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## RESEARCH

## Differences in Antennal Sensillae of Male and Female Peach Fruit Flies in Relation to Hosts

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**ABSTRACT.** Antennal sensillae of male and female peach fruit flies, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae), obtained from three different host fruit species (guava, *Psidium guajava* L. (Myrtales: Myrtaceae); peach, *Prunus persica* (L.) Stokes (Rosales: Rosaceae); and orange, *Citrus sinensis* (L.) Osbeck (Sapindales: Rutaceae)), were studied with scanning electron microscopy. This study was carried out to describe the different types of sensillae present on the three antennal segments (scape, pedicel, and flagellum or funiculus) of both sexes of *B. zonata* on different host fruit. The antennal segments of females tended to be larger than those of males feeding on peach and guava fruit. On orange, both sexes were similar (no significant differences were found). The first two antennal segments, scape and pedicel, are reinforced by some bristles and have different types of sensillae, including trichoid I, II, S; basiconic II; and sensilla chaetica in different numbers on different host fruit species. Numerous microtrichia, as well as trichoid (I, II), basiconic (I), clavate, and coeloconic (I, II) sensillae were observed on the funiculus with a great variation in number and length. As a result of feeding on different hosts, differences were found between sexes and some plasticity in size, number, distribution, and position of some sensillae, including trichoid, basiconic, chaetica, and clavate on the antennae of the female *B. zonata*. These sensillae were significantly larger in females. Also, some morphological and morphometric differences have been found according to their feeding on different host fruit.

**Key Words:** antenna, funicular sensillum, scanning electron microscopy

Fruit flies (Diptera: Tephritidae) are among the most damaging insect pests for agricultural and horticultural crops, either by causing losses to the yield or to the marketability of the products (Joomaye et al. 2000). Although there are between 4,000 and 5,000 described species of tephritid fruit flies, only about 70–250 species are considered of economic importance. Especially members of the genera *Bactrocera* and *Ceratitis* are known for their negative impact on the quality of fruits and vegetables (Dhillon et al. 2005, Lysandrou 2009).

*Bactrocera zonata* (Saunders) (Diptera: Tephritidae), the peach fruit fly, is one of the most important pests of peaches, and also for guava and citrus fruit. It causes damage when the females oviposit into the ripe fruit. This punctures the fruit and the larvae feed on the pulp. In addition to the direct losses in yield, this limits the possibilities of exporting the fruit to markets where blemished fruits are not accepted by the customers (Drew 1989, Aluja et al. 1996, EPO 2003, Shehata et al. 2008). Infestation levels can be very high, e.g., in Pakistan up to 50% of the summer guavas may be affected leading to small and poorly shaped that may be rotting inside at the time of harvest (Atwal 1976, Awad et al. 2014). *B. zonata* occurs in Southeast Asia from Indonesia over Thailand and Vietnam to India and Pakistan as well as on the islands of Mauritius, Moluccas, Reunion, and Sri Lanka. In the Middle East region, it is established and widespread in Egypt and is also present in Yemen, Iran, Saudi Arabia, United Arab Emirates, and Oman. It has been recently reported in Palestine and Lebanon (FAO/IAEA 2000).

In Egypt, *B. zonata* has become a serious pest within the last decade in part due to the suitability of the climate and its ability to attack a wide range of fruit hosts, e.g., figs, mango, peach, guava, citrus, apricot, and apple. Vegetables, such as peppers, tomato, or eggplant, may serve as additional secondary hosts (Hashem et al. 2004, Ghanim 2009). Because this species gradually increases its host range (more plant species attacked), their already significant damage of around 190€ million per year to Egyptian agriculture is continually increasing. However,

control of the pest is complicated by problems associated with the use of insecticides (FAO/IAEA 2000, Hashem et al. 2001, OEPP/EPO 2005, El-Aw et al. 2008).

Factors like time of adult emergence and longevity, female size and number of eggs produced, the length of oviposition period, and the time needed for larval development may all be influenced by the type and quality of their food sources (Tsitsipis 1989; Chan et al. 1990; Zucoloto 1991, 1993a,b; Cangussu and Zucoloto 1997, Medeiros et al. 2007). Information about the host plants and with that the basis of food choices are mainly mediated by sensory input through the insect antennae, which may contain several types of olfactory and gustatory sensilla perceiving plant volatiles and contact chemicals, and also water vapor and carbon dioxide levels. In addition, touch receptors may provide information about the surface structures on the plant. Finally, the antennae play a great role in pheromone-based communication (Ehmer and Gronenberg 1997, Renthal 2003). There is no doubt about the importance of the insect's antennae for various behaviors during adult life, including host location and host discrimination (Schneider 1964, Ochieng et al. 2000).

Therefore, in order to achieve successful control of agricultural pests using synthetic sex pheromones, it is essential to have a better understanding of the peripheral sensory structure involved in the perception of pheromones. Studying olfactory and gustatory sensilla can be useful in the development of new control strategies, e.g., by using insecticides that overstimulate or block the function of these sensilla (Hanna 2002, El-Akhdar and Afia 2009).

Ample information is available on the distribution of various sensilla located on the antennae of different fruit flies (Diptera: Tephritidae). Among these are *Bactrocera (Dacus) oleae* Gmelin (Hallberg et al. 1984); *Bactrocera (Dacus) tryoni* Froggatt (Giannakakis and Fletcher 1985, Hull and Cribb 1997); *Ceratitis capitata* Wiedemann (Levinson et al. 1987, Mayo et al. 1987, Dickens et al. 1988, Bigiani et al. 1989);

*Anastrepha ludens* Loew, *Bactrocera (Dacus) cucurbitae* Coquillett, *Bactrocera (Dacus) dorsalis* Hendel (Dickens et al. 1988); *Eurosta solidaginis* Fitch (Vasey and Ritter 1987); *Anastrepha serpentine* Wiedemann (Castrejón-Gómez 2006); *Bactrocera tau* Walker, *B. cucurbitae* Coquillett, *Bactrocera minax* Enderlein, *Bactrocera diaphora* Hendel, and *Bactrocera scutellata* Hendel (Hu et al. 2010), but limited work has been carried out on the sensilla of the peach fruit fly, *B. zonata*, and no references can be found on the sensory structure in both sexes of the fly according to different host fruit species. The aim of this article is to investigate the antennal sensory structures of both sexes of peach fruit fly in relation to three different host fruit species, with the goal of identifying and characterizing different types of sensilla involved in chemoreception. We present here the first examination of the morphology, abundance, and distribution of antennal sensilla in both male and female *B. zonata* collected from different host fruits. It is anticipated that this study will facilitate future research on the electrophysiology and neurobiology of olfaction in *B. zonata*.

## Materials and Methods

**Collection and Rearing the Flies.** Larvae of *B. zonata* were obtained from three host fruit species, guava, *Psidium guajava* L. (Myrtales: Myrtaceae); peach, *Prunus persica* (L.) Stokes (Rosales: Rosaceae); and orange, *Citrus sinensis* (L.) Osbeck (Sapindales: Rutaceae), which were collected from the field and placed in plastic trays containing sand at the bottom. The jumping larvae, which pupated in the sand, were collected and transferred to rearing cages until adult emergence. The newly emerged flies from all three hosts were separated by sex and were provided with adult food consisting of sugar mixed with hydrolyzed protein (yeast) at a ratio of 3:1 by weight. Adults were kept up to 7 days and then used in the microscopy studies.

**Scanning Electron Microscopy.** Both male and female adult flies (7 days old) were picked to be examined for ultrastructure and morphological characters by scanning electron microscope (SEM) as described by Azza (1999). The following steps were followed:

**Fixation.** Khal's solution fixation (using freeze drying): Khal's solution was used as a fixative and was prepared as follows: 30 ml (95% ethanol) + 12 ml formaldehyde + 4 ml glacial acetic acid + 60 ml distilled water. The solution was ready for fixation directly after mixing these components and was stored for up to 7–8 days in the refrigerator.

**Dehydration.** After fixation, the fixative was washed by three washes in the same buffer vehicle as used for the fixative. Ethanol was used as the dehydration agent. After secondary fixation, specimens were dehydrated in a series of ascending alcohols (30%, 50%, 70%, 90% [two washes], 100% [three or four washes], each for 2 h). Finally, excess alcohol was removed, and the specimen was submerged in amy-lacetate for 1–2 d.

**Drying.** Specimens were air dried for 1–3 h at 35°C.

**Final Mounting.** After the specimen had dried, it was mounted on an SEM specimen stub (copper stub) with sticky tapes (adhesive).

**Sputter Coating.** The specimen was then coated with gold film with 150 Å thickness using a JEOL (JFC-1100 E, www.jeol.com) sputtering device for 2–3 min.

**SEM and Analysis.** The specimen then was examined using a JEOL 5400LV SEM. Identification of the different sensillar types was carried out following the descriptions of Snodgrass (1944) and Zacharuk (1985). For both sexes of *B. zonata*, images of the sensilla on the dorsal surfaces of the antennae were taken at magnification of 1,500× to 3500×, then classified and measured. In order to calculate the mean length of a sensillar type, measurements were used of at least 10 sensilla of the same sensillar type located on the same antennal segment but from different individuals feeding on same fruit. Statistical analysis of the data was performed with SPSS 12.0 for Windows (IBM, www.ibm.com). Comparisons of the data from different segments, of males and females, and for individuals from the three host fruits were made (*t*-test, significance level:  $P < 0.05$ ).

## Results

**Morphology of the Fly Antennae.** The antennae of *B. zonata* were situated in a frontal depression between the compound eyes (the antennal fossa). The antenna had three segments, the scape, pedicel, and flagellum or funiculus. The scape (short basal segment, semicircle shape) was attached to the pedicel, which was movable, allowing the movement of antenna. Both the scape and the pedicel were heavily covered with microtrichia and bear bristles. The funiculus (third antennal segment) was unsegmented flagellum. The arista was found on the dorso-proximal end of the funiculus (Fig. 1).

The antennal segments of females were significantly larger than those of males collected on peach and guava host fruits. However, in flies originating from orange, no significant differences were found between sexes (Table 1).

**Scape (Sc).** The scape (basal segment) was a very narrow area that attaches the antennae to the head capsule (Fig. 2). The scape was reinforced by some bristles and carries sensilla (Table 2; Fig. 2). Trichoid sensilla (TrI, II) were scattered over the surface area of the scape in both sexes of all host fruits, but in males they were densely distributed (Fig. 2A–C). Basiconic sensilla (BSII) were scattered over the surface area in both sexes of all host fruits. They had a characteristic swollen base and short neck shaft (Fig. 2A1–C1). Sensilla chaetica (Ch) were a single row of bristle-like structures running in the middle area of the scape. They had a stout and very long shaft that arose from a rounded cavity in the surface of the cuticle. There were only small differences in the number of sensilla chaetica (Ch) of male and female *B. zonata*.

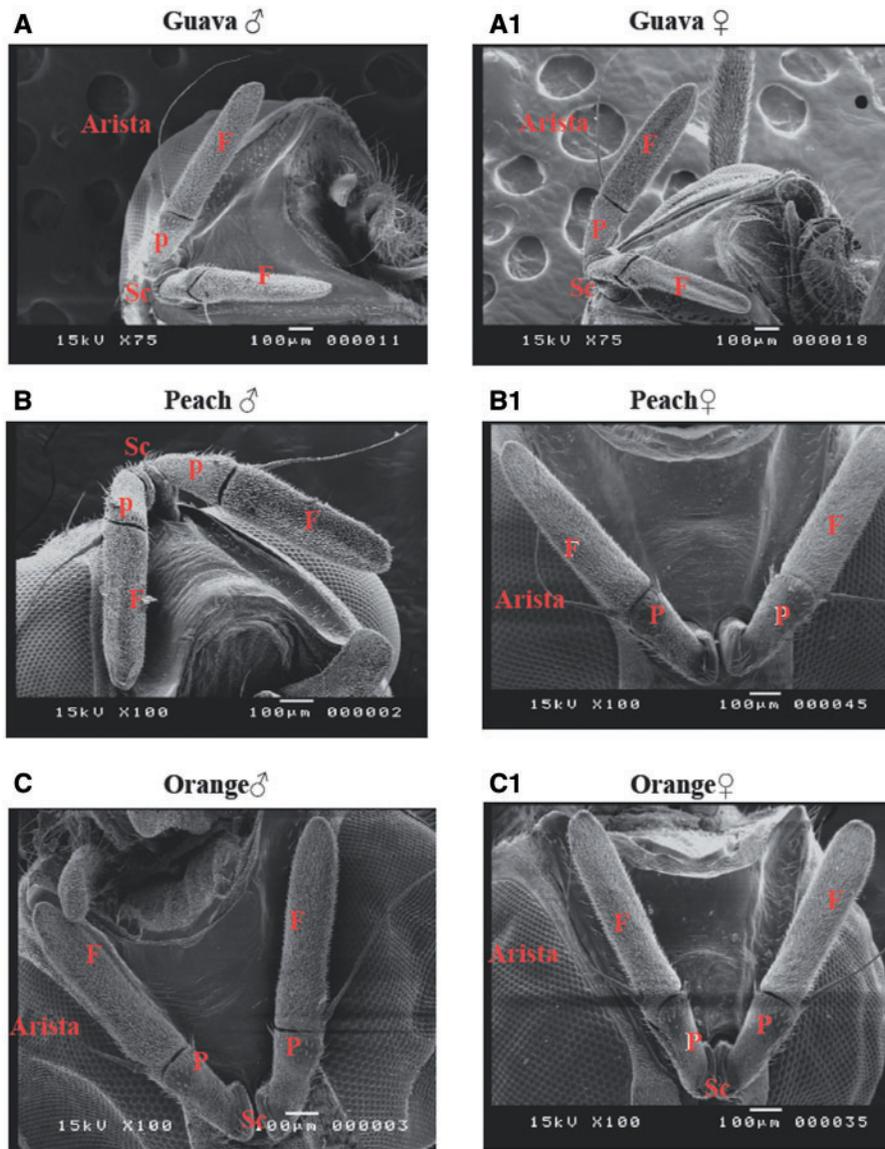
**Pedicel (P).** The pedicel (second segment) was a cone-like structure that measured ~284.5 μm in its maximum length, slightly longer than scape, which was movable with it to allow the movement of antenna (Fig. 3).

The pedicel was reinforced and fringed with many types of sensilla (Table 3). Numerous microtrichia as well as trichoid sensilla (TrI, II, and Sharp), sensilla chaetica, and basiconic (II) sensilla were observed on the pedicel. Trichoid sensilla (TrI, II) were the most conspicuous sensilla and were observed in both sexes collected from all tested host fruits. They all had the same length, but were thicker in males (Fig. 3A–C). Trichoid sharp (TrS) were found only in males and females collected from peach (Fig. 3B and B1). Basiconic sensilla (BSII) were similar to trichoid hairs but were much reduced in length and changed in form to be swollen at the base with a short neck. They were found in both sexes collected from guava and orange hosts, but were absent or with small numbers on individuals collected from peach (Fig. 3A, A1, C, and C1). Sensilla chaetica (Ch) were long fluted spines or bristles that arose from a depression on the surface of the cuticle. They were found at the periphery of the pedicel near the base of the funiculus (Fig. 3). They were found in both sexes, being larger in females than in males collected from peach and orange hosts. However, when collected from guava, the sensilla chaetica of males were larger and thicker than those of females.

**Funiculus.** The funiculus (third segment) was the most important antennal segment, an elongated and unsegmented flagellum (Fig. 4). A large protruding arista extends from the superior edge of the outer surface of the funiculus.

### Different Types of Sensilla Observed on the Funiculus Segment.

Six distinct morphological types of sensilla were observed in four groups (trichoid I, II; basiconic I; clavate; and coeloconica I, II) on the flagellum (funiculus) of male and female *B. zonata* (Table 4). All sensillae were oriented in a direction to the tip of antenna giving the flagellum a velvety appearance (Fig. 4). The first type of trichoid sensilla (TrI) was densely distributed over the dorsal surface, but rarely found on the proximal part of the ventral surface. The second type (TrII) was usually slightly curved and thin walled sensilla as described by Giannakakis and Fletcher (1985). Trichoid sensilla were longer in females than in males from all tested hosts. Basiconic sensilla (BSI) were well distributed in the floor of the funicular surface. They were characterized as digitiform (finger like) with a rounded point and a smooth surface.



**Fig. 1.** Scanning electron micrograph of the antennal segment of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing scape (Sc), pedicel (P), funiculus (F), and arista.

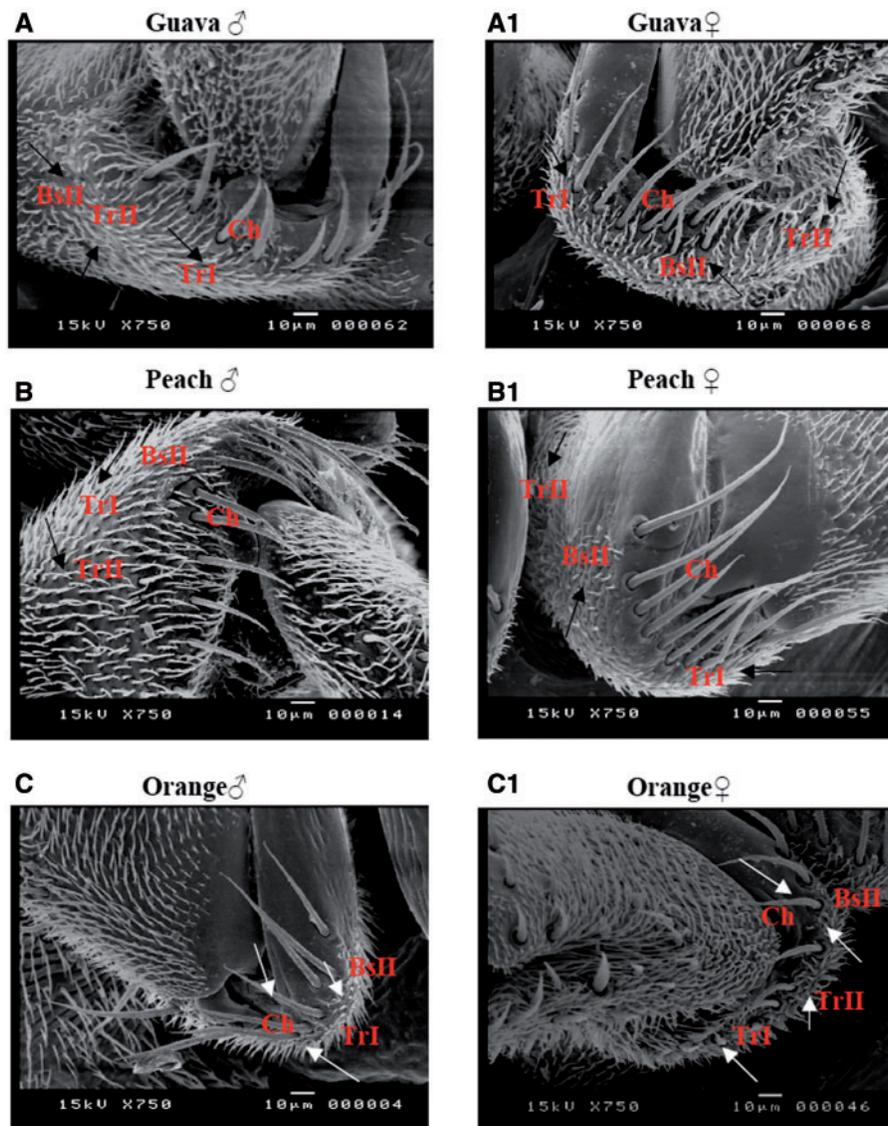
**Table 1.** Effect of different host fruit species (guava, peach, and orange) on the antennal length ( $\mu\text{m}$ ) of male and female peach fruit fly, *Bactrocera zonata*

Host Segment	Guava		Peach		Orange	
	July–Oct.		April–June		Sept.–Dec.	
	♂ ( $\mu\text{m}$ )	♀ ( $\mu\text{m}$ )	♂ ( $\mu\text{m}$ )	♀ ( $\mu\text{m}$ )	♂ ( $\mu\text{m}$ )	♀ ( $\mu\text{m}$ )
Scape	121.20 $\pm$ 9 <sup>a</sup>	193.87 $\pm$ 11 <sup>d</sup>	138.46 $\pm$ 19 <sup>b</sup>	153.84 $\pm$ 22 <sup>c</sup>	183.33 $\pm$ 8 <sup>d</sup>	191.66 $\pm$ 10 <sup>d</sup>
Pedicel	218.08 $\pm$ 10 <sup>a</sup>	244.89 $\pm$ 14 <sup>d</sup>	223.07 $\pm$ 25 <sup>a</sup>	284.61 $\pm$ 22 <sup>c</sup>	287.50 $\pm$ 15 <sup>c</sup>	290.66 $\pm$ 12 <sup>c</sup>
Funiculus	581.63 $\pm$ 15 <sup>a</sup>	520.41 $\pm$ 12 <sup>d</sup>	530.76 $\pm$ 33 <sup>d</sup>	615.38 $\pm$ 49 <sup>c</sup>	612.50 $\pm$ 20 <sup>c</sup>	608.33 $\pm$ 19 <sup>c</sup>
Aristal hair	950 $\pm$ 13 <sup>a</sup>	800 $\pm$ 9 <sup>d</sup>	700 $\pm$ 12 <sup>b</sup>	800 $\pm$ 9 <sup>d</sup>	800 $\pm$ 9 <sup>d</sup>	890 $\pm$ 11 <sup>c</sup>
Total length of antenna	920.91 $\pm$ 21 <sup>a</sup>	959.17 $\pm$ 20 <sup>d</sup>	892.30 $\pm$ 26 <sup>b</sup>	1,038.6 $\pm$ 18 <sup>c</sup>	1,083.33 $\pm$ 15 <sup>e</sup>	1,090.66 $\pm$ 13 <sup>e</sup>

<sup>a–e</sup>Values are mean  $\pm$  SE;  $n = 5$  (antennae). The values for each segment within a parameter by sex followed by the same letter in the same row are not significantly different (Student's  $t$ -test,  $P > 0.05$ ).

Basiconic sensilla showed great variation in length according to different species of host fruits (Fig. 5). Regardless of which fruit host the insects were collected from, basiconic sensilla were larger in females than in males (Fig. 5A1–C1). Clavate sensilla were a not a

very common receptor type. They were localized on the proximal end of the funiculus, close to the pedicel. Clavate sensilla were similar to the basiconic sensilla, but shorter and club like. They were absent or very few were present in both sexes on insects collected from guava

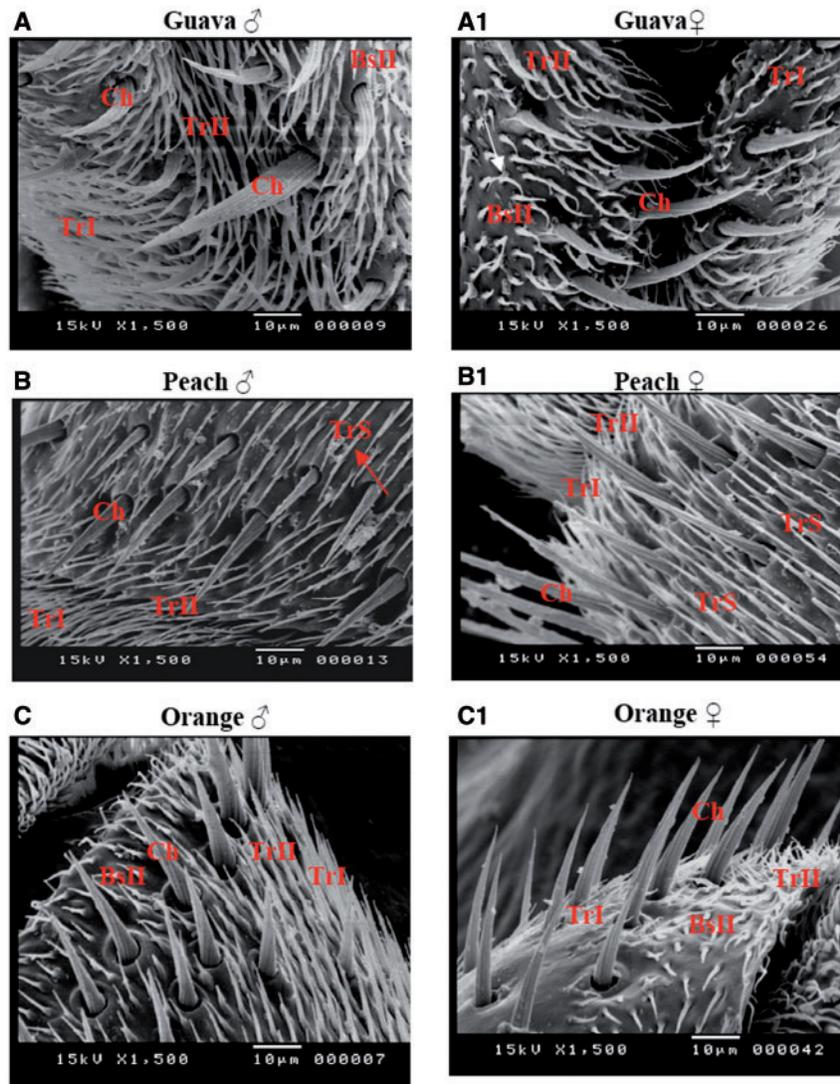


**Fig. 2.** Scanning electron micrograph of the scape of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing different types of sensilla trichoid (TrI,II), basiconica (BSII), and different numbers of sensilla chaetica (Ch).

**Table 2.** Different types of sensilla observed on the scape of male and female peach fruit fly, *Bactrocera zonata*, according to different host fruit species

Hosts Types of sensillae	Guava		Peach		Orange	
	July–Oct.		April–June		Sept.–Dec.	
	♂	♀	♂	♀	♂	♀
Trichoid sensilla (TrI,II) (hair-like structure)	+++	+	+++	+	+++	+
Dense			D		D	
Basiconica sensilla (BSII) (swollen base and short neck shaft)	+	+++	+	+++	+	+++
D		D		D		D
Chaetica sensilla (Ch) (one row of bristle-like structure)	+	+	+	+	+	+
(n = 9)	(n = 11)	(n = 11)	(n = 12)	(n = 9)	(n = 10)	

+ to +++ indicate relative numbers of sensilla.

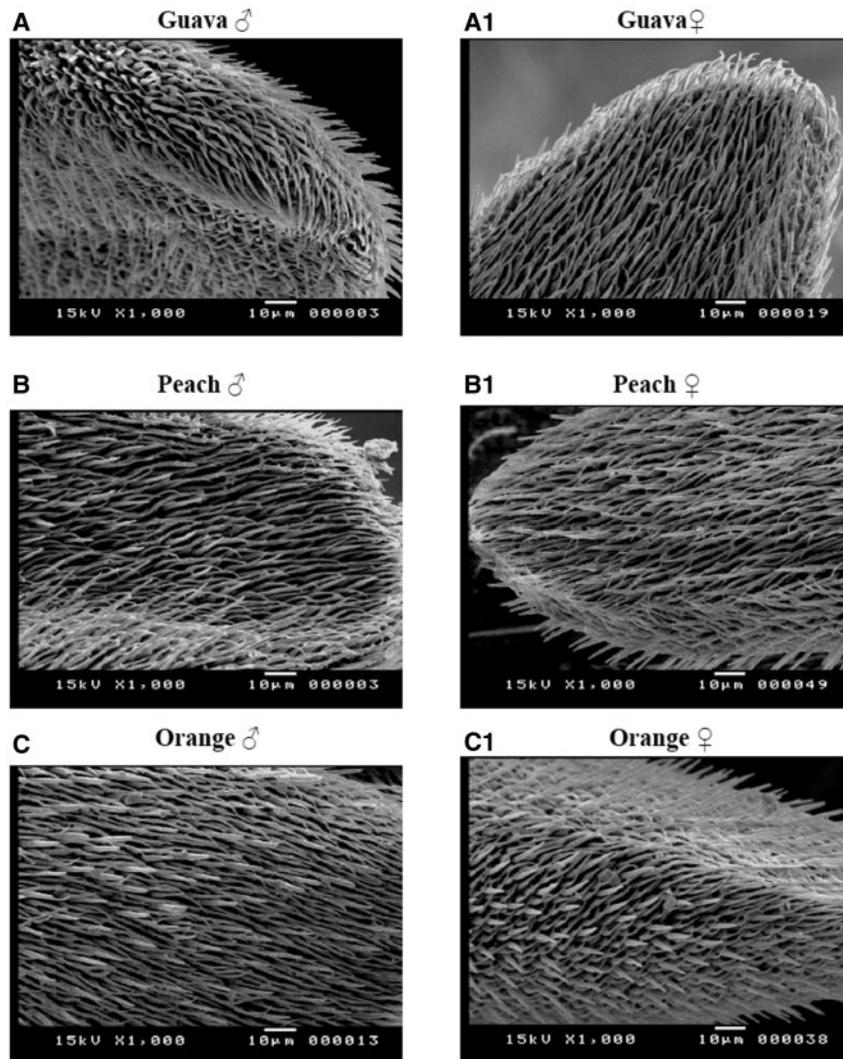


**Fig. 3.** Scanning electron micrograph of the pedicel of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing different types of sensilla trichoid (TrI, TrII, TrS), basiconica (BSII), and chaetica sensilla (Ch).

**Table 3.** Different types of sensilla observed on the pedicel of male and female peach fruit fly, *Bactrocera zonata*, according to different host fruit species derived from at least 10 measurements of each sensillar type

Hosts Types of sensillae	Guava		Peach		Orange	
	July–Oct.		April–June		Sept.–Dec.	
	♂	♀	♂	♀	♂	♀
Trichoid sensilla (TrI, II) (hair-like structure)	+++ Dense $11.8 \pm 0.9^a$ (~10–13.6) $\mu\text{m}$	+ Slight $11.6 \pm 1^a$ (~10–13.6) $\mu\text{m}$	+ S $11.9 \pm 0.8^a$ (~10–13.6) $\mu\text{m}$	+ S $11.7 \pm 0.8^a$ (~10–13.6) $\mu\text{m}$	+++ D $11.8 \pm 1^a$ $\mu\text{m}$	+ S $11.7 \pm 0.7^a$ (~10–13.6) $\mu\text{m}$
Trichoid sharp (TrS) (sharp hair)	Absent		+++ $11.28 \pm 3^a$ (~10–12.7) $\mu\text{m}$	+++ $15.90 \pm 4^b$ (~13.6–18.2) $\mu\text{m}$	Absent	
Basiconic sensilla (BSII) (swollen base and short neck shaft)	+	++	Absent		+	+++
Sensilla chaetica (Ch) (one row of bristle-like structure)	+ Larger $28.65 \pm 4^a$ (~20–37.3) $\mu\text{m}$	+ $23.10 \pm 4^b$ (~21.8–24.5) $\mu\text{m}$	+ $19.80 \pm 5^c$ (~14.5–25.4) $\mu\text{m}$	+ L $32.33 \pm 3^d$ (~28.2–36.4) $\mu\text{m}$	+ $17.21 \pm 4^c$ (~12.7–21.8) $\mu\text{m}$	+ L $24.95 \pm 4^b$ (~21.8–28.2) $\mu\text{m}$

+ ( $\leq 100$ ) to +++ ( $\geq 100$ ) indicate relative numbers of sensilla.

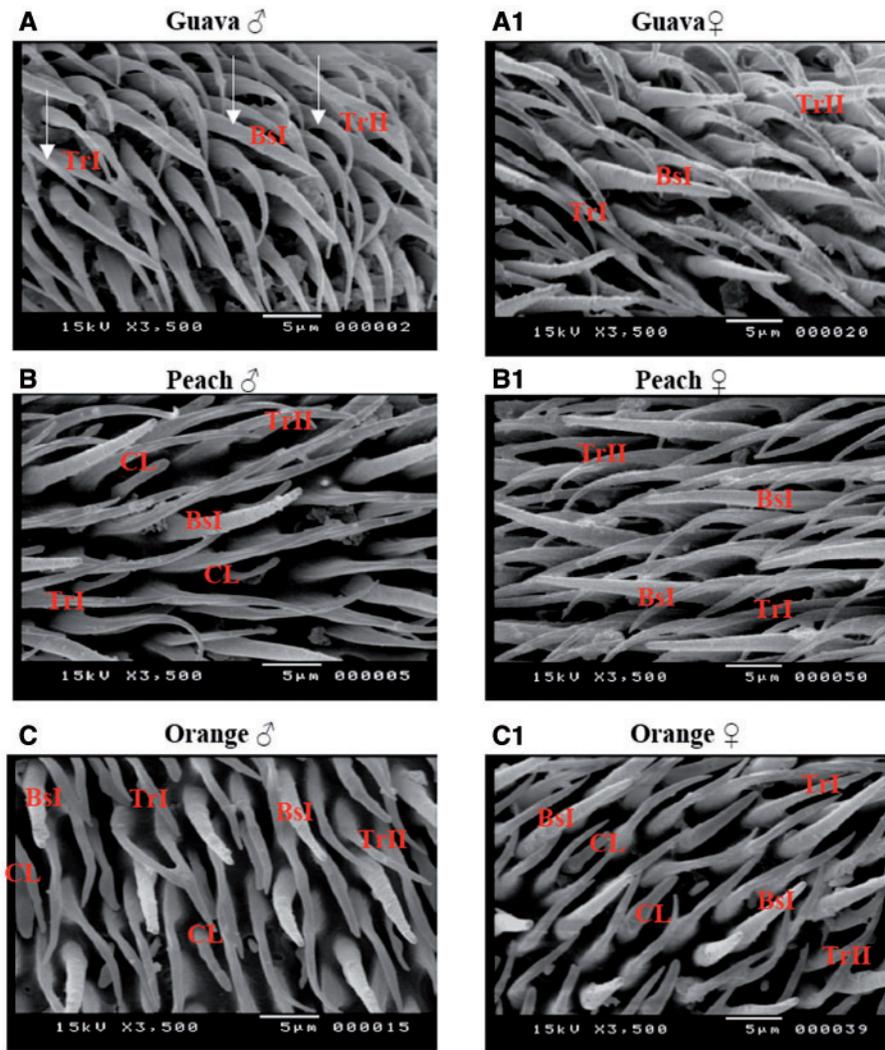


**Fig. 4.** Scanning electron micrograph of the funiculus of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing dense microtrichia giving the funiculus a velvety appearance.

**Table 4.** Different types of sensilla observed on the funiculus of male and female peach fruit fly, *Bactrocera zonata*, according to different host fruit species derived from at least 10 measurements of each sensillar type for each sex

Hosts Types of sensillae	Guava		Peach		Orange	
	July-October		April- June		September-Dec.	
	♂	♀	♂	♀	♂	♀
Trichoid sensilla (TrI, II) (hair-like structure)	++	++ Large	++	++ L	++	++ L
	$10.7 \pm 0.9^a$ (~10–11.4) $\mu\text{m}$	$12.99 \pm 1^b$ (~11.4–14.1) $\mu\text{m}$	$15.59 \pm 0.9^c$ (~14.1–16.8) $\mu\text{m}$	$17.2 \pm 2^d$ (~13.6–18.6) $\mu\text{m}$	$10.9 \pm 0.8^a$ (~10–11.8) $\mu\text{m}$	$12.11 \pm 0.9^b$ (~9.1–14.1) $\mu\text{m}$
Basiconica sensilla (BSI) digitiform (finger-like)	++	++ L	++	++ L	++	++ L
	$10.9 \pm .89^a$ (~10.5–11.4) $\mu\text{m}$	$12.01 \pm 1^b$ (~9.1–13.6) $\mu\text{m}$	$12.29 \pm 0.9^b$ (~12.3) $\mu\text{m}$	$17.98 \pm 0.9^c$ (~17.7–18.2) $\mu\text{m}$	$8.96 \pm 1.1^d$ (~7.7–9.5) $\mu\text{m}$	$10.01 \pm 1^a$ (~7.3–11.4) $\mu\text{m}$
Clavate sensilla (Cl) (club like)		Absent	++	++	++	++
			$5.97 \pm 1^a$ (~5.5–6.4) $\mu\text{m}$	$5.99 \pm 0.9^a$ (~5.5–6.4) $\mu\text{m}$	$6.65 \pm 0.9^b$ (~6.8) $\mu\text{m}$	$7.94 \pm 1.2^c$ (~6.8–8.7) $\mu\text{m}$
Coeloconica sensilla (Col) (arise from acavity)	Absent	+	+	+	+	+
		$2.97 \pm 1^a$ ~3.0 $\mu\text{m}$	$3.1 \pm .58^a$ ~3.2 $\mu\text{m}$	$4.15 \pm 0.9^b$ ~4.2 $\mu\text{m}$	$3.69 \pm 0.8^a$ ~3.7 $\mu\text{m}$	$3.29 \pm 0.72^a$ ~3.3 $\mu\text{m}$
Coeloconica sensilla (ColI) (curved)	+			L		
	$2.39 \pm 0.98$ ~2.5 $\mu\text{m}$			Absent		

+ ( $\leq 50$ ) to +++ ( $\geq 50$ ) indicate relative numbers of sensilla.



**Fig. 5.** Scanning electron micrograph of the funicular sensilla of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing trichoid type I, II (TrI, Tr II), basiconica type I (BSI), and clavate (CL) sensilla.

(Fig. 5A and A1), but the number increased on flies collected from the other hosts, peach and orange (Fig. 5B, C, and C1). Coeloconica sensilla were the shortest and fewest of all sensillar types and were found on the flagellum of both sexes. They were scattered irregularly on the whole surface and arose from a depression of the integument or cavity called the sacculus that had a single opening with an irregular rounded margin at the cuticle surface (Fig. 6).

On males collected on guava, the coeloconica sensilla were of type (II) and were curved (Fig. 6A). Males collected on orange and peach had type (I) coeloconica sensilla, being longer on those collected from orange than from peach. On females, coeloconic sensilla (I) were found on insects from all hosts but with great variation in length—those from peach being the longest, followed by orange and then guava.

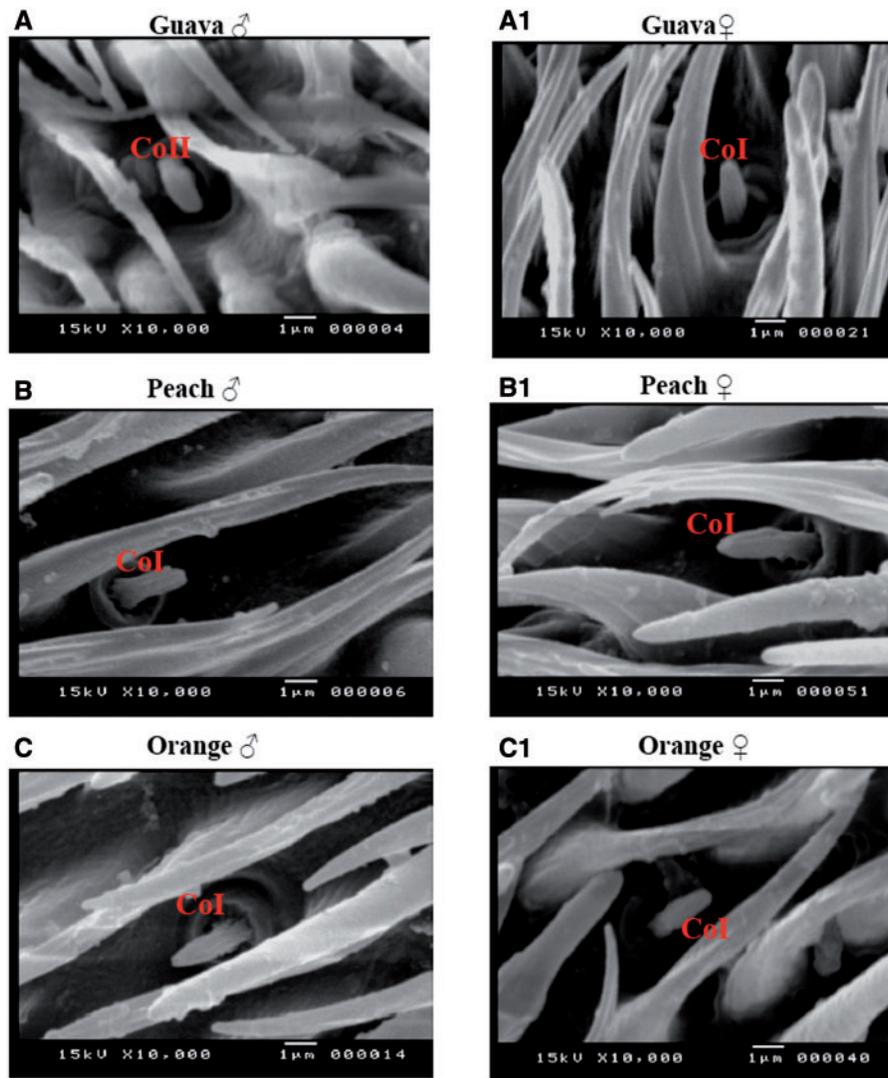
*Arista.* The arista (Fig. 7) was located proximally near the base of the funiculus and consisted of three segments, two small basal segments and one long distal segment. The aristal hair of females was significantly longer than that of males from peach and orange hosts, but from guava, the male aristal hair was significantly longer (Table 1).

## Discussion

The insect antenna is a complex sensory structure perceiving external information important for the survival of the individuals. They are involved in the orientation behavior of the individuals, e.g., toward

food sources or mates (Azza 1999). The antennae of *B. zonata* were very similar in terms of their general structure to those of other fruit flies studied such as *B. (D.) oleae* (Hallberg et al. 1984); *B. tryoni* (Giannakakis and Fletcher 1985, Hull and Cribb 1997); *A. ludens*, *C. capitata*, *D. cucurbitae*, *D. dorsalis*, *A. serpentine*, *E. solidaginis*, and *Toxotrypana curvicauda* (Levinson et al. 1987, Vasey and Ritter 1987, Dickens et al. 1988, Castrejón-Gómez 2006, Arzuffi et al. 2008); *B. tau*, *B. minax*, and *B. scutellata* (Hu et al. 2010), which are all composed of three segments (scape, pedicel, and funiculus). Although the size of the various sensillar types varies from species to species, the significant conspecific morphometric difference was in the total length of the antennae of male and female *Dacus* species. The present results on flies from peach and guava host fruits were similar to that of the Queensland fruit fly, *D. tryoni* (Giannakakis and Fletcher 1985).

The study revealed some plasticity in forms, placement, distribution, and number of sensilla, dependent on different host fruit species (guava, peach, and orange), especially on the antennae in both sexes. Also, some morphological and morphometric differences were found between this destructive pest according to their feeding on the different host fruits. This study showed that in *B. zonata*, both sexes on all tested host fruits had three distinct types of the sensilla on the scape: trichoid I, II (dense in male); basiconic II and chaetica that varied in number on different hosts. However, Arzuffi et al. (2008) reported that both sexes



**Fig. 6.** Scanning electron micrograph of the funicular segment of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing coeloconic sensilla type I, II (CoI and CoII).

of *T. curvicauda* had only trichoid sensilla. Also, Giannakakis and Fletcher (1985) and Lee et al. (1994) noted the presence only of sensilla chaetica on the scape and pedicel of *D. tryoni* and *B. dorsalis*.

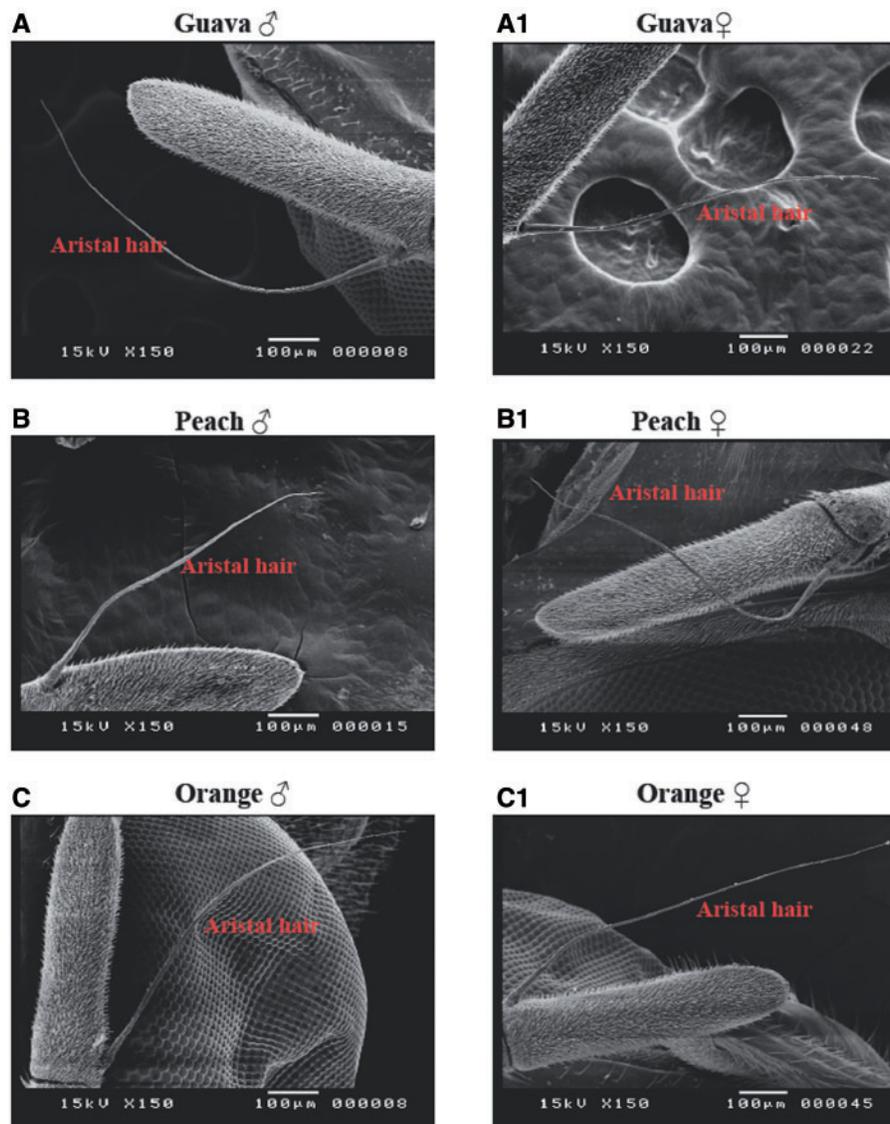
The present results indicate that the pedicel had two types of trichoid sensilla in both sexes of all tested hosts, and trichoid sharp was found only in male and female on peach host fruit. Basiconic II was found in both sexes of all tested hosts, except in female peach host where they were absent or very few were present. Sensilla chaetica were present on both sexes of insects from all tested hosts. However, Manoj and Sofian-Azirun (2002) found only sensilla chaetica on the scape and pedicel of *B. caraznbolae*. This sensilla is known as an organ of touch.

Six morphologically distinct types of the sensillae were observed in four groups on the funiculus: trichoid (I, II), basiconic (I) (significantly larger in female), clavate (absent or in low numbers in both sexes from guava host, but the number increased on individuals from peach and orange fruit), and coeloconica (I) (found in females collected from all tested hosts, but varied in length, and also in males from orange and peach fruit). Finally, the males collected from guava carried curved coeloconic sensilla (II), which are most often reported to be chemo-, thermo-, or hydro-sensitive (Snodgrass 1926, 1944).

Similar findings were reported (trichoid, basiconic, and clavate sensilla) about the funicle in other species of tephritids (Hallberg et al. 1984,

Giannakakis and Fletcher 1985, Levinson et al. 1987, Mayo et al. 1987, Vasey and Ritter 1987, Dickens et al. 1988, Bigiani et al. 1989, Hull and Cribb 1997, Castejón-Gómez 2006). A wide variety of olfactory functions of the basiconic sensillae has been established by numerous authors. They perceive sex pheromones and are involved in host location and selection because of their ability to detect plant volatiles. Basiconic sensilla may be involved in the detection of a wide range of chemicals from simple molecules like carbon dioxide and ammonia, over fatty acids, esters, and amines, to complex meat odors or volatile *n*-alcohols (Lewis 1972, Kaib 1974, Altner et al. 1977, Zacharuk 1985, Levinson et al. 1987, Mayo et al. 1987, Dickens et al. 1988, Hunter and Adserballe 1996, Shields and Hildebrand 1999, Broeckling and Salom 2003). The arista is most likely an acoustic receptor in *Anastrepha suspensa* (Loew) (Sivinski and Webb 1985). In addition, in *B. oleae*, sensilla on the third antennal segment respond to sex pheromones and other volatiles. Therefore, aristae and antennae of *B. zonata* were most likely sound receptors as well as the major sensory input conveying olfactory information about plant volatiles and pheromones (Morton and Bateman 1981, Robacker and Hart 1987, Ehmer and Gronenberg 1997, Renthal 2003, El-Akhdar and Afia 2009).

As a result, the differences between physical properties and chemical composition of each host fruit species (thickness, hardness, acidity,



**Fig. 7.** Scanning electron micrograph of arista hair of male and female *Bactrocera zonata* on different host fruit species (guava, peach, and orange), showing different arista lengths.

water content, volatile oils, and odors emitted from each fruit) play an important role in female host preferences and location behavior, where their responses depend on fruit species.

Recently, several countries imposed embargoes for fruit from Egypt, in order to avoid the spread of fruit flies that would likely happen with the transport of the fruit. The loss of export opportunities has led to tremendous losses for growers. In addition, the pest directly deteriorates the quality of the fruit and reduces the yields. Unfortunately, studies on *B. zonata* are still lacking, and the damage the insect causes is increasing with time, especially on the commercial crops, e.g., mango, guava, apricot, peach, fig, and citrus. This study contributes to the understanding of the peripheral sensory structure involved in the perception of pheromones, especially those of the antenna, which could be useful in the development of new control strategies that prevent female perception to sex pheromones by disturbing the intraspecific communication between males and females (Chapman 1972). Also, this study will contribute to the success of the application of sterile insect techniques against the peach fruit fly in the field. The effects of gamma irradiation on the structure of antennae and their associated sensilla may cause failure of irradiated males to disperse to host plant fruits. It is recommended that more electrophysiological and behavioral studies be

carried out to elucidate the precise function of the antennae receptors (EL-Akhdar and Afia 2009).

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