. (1989) Posible epizootia de tipo viral en larvas de *Eueides isabella* Ménétries y *Dione juno juno* (Cramer) defoliando plantaciones de parchita maracujá en el Estado Zulia. In: *Resúmenes del 11 Congreso Venezolano de Entomología*. Sociedad Venezolana de Entomología, Maracaibo, p. 33.
- Donadio, L.C. (1983) Frutíferas tropicais de valor potencial. In: Donadio, L.C. (ed.) *Fruticultura Tropical*. FCAV/UNESP, Jaboticabal, pp. 20–30.
- Echeverri, F., Cardona, G., Torres, F., Pelaez, C., Quiñones, W. and Renteria, E. (1991) Ermanin: an insect deterrent flavonoid from *Passiflora foetida* resin. *Phytochemistry* 30, 153–155.
- Fancelli, M. (1992a) *A Broca da Haste do Maracujazeiro*. EMBRAPA/CNPMP, Bahia, Maracujá em Foco 53, 2 pp.
- Fancelli, M. (1992b) *A Lagarta de Teia do Maracujazeiro*. EMBRAPA/CNPMP, Bahia, Maracujá em Foco 54, 2 pp.
- Fancelli, M. (1993) Ocorrência de *Azamor penicillana* (Walk.) (Pyralidae: Chrysauginae) em maracujá silvestre. *Anais da Sociedade Entomológica do Brasil* 22, 121–124.
- Fancelli, M. (1996) Insetos-pragas do maracujazeiro e controle. In: Lima, A.A., Borges, A.L., Santos Filho, H.P., Fancelli, M. and Sanches, N.F. (eds) *Instruções Práticas Para o Cultivo do Maracujazeiro*. EMBRAPA/CNPMP, Bahia, Circular Técnica, 20, 44 pp.
- Fancelli, M. and Mesquita, A.L.M. (1998) Pragas do maracujazeiro. In: Braga Sobrinho, R., Cardoso, J.E. and Freire, F.C.O. (eds) *Pragas de Fruteiras Tropicais de Importância Agroindustrial*. EMBRAPA/SPI, Brasília, pp. 169–180.
- Figueiro, C.L.M. (1995) Aspectos biológicos e controle da lagarta *Dione juno juno* (Lepidoptera: Heliconiinae) do maracujazeiro (*Passiflora edulis*) por *Baculovirus dione*. MSc thesis, UFPA, Brazil, 73 pp.
- Fisher, T.W. (1963) *Mass Culture of Cryptolaemus and Leptomastix – Natural Enemies of Citrus Mealybug*. University of California Agricultural Experiment Station Bulletin, No. 797.
- Flechtmann, C.H.W. (1989) *Ácaros de Importância Agrícola*. Nobel, São Paulo, 189 pp.
- Forster, L.D., Luck, R.F. and Grafton-Cardwell, E.E. (1995) *Life Stages of California Red Scale and its*

- Parasitoids*. University of California, Division of Agricultural Natural Research Publication, 21529.
- Free, J.B. (1993) *Insect Pollination of Crops*, 2nd edn. Academic Press, London, pp. 404–409.
- Gilmartin, A.L. (1958) Post-fertilization seed and ovary development in *Passiflora edulis* Sims. *Tropical Agriculturist* 35, 41–58.
- Grasswitz, T.R. and Paine, T.D. (1993) Influence of physiological state and experience on the responsiveness of *Lysiphlebus testaceipes* (cresson) (Hymenoptera: Aphidiidae) to aphid honeydew and host plants. *Journal of Insect Behaviour* 6, 511–528.
- Gravena, S. (1987) Perspectiva do manejo integrado de pragas. In: Ruggiero, C. (ed.) *Cultura do Maracujazeiro*. Legis Summa, Ribeirão Preto, pp. 134–145.
- Haddad, G.O. and Millán, F. (1975) *La Parchita Maracuyá* (*Passiflora edulis* f. *flavicarpa* Degener). Fondo de Desarrollo Frutícola, Caracas, Boletim Técnico 2, 82 pp.
- Hadlington, P. (1987) *Australian Termites*. University Press, New South Wales, Australia.
- Hammer, L.H. (1987) The pollinators of yellow passionfruit – do they limit the success of *Passiflora edulis* f. *flavicarpa* as a tropical crop? In: *Proceedings of the Annual Meeting of the Florida State Horticulture Society* 100, 283–287.
- Hardin, L.C. (1986) Floral biology and breeding systems for the yellow passion-fruit, *Passiflora edulis* f. *flavicarpa*. In: *Proceedings of the Inter-American Society of Tropical Horticulture* 30, 35–44.
- Hargreaves, J.R. (1979) Damage of passion-fruit by the Queensland fruit fly, *Dacus tryoni* (Froggatt). *Queensland Journal of Agricultural and Animal Sciences* 36, 147–150.
- Hernández, M.R., Rojas, M. and Trochez, A. (1985) Evaluación de la proteína hidrolizada de maíz para la captura de *Lonchaea cristula* (Diptera: Lonchaeidae), plaga de la curuba en el Valle del Cauca. *Revista Colombiana de Entomología* 11, 47–50.
- Hernández-Ortiz, V. (1992) *El Genero Anastrepha Schiner (Diptera: Tephritidae) en México, Taxonomía, Distribución y Sus Plantas Huespedes*. Instituto de Ecología, Veracruz, 162 pp.
- Hoffmann, M. (1997) Polinização do maracujá amarelo *Passiflora edulis* f. *flavicarpa*. In: São José, A.R.S., Bruckner, C.H., Manica, I. and Hoffmann, M. (eds) *Maracujá: Temas Seleccionados (1), Melhoramento, Morte Prematura, Polinização e Taxonomia*. Cinco Continentes, Porto Alegre, 5, pp. 58–70.
- Hoffmann, M. and Pereira, T.N.S. (1996) Polinização do maracujá-amarelo (*Passiflora edulis* f. *flavicarpa* Deg.) na região de Campos dos Goytacazes, RJ. In: *Anais do 2 Encontro Sobre Abelhas*. Ribeirão Preto, p. 330.
- Hsieh, C.Y. and Allen, W.W. (1986) Effects of insecticides on emergence, survival, longevity, and fecundity of the parasitoid *Diaretiella rapae* (Hymenoptera: Aphidiidae) from mummified *Myzus persicae* (Homoptera: Aphididae). *Journal of Economic Entomology* 79, 1599–1602.
- Hurd, P.D. (1978) *An Annotated Catalog of the Carpenter Bees (Genus Xylocopa Latreille) of the Western Hemisphere (Hymenoptera: Anthophoridae)*. Smithsonian Institution Press, Washington, 106 pp.
- Hurd, P.D. and Moure, J.S. (1963) *A Classification of the Large Carpenter Bees (Xylocopini) (Hymenoptera: Apoidea)*. University of California Publications in Entomology, 366 pp.
- ICA (1987) *Guia para el Control de Plagas*, 4th edn. Ministerio de Agricultura, Instituto Colombiano Agropecuario/SOCOLEN, Manual de Asistencia Técnica 1, pp. 232–237.
- Kluge, R.A. (1998) Maracujazeiro *Passiflora* sp. In: Castro, P.R.C. and Kluge, R.A. (ed.) *Ecofisiologia de Fruteiras Tropicais*. Nobel, São Paulo, pp. 32–47.
- Krishna, K. and Weesner, F.M. (1970) *Biology of Termites*. Academic Press, New York, 643 pp.
- Leão, J.A.C. (1980) Considerações sobre as principais doenças e pragas do maracujá no Nordeste do Brasil. In: *Anais do 1 Encontro Estadual da Cultura do Maracujá*. EMATER-SE, Aracaju, pp. 67–71.
- Lima, M.F.C. and Veiga, A.F.S.L. (1993) Ocorrência do vírus da poliedrose nuclear (PNV) em lagartas de *Dione junio junio* (Cramer, 1779) sobre maracujazeiro, em Recife – Pernambuco. In: *Resumos do 14 Congresso Brasileiro de Entomologia*. SEB, Piracicaba, p. 143.
- Lima, M.F.C. and Veiga, A.F.S.L. (1995) Ocorrência de inimigos naturais de *Dione junio junio* (Cr.), *Agraulis vanillae maculosa* S. e *Eueides isabella dianosa* (Hüb.) (Lepidoptera: Heliconiidae) em Pernambuco. *Anais da Sociedade Entomológica do Brasil* 24, 631–634.
- Lordello, L.G.E. (1952a) Insetos que vivem sobre o maracujazeiro. I – Notas bionômicas acerca de *Dione vanillae* (L., 1758) (Lep.: Nymphalidae). *Revista de Agricultura* 29, 23–29.
- Lordello, L.G.E. (1952b) Insetos que vivem sobre o maracujazeiro. II – Contribuição ao conhecimento de *Cascoscelis famelica* (F., 1787) (Col.: Chrysomelidae). *Dusenja* 3, 387–393.
- Lordello, L.G.E. (1954) Insetos que vivem sobre maracujazeiro. III – Notas acerca de *Dione junio* (Cramer) (Lep.: Nymphalidae) e relação de alguns outros insetos habitualmente coligidos

- de *Passiflora* spp. *Revista de Agricultura* 31, 23–29.
- Manica, I. (1997) Maracujazeiro: taxonomia, anatomia e morfologia. In: São José, A.R.S., Bruckner, C.H., Manica, I. and Hoffmann, M. (eds) *Maracujá: Temas Seleccionados* (1), *Melhoramento, Morte Prematura, Polinização e Taxonomia*. Cinco Continentes, Porto Alegre, pp. 7–24.
- Mardan, M., Yatim, I.M. and Khalid, M.R. (1991) Nest biology and foraging activity of carpenter bee on passion fruit. In: *The 6th International Symposium on Pollination*. Tilburg, pp. 127–132.
- Mariconi, F.A.M. (1952) Contribuição para o conhecimento do *Diactor bilineatus* (Fabricius, 1803) (Hemiptera: Coreidae), praga do maracujazeiro (*Passiflora* spp.). *Arquivos do Instituto Biológico* 21, 21–42.
- Martin, F.W. and Nakasone, H.Y. (1994) The edible species of *Passiflora*. In: Schaffer, B. and Andersen, P.C. (eds) *Handbook of Environmental Physiology of Fruit Crops, Subtropical and Tropical Crops*, Vol. 2. CRC Press, Boca Raton, pp. 101–113.
- May, A.W.S. (1953) Queensland host records for the Dacinae. *Queensland Journal of Agricultural Science* 10, 36–79.
- McAlpine, J.F. (1964) Descriptions of new Lonchaeidae (Diptera). *Canadian Entomologist* 96, 661–700.
- Medina, J.C., Garcia, J.L.M., Lara, J.C.C., Tocchini, R.P., Hashizume, T., Moretti, V.A. and Canto, W.L. (1980) *Maracujá, da Cultura ao Processamento*. ITAL, Campinas, Frutas Tropicais 9, 207 pp.
- Menezes, E.B., Rabinovitch, L., Ferreira, I.T., Moura, V.R.A., Pereira, A.C. and Guaycurus, T.V. (1989) Ação da biomassa de *Bacillus thuringiensis* isolados no Brasil: uma aproximação preliminar contra lepidópteros. In: *Resumos do 12 Congresso Brasileiro de Entomologia*. SEB, Belo Horizonte, p. 232.
- Morgante, J.S. (1991) *Moscas-das-frutas (Tephritidae): Características Biológicas, Detecção e Controle*. SENIR, Brasília, Boletim Técnico 2, 19 pp.
- Moura, M.F., Picanço, M., Gonring, A.H.R. and Bruckner, C.H. (2000) Seletividade de inseticidas a três Vespidae predadores de *Dione juno juno* (Lepidoptera: Heliconidae). *Pesquisa Agropecuária Brasileira* 35, 251–257.
- Murray, D.A.H. (1976) Insect pests on passion fruit. *Queensland Agricultural Journal* 102, 145–151.
- Murray, D.A.H. (1978) Effect of fruit fly sprays on the abundance of the citrus mealybug, *Planococcus citri* (Risso) and its predator, *Cryptolaemus montrouzieri* Mulsant, on passion-fruit in southeastern Queensland. *Queensland Journal of Agricultural and Animal Science* 35, 344–346.
- Nishida, T. (1954) Entomological problems of the passion fruit. *Hawaii Farm Science* 3, 3–7.
- Nishida, T. (1958) Pollination of the passion fruit in Hawaii. *Journal of Economic Entomology* 51, 146–149.
- Nishida, T. (1963) *Ecology of the Pollinators of the Passion Fruit*. Hawaii Agricultural Experiment Station, Honolulu, Technical Bulletin 55.
- Norrbom, A.L. and Kim, K.C. (1988) *A List of the Reported Host Plants of Species of Anastrepha (Diptera: Tephritidae)*. USDA-APHIS, Washington, Miscellaneous Publications 8, 52 pp.
- Oliveira, C.A.L. (1987) Ácaros. In: Ruggiero, C. (ed.) *Cultura do Maracujazeiro*. Legis Summa, Ribeirão Preto, pp. 104–110.
- Oliveira, J.C. and Busoli, A.C. (1983) *Philonis* sp. (Coleoptera, Curculionidae), nova praga do maracujazeiro em Jaboticabal, SP. In: *Resumos do 8 Congresso Brasileiro de Entomologia*. SEB, Brasília, p. 281.
- Orlando, A. and Sampaio, A.S. (1973) ‘Moscas das frutas’, notas sobre o reconhecimento e combate. *O Biológico* 39, 143–150.
- Peñaranda, I.A., Chacón, P. and Rojas, M. (1986) Biología de la mosca de los botones florales del maracuyá *Dasiops inedulis* (Diptera: Lonchaeidae) en el Valle del Cauca. *Revista Colombiana de Entomologia* 12, 16–22.
- Pires, M.M. and São José, A.R. (1994) Custo de produção e rentabilidade da cultura do maracujazeiro. In: São José, A.R. (ed.) *Maracujá, Produção e Mercado*. DFZ/UESB; Vitória da Conquista, pp. 223–233.
- Piza Júnior, C.T. (1992) *Pragas e Doenças do Maracujá*. CATI, Campinas, Comunicado Técnico 96, 9 pp.
- Piza Júnior, C.T. and Kavati, R. (1995) *7th Ciclo de Debates Sobre a Cultura do Maracujá*. CATI, Campinas, Comunicado Técnico 124, 6pp.
- Piza Júnior, C.T. and Resende, J.A.M. (1993) Virose do endurecimento dos frutos do maracujazeiro. CATI, Campinas, Comunicado Técnico 103, 5 pp.
- Pope, W.T. (1935) *The Edible Passion Fruit in Hawaii*. Hawaii Agricultural Experiment Station, Honolulu, Technical Bulletin 74, 22 pp.
- Price, P.W. (1997) Pollination ecology. In: Price, P.W. (ed.) *Insect Ecology*. John Wiley & Sons, New York, pp. 239–266.
- Puzzi, D. (1966) *Pragas dos Pomares de Citros do Estado de São Paulo*. Instituto Biológico de São Paulo, São Paulo, Publicações 116, 58 pp.
- Racca Filho, F., Guajará, M.S. and Lima, A.F. (1993) O gênero *Philonis* Champion, 1906 no Estado do Rio de Janeiro (Coleoptera, Curculionidae).

- In: *Resumos do 14th Congresso Brasileiro de Entomologia*. SEB, Piracicaba, p. 166.
- Riek, E.F. (1979) Hymenoptera (wasps, bees, ants). In: *The Insects of Australia*. Melbourne University Press, Carlton, pp. 867–959.
- Rossetto, C.J., Cavalcante, R.D., Grisi Júnior, C. and Carvalho, A.M. (1974) *Insetos do Maracujazeiro*. Instituto Agrônômico, Campinas, Circular Técnica 39, 12 pp.
- Rossetto, C.J., Longo, R.S., Rezende, J.A.M. and Branco, E.M.C. (1978) Ocorrência de *Philonis* sp. (Coleoptera: Curculionidae) como praga de maracujazeiro. *Ciência e Cultura* 30, 9.
- Ruggiero, C., Lam-Sanchez, A. and Miguel, S. (1975) Estudos da incompatibilidade em flores do maracujá amarelo (*Passiflora edulis* f. *flavicarpa* Deg.). In: *Anais do 3rd Congresso Brasileiro de Fruticultura*. SBF, Rio de Janeiro, pp. 491–495.
- Ruggiero, C., Banzatto, D.A. and Lam-Sanchez, A. (1976) Studies on natural and controlled pollination in yellow passion fruit (*Passiflora edulis* f. *flavicarpa* Deg.). *Acta Horticulturae* 57, 121–124.
- Ruggiero, C., São José, A.R., Volpe, C.A., Oliveira, J.C., Duringan, J.F., Baumgartner, J.G., Silva, J.R., Nakamura, K., Ferreira, M.E., Kavati, R. and Pereira, V.P. (1996) *Maracujá Para Exportação: Aspectos Técnicos da Produção*. EMBRAPA/SPI, Brasília, Publicações Técnicas FRUPEX 19, 64 pp.
- Sanches, N.F. (1996) Ácaros do maracujazeiro. In: Lima, A.A., Borges, A.L., Santos Filho, H.P., Fancelli, M. and Sanches, N.F. (eds) *Instruções Práticas Para o Cultivo do Maracujazeiro*. EMBRAPA/CNPMP, Bahia, Circular Técnica 20, 44 pp.
- Santo, E. (1931) *Inimigos e Doenças das Fruteiras*. Biblioteca Agric. D'O Campo, Rio de Janeiro, 80 pp.
- Santos, Z.F.A.F. and Costa, J.M. (1983) *Pragas da Cultura do Maracujá no Estado da Bahia*. EPABA, Salvador, Circular Técnica 4, 10 pp.
- Sazima, I. and Sazima, M. (1989) Mamangavas e irapuás (Hymenoptera: Apoidea): visitas, interações e consequências para polinização do maracujá (Passifloraceae). *Revista Brasileira de Entomologia* 33, 109–118.
- Semir, J. and Brown, K.S. (1975) Maracujá: flor da paixão. *Revista Geográfica Universal* 2, 41–47.
- Silva, A.G.A., Gonçalves, C.R., Galvão, D.M., Gonçalves, A.J.L., Gomes, J., Silva, M.N. and Simoni, L. (1968) *Quarto Catálogo dos Insetos que Vivem nas Plantas do Brasil, Seus Parasitos e Predadores*, Part II, Vol. 1. Ministério da Agricultura/DDIA, Rio de Janeiro, 622 pp.
- Silva, C.C.A. (1979) Morfologia e biologia de *Dione juno juno* (Cramer, 1779) (Lepidoptera: Heliconiidae). MSc. thesis, UFPR, Curitiba, Brazil, 99 pp.
- Silva, L.M.S. (1982) O controle das pragas do maracujazeiro e a preservação dos seus inimigos naturais. In: *Anais do 2nd Encontro Estadual Sobre a Cultura do Maracujá*, pp. 54–58.
- Stefani, R.N. and Morgante, J.S. (1996) Genetic variability in *Anastrepha pseudoparallela*: a specialist species. In: McPheron, B.M. and Steck, G.J. (eds) *Fruit Fly Pests, a World Assessment of Their Biology and Management*. St Lucie Press, Delray Beach, pp. 277–280.
- Stegmaier, C.E. (1973) *Dasiops passifloris* (Diptera: Lonchaeidae), a pest of wild passion fruit in south Florida. *Florida Entomologist* 56, 8–10.
- Steyskal, G.C. (1980) Two-winged flies of the genus *Dasiops* (Diptera: Lonchaeidae) attacking flowers or fruit of species of *Passiflora* (passion fruit, granadilla, curuba, etc.). In: *Proceedings of Entomological Society of Washington* 82, 166–170.
- Stone, A. (1942) *The Fruit Flies of the Genus Anastrepha*. United States Department of Agriculture, Washington, Miscellaneous Publications 439, 112 pp.
- Swaine, G., Ironside, D.A. and Yarrow, W.H.T. (1985) *Insect Pests of Fruit and Vegetables*. Queensland Department of Primary Industries, Brisbane.
- Teixeira, C.A.D., Aviles, D.P. and Fernandes, L.M. (1996) Danos de *Trigona* sp. (Hymenoptera: Apidae) em flores de maracujazeiro (*Passiflora edulis*) em Porto Velho. In: *Resumos do 8th Encontro de Pesquisadores da Amazonia*. UNIR/PIUAL, Porto Velho, p.13.
- Teixeira, C.G. (1994) Maracujá. I – cultura. In: Teixeira, C.G., Castro, J.V., Tocchini, R.P., Nishida, A.L.A.C., Turatii, J.M., Leite, R.S.S., Bliska, F.M.M. and Garcia, E.B. (eds) *Maracujá, Cultura, Matéria-Prima, Processamento e Aspectos Econômicos*, 2nd edn. ITAL, Campinas, pp. 3–131.
- Toledo, Z.D.A. (1991) Fauna del noroeste argentino. Contribucion al conocimiento de los lepidopteroseos argentinos. IX. *Dione juno* (Cramer) (Lepidoptera: Rhopalocera: Heliconiidae). *Acta Zoológica Lilloana* 40, 109–117.
- Torres Filho, J. and Araújo, G.C. (1981) Broca do caule *Philonis* sp., nova praga do maracujazeiro, *Passiflora edulis* Sims. no Estado do Ceará. *Fitossanidade* 5, 50–51.
- Vasconcellos, M.A.S. (1991) Biologia floral do maracujá doce (*Passiflora alata* Dryand) nas condições de Botucatu – SP. MSc thesis, UNESP, Jaboticabal, SP, Brazil, 98 pp.
- Vasconcellos, M.A.S., Aguiar, E.L., Bicalho, A.C., Menezes, E.B. and Prado, A.P. (1995)

- Ocorrência de *Dasiops* n. sp. (Diptera: Lonchaeidae) em maracujazeiro, no município de Itaguaí, RJ. In: *Resumos do 15 Congresso Brasileiro de Entomologia*. SEB, Caxambu, p. 335.
- Warumbi, T.T. and Veiga, A.F.S.L. (1978) Uma nova praga no maracujá no nordeste do Brasil. In: *Resumos do 3 Congresso Latinoamericano de Entomologia*. CEPLAC, Ilhéus, p. 20.
- Wharton, R.A. (1996) Parasitoids of fruit-infesting Tephritidae – how to attack a concealed host. In: *Abstracts of XX International Congress of Entomology*. Firenze, Italia, p. 665.
- Zucchi, R.A. (1988) Moscas-das-frutas (Dip., Tephritidae) no Brasil; taxonomia, distribuição geográfica e hospedeiros. In: *Anais do 1 Encontro Nacional Sobre Moscas-das-Frutas*. Fundação Cargill, Campinas, pp. 1–10.
- Zucchi, R.A. (2000) Espécies de *Anastrepha*, sinônímias, plantas hospedeiras e parasitóides. In: Malavasi, A. and Zucchi, R. A. (eds) *Moscas-das-frutas de importância econômica no Brasil, conhecimento básico e aplicado*. Holos, Ribeirão Preto, pp. 41–48.