MORPHOLOGY AND DISTRIBUTION OF THE SENSE ORGANS ON THE ANTENNAE OF *COPITARSIA CONSUETA* (LEPIDOPTERA: NOCTUIDAE)

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ABSTRACT

Five types of sensilla were found on the antennae of adult *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae) by scanning electron microscopy and light microscopy. Those sensilla were trichoidea, coeloconica, styloconica, basiconica and squamiformia. Two types of sexually dimorphic sensilla trichodea were found; type I is in the border of the sensory field of the flagellar segments and present only on male antennae. This suggests that the sensillum may contain the receptor sites for the female sex pheromone. Type II is located within the ventro-medial sensillar field where it is arranged without apparent pattern. Six types of sensilla chaetica were found around antennal segments, and were particularly abundant on the apical antennal segment. One sensillum styloconicum was identified per segment, except for the apical segment, where it varies in number. Each sensillum consists of a base, a stalk and a cone. Each flagellar segment bears several sensilla coeloconica on the ventral surface, situated on or near distal edge. Each sensillum consists of a depression surrounded by 15 to 17 "teeth" and one peg. Two types of sensilla basiconica were identified, type I is more curved and broader than type II.

Key Words: antennal morphology, sensilla types, sexual dimorphism

RESUMEN

Se reconocieron cinco tipos de sénsulos en la antena de la palomilla *Copitarsia consueta* (Walker) (Lepidoptera: Noctuidae) por medio de microscopía electrónica de barrido y microscopía de luz. Dos tipos de sénsulos tricoideos fueron observados; el tipo I se localizó en las partes laterales del área sensorial y estuvo presente sólo en la antena del macho, lo cual sugiere que este tipo de sénsulo puede ser el receptor de la feromona sexual de la hembra. El tipo II se localizó en la parte ventral y no tuvo ningún patrón de distribución. Además se observaron otros seis sénsulos quéticos alrededor de cada segmento, excepto en el segmento apical donde el número fue mayor. Se identificó un solo sénsulo estilocónico por segmento ubicado en la parte media distal, pero en el segmento terminal el número varió, este sénsulo consta de una base, un peciolo y un cono. Varios sénsulos celocónicos se identificaron en la superficie ventral, se observaron de la parte media a la distal del segmento antenal, cada uno estuvo formado de una depresión rodeada por 15 a 17 "dientes o espinas" y una "estaquilla". Dos tipos de sénsulos basicónicos fueron identificados; el tipo I fue más curvado en la parte final y más ancho en la base que el tipo II.

Copitarsia consueta infests various crops of economic importance throughout most of the Americas (Angulo & Weigert 1975). In Bolivia it is considered a pest of potatoes, (Munro, 1968), and in Mexico a pest of cabbage (Monge, 1984).

Rojas et al. (1995) identified the sites of sex pheromone production in *C. consueta* using morphological and histological evidence. Typically, the detection of the sexual pheromone in noctuid moths is by olfactory neurons in sensilla on the male antenna (Lavoie & McNeil 1987). A knowledge of the structure and distribution of sensory sensilla of the male is an important precursor to electrophysiological and behavioral studies.

In this paper we describe the sensory structures of male and female *C. consueta* antennae, as seen through scanning electron and light microscopes.

Materials and Methods

The insects were obtained from a colony raised on an artificial diet (Cibrián & Sugimoto 1992) in a laboratory at Colegio de Postgraduados, Estado de México at 25 ± 3°C, 60 ± 5% RH and a photoperiod of 14:10 hr L:D.

Scanning Electron Microscopy (SEM)

The antennae of 15 males and 15 females were separately placed in a solution of 70% ethanol and 2% formaldehyde for 24 hours. They were then dehydrated in 80%, 90%, and 100% ethanol for 8 hr each. Afterwards, they were dried at the critical point and finally gold coated (70 nm) for observation with a JEOL 35-C microscope at 5 and 10 kV (Wall 1978, Valdez 1991). The average length and basal diameter of the external part of each sensillum was calculated through 15 measurements taken from photomicrographs (Faucheux 1991).

Light Microscopy (LM)

The antennae of both sexes were macerated in 10% KOH at 80°C until they cleared (approximately 30 minutes). They were washed with distilled water of equal temperature and for the same amount of time. The scales were removed with a 60 Hz ultrasonic cleaner for one minute, and the antennae were then dehydrated in 70% and 100% alcohol for 30 and 60 minutes respectively. Finally, they were cleared with xylol and mounted in Canada balsam. The observations were made with a Meiji (40×) microscope. The sensilla were counted on each flagellar segment on the antennae of 10 males and 30 females (Faucheux 1991).

Results

General Morphology of the Antennae

The antenna of *C. consueta is* filiform and segmented, and the flagellum is spindle-shaped. Each antenna consists of two basal segments: the scape and the pedicel. On the antennae's dorsal surface are "Böhm" bristles. The number of flagellar segments is similar in males and females. A typical antennal segment is cylindrical and divided into two main areas. The dorsal surface has two rows of scales; the second row overlaps the first row of the following segment. The only obvious type of dorsal sensillum is of the squamiform type (Fig. 1). The ventral surface possesses most of the sensilla, and these are of various types (Fig. 2).

External Morphology and Distribution of Sensilla

The antenna of the male is approximately 11.22 mm long ± 0.08 (SEM). In the female the antenna measures 11.37 ± 0.09 mm. The number of segments is slightly greater in the flagellum of the female (77.3 ± 0.57) than in the male (75.6 ± 0.45) (average of 30 antennae, 15 insects in each case) (Table 1). The flagellar segments diminish in length and diameter from the base to the apex of the antenna and have the same general organization and pattern of sensory structures. The segments are larger in the male than in the female (Table 1). There are 5 types of sensilla on the flagellum: trichoid, basiconic, coeloconic, styloconic and squamiform sensilla.

Males and females have the same types of sensilla on the ventral surface of flagellar segments, except for the lateral chemoreceptive trichoid sensilla, which are present only in the male.

The chemoreceptive trichoid sensilla are the most numerous type. They can be divided into two groups according to their external structure and location. Type I, present only on the antenna of the male are the longest (Table 2). They are set in 4 or 5 parallel rows on the sides of the ventral sensory area of the proximal and median segments (Fig. 3). The number of sensilla decrease from 278 at the base of the flagellum (average of the first 5 segments of 5 antennae), to fewer than 100 (average of the segments 51 to 55 of 5 antennae) and disappear between segments 66 and 68. The total number of these sensilla was estimated to be 2814 ± 144.6 (Table 3).

Type II sensilla are localized on the ventral surface of each segment and are shorter than type I sensilla. They are not arranged in rows (Fig. 2), and are larger in the male than in the female (Table 2). Some of these sensilla are more curved than others (Fig. 4), but the differences are too small to reliably characterize two forms. The total number of these sensilla was larger in the male than in the female (Table 3).

Each segment the male and female antennae bear six mechanoreceptive sensilla chaetica, except the apical segment which has more than six (Fig. 5). Each sensillum is straight, wide at the basal part and slightly curved at the distal part, blunt (rounded), and without a pore. These sensilla can be divided into two groups according to their length. Long sensilla chaetica, found on the superior dorsal surface (2) and lateroventrally (2) (Fig. 5), are larger in the male than in the female (Table 2). The total number of these sensilla was calculated as 302.4 ± 1.82 in the male, and 309.2 ± 2.31 in the female (Table 3). Contrasting with this, are the short sensilla chaetica, localized on the medio-ventral surface (2) (Fig. 5). They are shorter and narrower in the male (65.17 ± 3.18 in length and 3.44 ± 0.35 in width at the base) than in the female (67.10 ± 4.61 in length and 3.55 ± 0.01 in width) (Table 2). The total number of short sensilla was estimated to be 151.13 ± 0.93 in the male and 154.53 ± 1.13 in the female (Table 3).

In both males and females there is a single styloconic sensillum (from the third segment onward) in the middle part of the distal edge of each segment (Fig. 6), however, their number varies on the terminal segment. The average length of the complete structure (stalk and cone) in males and females is 2.58 ± 0.04 and 2.20 ± 0.04 respectively (Table 2). On the antenna of the male there are approximately 72.6 ± 0.45 sensilla and on the female antenna 74.3 ± 0.58 (Table 3). The styloconic sensillum in *C. consueta* has a reticulated base, a relatively smooth (plain) petiole and a conic extremity; some of them have a double or triple apical structure (Fig. 6).

On each flagellar segment there are several coeloconic sensilla on the ventral surface (Fig. 7); they are situated mainly from the middle to the distal portion of the segment. Each sensillum consists of a depression surrounded by 15 to 17 cuticular "spines" and a porous peg with longitudinal striations on its surface, arising from the center of the depression (Fig. 7). The diameter of the coeloconic sensilla varies from

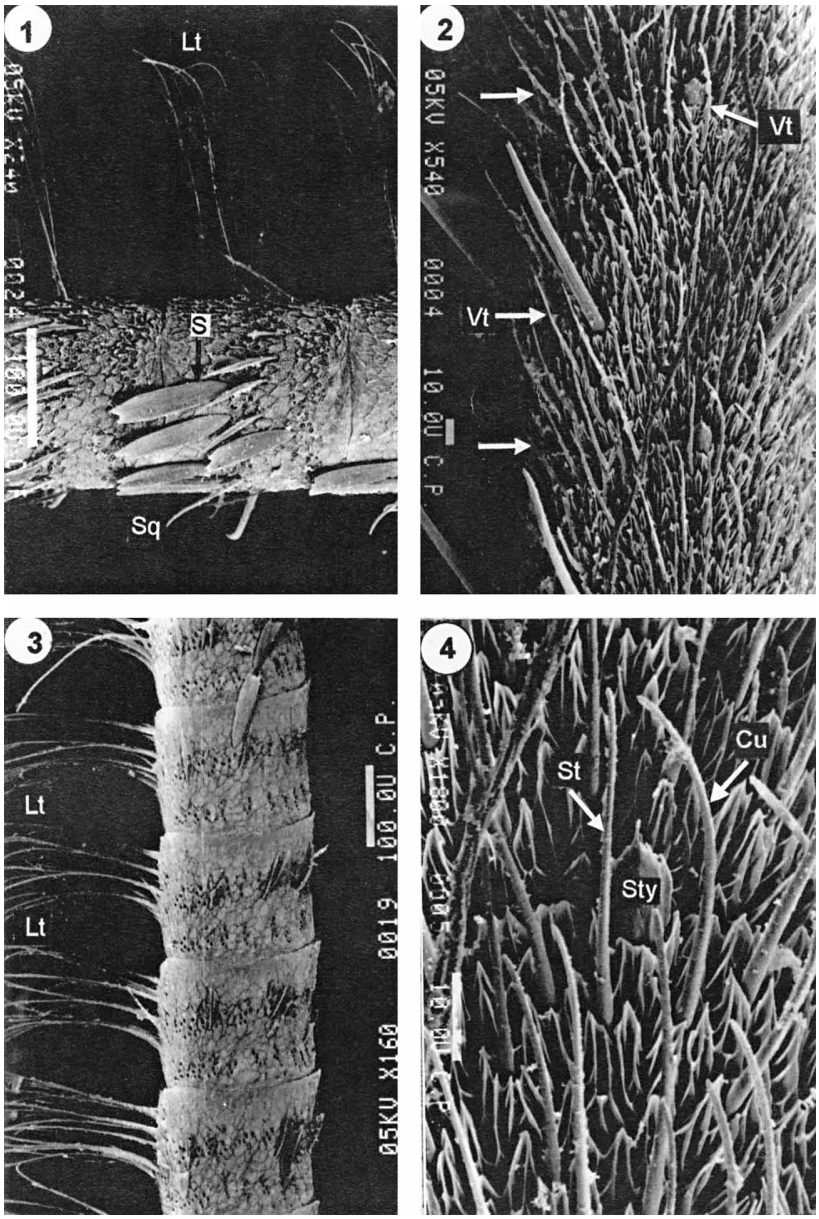

Fig. 1. Dorsal surface of a *C. consueta* male antenna. Sq = sensillum squamiformium. S = scales; Lt = lateral trichoid sensilla. Bar = 100 μm. Fig. 2. Ventral surface of a female antenna. Vt = ventral trichoid sensilla; Arrows indicate limits of one segment. Bar = 10 μm. Fig. 3. Laterodorsal surface of a male antenna. Lt = lateral trichoid sensilla. Bar = 100 μm. Fig. 4. Types of ventral trichoid sensilla. St = straight; Cu = curved; Sty = sensillum styloconicum. Bar= 10 μm.

TABLE 1. THE TOTAL LENGTH AND NUMBER OF SEGMENTS ($\bar{X}$ ± SEM) IN THE ANTENNAL FLAGELLUM OF MALE AND FEMALE *COPITARSIA CONSUETA* (WALKER).

Sex	Length of the antennae (μm)	Number of segments	Length of the segments (μm)	Width of the segments (μm)
Male	11.22 ± 0.08* (10.4-12)	75.6 ± 0.45* (71-80)	155.72 ± 12.4¤ (89.65-13.79)	139 ± 3.2¤ (117.24-158.62)
Female	11.37 ± 0.09* (10.2-12)	77.3 ± 0.57* (72-83)	150.86 ± 5.11¤ (120.68-175.86)	130.06 ± 2.56¤ (120.68-151.72)

*n = 30 antennae. ¤n = 15 segments (range in parentheses).

10.44 ± 0.45 in the male to 11.13 ± 0.55 in the female (Table 2). The number of sensilla per insect is similar in males and females, 422.9 ± 17.18 in males and 419.9 ± 2.97 in females (Table 3). There are fewer of them at the base (<3 per segment). The number increases in the central part (≈ 8) and diminishes again at the point (≈ 4).

Two types of basiconic sensilla, different in shape, can be observed on the ventral part of the antenna of *C. consueta* (Fig. 8). They are smaller than all but the coeloconic sensilla. Type I is more curved at the terminal part, and the base is wider than in type II, which has the shape of a small stake; both are rounded at the apex. There are approximately 2 sensilla of each type per segment.

The squamiform sensilla, positioned on the dorsal part of the antenna among the scales, are shorter and finer than the scales (Fig. 1).

DISCUSSION

The general structure of the antenna of *C. consueta is* similar to that in other noctuids: *Trichoplusia ni* (Hübner), *Helicoverpa zea* (Boddie), *Spodoptera ornithogalli* (Gueneé), *Spodoptera exigua* (Hübner) (Jefferson et al. 1970), and *Pseudaletia unipuncta* (Haworth) (Lavoie & McNeil 1987). Typically, scales occur along with sensilla on the surface of the noctuid antenna. Van der Pers et al. (1980), do not believe that scales protect the sensilla from mechanical damage, but rather suggest that their disposition contributes to the insect's ability to detect the direction of the stimulus. Wall (1978) argued that scales may be a mechanism to trap and concentrate odorous molecules.

The Böhm hairs of *C. consueta* are morphologically similar to those present in the scape and the pedicel of the antenna of *T. ni, H. zea, S. ornithogalli, S. exigua* (Jefferson et al. 1970), and a pyralid (Cornford et al. 1973). Schneider (1964) suggested they have a mechano-sensitive function. Similarly, Cuperus (1983) argues that these hairs in an yponomeutid may have a mechano-receptor function at the scape-pedicel junction.

There is sexual dimorphism in *C. consueta* antennae. The antenna of the male has a large number of long trichoid sensilla which are absent in the female. The presence of these sensilla has also been reported in other noctuids: *H. zea* (Callahan 1969), *T. ni, H. zea, S. ornithogalli* and *S. exigua* (Jefferson et al. 1970). It has been demonstrated in several moths that the long trichoid sensilla on the antenna of the male are receptors for the sex pheromone of the female (Boekh et al. 1965, Schneider & Steinbrecht 1968, Van der Pers & Den Otter 1978, Kaissling 1979, Zacharuk 1985).

Chaetica sensilla of *C. consueta* are similar in structure to those reported for other noctuids by Callahan (1969), Jefferson et al. (1970), and Liu & Liu (1984). They were suggested to be contact chemoreceptors in *T. ni, S. ornithogalli* and *S. frugiperda* (J. E. Smith) (Jefferson et al. 1970) and a tortricid (Albert & Seabrook 1973), but to have a mechanoreceptive function in a mosquito (Davis & Socolove 1975) and in

TABLE 2. DIMENSION OF THE SENSILLA ON THE ANTENNA OF *COPITARSIA CONSUETA* (WALKER).

	Dimension of the sensilla $\bar{X}$ ± sem (μm)			
	Male		Female	
Type of sensillum	Length	Width	Length	Width
Lateral chemoreceptive trichoid	218.4 ± 5.76 (160.7-261.2)	4.40 ± 0.09 (3.27-4.91)	—	—
Ventral chemoreceptive trichoid	74.2 ± 4.28 (45-100)	3.23 ± 0.1 2.38 ± 3.80	34.81 ± 1.34 (26.25-42.85)	1.76 ± 0.04 (1.7-2.17)
Long (4) mechanoreceptive chaetica	108.27 ± 12.47 (63.79-175.86)	4.96 ± 0.40 (3.44-6.89)	86.89 ± 6.79 (44.82-127.58)	4.62 ± 0.32 (3.44-6.89)
Short (2) mechanoreceptive chaetica	65.17 ± 3.18 (53.44-68.96)	3.44 ± 0.35 (3.10-3.79)	67.10 ± 4.61 (41.37-82.75)	3.55 ± 0.1 (3.44-5.17)
Styloconic	2.58 ± 0.04 (2.41-2.75)	—	2.20 ± 0.04 (2.06-2.41)	—
Coeloconic	10.44 ± 0.45* (8.62-13.79)	—	11.13 ± 0.55* (8.62-13.79)	—

n = 15 sensilla. *refers to diameter (range in parentheses).

TABLE 3. AVERAGE NUMBER OF SENSILLA ESTIMATED ON THE ANTENNA OF *COPITARSIA CONSUETA* (WALKER).

Type of sensillum	Number of sensilla $\bar{X}$ ± sem	
	Male	Female
Lateral chemoreceptive trichoid	2814 ± 144.6* (2481-3335)	—
Ventral chemoreceptive trichoid	3477 ± 36.4* (3266-3680)	3298 ± 186.64* (3168-3562)
Long (4) mechanoreceptive chaetica	302.4 ± 1.82¤ (284-320)	309.2 ± 2.31¤ (288-332)
Short (2) mechanoreceptive chaetica	151.13 ± 0.93¤ (142-160)	154.53 ± 1.13¤ (144-162)
Styloconic	72.6 ± 0.45¤ (68-77)	74.3 ± 0.58¤ (69-79)
Coeloconic	422.9 ± 17.18* (326-545)	419.9 ± 2.97* (405-463)

n = 10 antennae. ¤n = 30 antennae (range in parentheses).

yponomeutids (Van der Pers & Den Otter 1978). Type I has a constant length in all antennal segments, type II is smaller in the proximal segments, but increases in length towards the distal segments of the flagellum, equaling the previous ones in size in both sexes. These types also occur in *H. zea* (Callahan 1969), *P. unipuncta* (Lavoie & McNeil 1987), and a pyralid (Cornford et al. 1973). A similar, but distinct, form occurs in males of a tortricid (Wall 1978).

The presence of styloconic sensilla with double or triple apical structure is common in noctuids: *T. ni, H. zea, P. ornithogalli and S. exigua* (Jefferson et al. 1970), *P. unipuncta* (Lavoie & McNeil 1987) and *Mamestra configurata* Walker (Liu & Liu 1984). In another tortricid, (*Adoxophyes orana* F. von R.), similar structures have been reported as cuspiform organs (Den Otter et al. 1978).

Styloconic sensilla of *C. consueta* lack pores. However, pores occur on the stalk near the reticulated base in *P. unipuncta* (Lavoie & McNeil 1987), at the apex in a pyralid (Faucheux 1991), and at the side of the apex in a tortricid (Wall 1978). These pored sensilla are thought to be chemoreceptors (Albert & Seabrook 1973), or, as in *H. zea,* contact chemoreceptors (Callahan 1969). However, in yponomeutids, they may have some other sensory function because they are located under scales where contact chemoreception is not likely (Van der Pers et al. 1980).

Coeloconic sensilla, mostly present on each segment of males and females of *C. consueta* from the medial to the distal part have also been found in other noctuids, *S. unipuncta* (Lavoie & McNeil 1987) and *M. configurata* (Liu & Liu 1984), and a tortricid (Albert & Seabrook 1973), and a pyralid (Cornford et al. 1973). Three to four sensilla occur per segment of males and females in *C. consueta* and in pyralids (Cornford et al. 1973, Faucheux 1991). There was no size variation in these sensilla on the antennae of either sex of *C. consueta.* This was not the case in an a tortricid examined by Wall (1978). Such sensilla have been considered to be temperature receptors in a mosquito (Davis & Sokolove 1975) and a cockroach. In the latter insect, they are also sen-

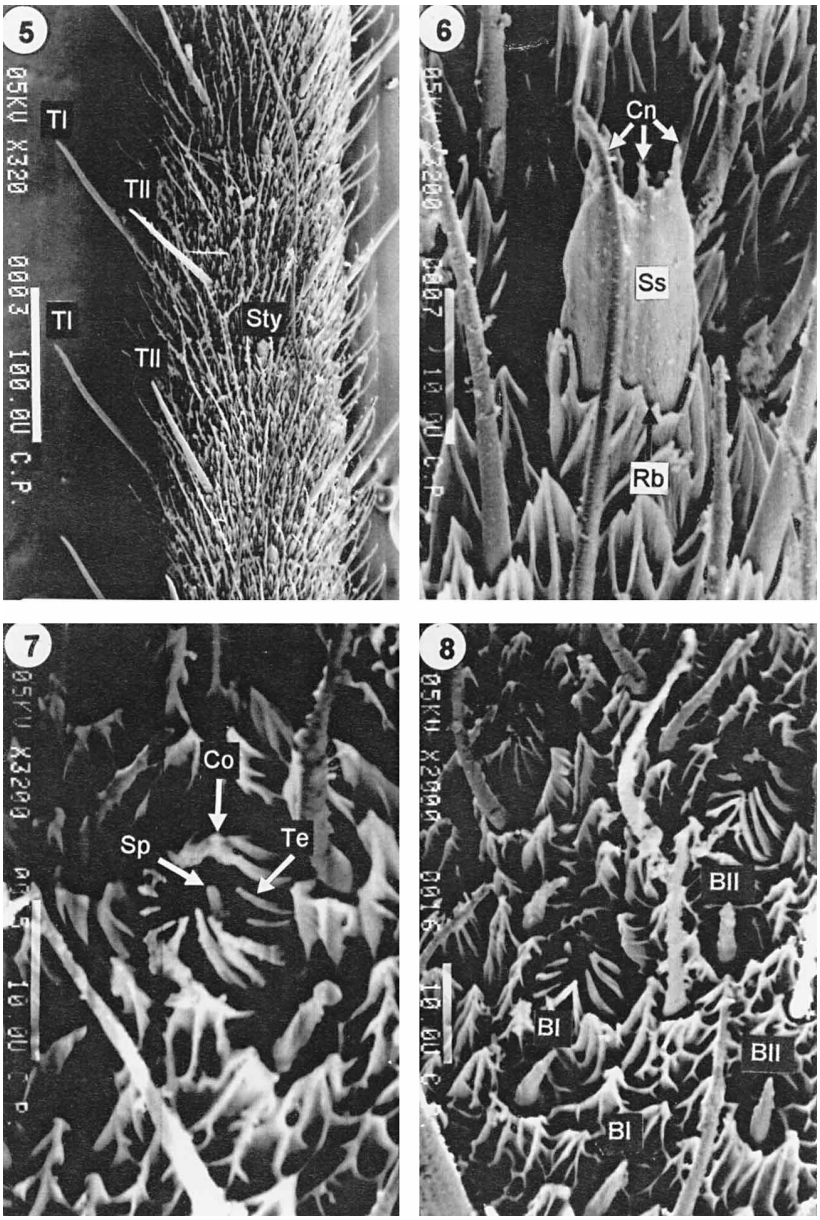

Fig. 5. Central portion of antennal flagellum of a female. Sensillum chaeticum type I = Ch I and type II = Ch II; Sty = sensillum styloconicum. Bar = 100 μm. Fig. 6. Sensillum styloconicum (Sty). Cn = conical extremity with triple apical structure; Rb = reticulated base; Ss = smooth stalk. Bar = 10 μm. Fig. 7. Sensillum coeloconicum (Co). Sp = spike, Te = teeth. Bar = 10 μm. Fig. 8. Basiconic sensilla. Type I = BI, Type II = BII. Bar = 10 μm.

sitive to humidity (Altner et al. 1977). However, their ultrastructure suggests they are olfactory receptors, possibly sensitive to volatile odors of plants (Van der Pers 1981).

Basiconic sensilla are shorter than the ventral chemoreceptive trichoids, the apex is rounded and they are located among the trichoids. Similar structures have been reported for a tortricid (George & Nagy 1984) and an yponomeutid (Cuperus 1983). Cuperus (1983) and Faucheux (1991) observed pores in a basiconic sensilla. The presence of this pores suggests an olfactory function, perhaps the reception of volatile odors of plants (Van der Pers 1981).

Squamiform sensilla are similar to those described in an yponomeutid by Cuperus (1983) and in a pyralid by Faucheux (1991). In the yponomeutid they were positioned on the scape, the pedicel, and the first 5 segments of the flagellum, but in *C. consueta* they occur as far as the middle of the flagellum. Lavoie & McNeil (1987) observed such sensilla laterally on the ventral surface of each antennal segment in *P. unipuncta,* but we found them in a transverse line on the entire ventral surface of the antennal segments of *C. consueta.*

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