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Morphology of the Antennal Sensilla of the Oriental Fruit Fly, *Dacus dorsalis* Hendel (Diptera: Tephritidae)[1]

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Wen-Yung Lee, Jui-Chun Chang, Yu-Bing Hwang, and Tai-Lang Lin (1994) Morphology of the antennal sensilla of the oriental fruit fly, *Dacus dorsalis* Hendel (Diptera: Tephritidae). *Zoological Studies* **33**(1): 65-71. The external antennal sensilla morphology of the oriental fruit fly, *Dacus dorsalis* Hendel has been studied with scanning electron microscopy. The antennae of this fly, exhibiting no sexual dimorphism, consists of 3 segments: basal scape, pedicel, and elongated funiculus. The scape and the pedicel have dense microtrichia and chaetae. Seven distinct morphological types of sensilla belong to 4 groups on the funiculus, among the microtrichia. These sensilla are: trichoid sensilla types I and II, clavate sensilla types I and II, basiconic sensilla types I and II, and styloconic sensilla. The morphological characteristics, distribution, and quantity of each sensillum on the funiculus are described below.

Key words: Funiculus, External morphology, Scanning electron microscopy.

The oriental fruit fly, *Dacus dorsalis* is an economically important insect pest in the Pacific region. The Department of Agriculture and Forest, Taiwan Provincial Government and the Taiwan Fruit Marketing Cooperative currently employ control methods involving the use of attractants with poisoned methyl eugenol for male extermination and poisoned protein hydrolyzate bait spray for extermination of both sexes. Taiwan entomologists are seeking integrated control methods. The discovery of a sex pheromone produced by the male fly (Lee and Chang 1986, and unpublished data), oviposition preference (Chiu and Chu 1987, Liu and Huang 1990), and food attractants have stimulated insect control research. Olfactory receptors must be understood for effective pheromone or attractant pest management. This paper attempts to investigate the morphological characteristics of antennal sensilla in order to provide a structural basis for the study of the physiological properties of the antennal sensory system of *Dacus dorsalis*.

MATERIALS AND METHODS

Adult *Dacus dorsalis* were obtained from the laboratory colony at the Institute of Zoology, Academia Sinica for this study. The antennae of both sexes were immersed in a 2.5% glutaraldehyde in 0.1 M cacodylate buffer for 12 hrs at 6°C and shaken at room temperature for 2 hrs to increase the penetration of the fixant and to clean the dirt from the antennae surface. After fixation, the antennae were washed in the buffer, then dehydrated through an acetone series; percentages from 50% to absolute. They were then mounted on aluminum stubs with double-sided sticky tape, and gold coated with an IB-2 Ion coater at ion current 8 mA for 2-3 min under electron current. Morphology and distribution of sensilla of male and female antennae sensilla were studied with an Hitachi S-450 scanning electron microscope at accelerating voltages of either 15 kv or 20 kv.

RESULTS

Each antenna of both sexes of *Dacus dorsalis* consists of 3 segments (Fig. 2): basal scape (S),

1. This is contribution no. 386 of the Institute of Zoology, Academia Sinica, ROC.

pedicel (P), and an elongated funiculus (F). The scape is inserted into the antennal socket at the antennal fossa between two compound eyes (Fig. 1, E). The pedicel is distally enlarged and dorsally evaginated to the funicular joint at. The funiculus has a long arista (Fig. 2, A) arising from the dorsoproximate region, and a sensory pit (Pit) located on the externo-lateral surface.

The scape and the pedicel have dense microtrichia (Fig. 3, m). There is one row of chaetae (Fig. 3, C) at the distal margin of these two segments and on the evagination of the pedicel at the funiculus. The funiculus (Fig. 2, F) is covered by dense, curved, long, and tapering cuticular microtrichia (Figs. 4, m). Among these microtrichia seven distinct morphological types of sensillae are identiable by scanning electron microscopy (Figs. 4 and 5): Trichoid sensilla type I (Fig. 4, T1; Fig. 5a) and type II (Fig. 4, T2; Fig. 5b), Clavate sensilla type I (Fig. 4, c1; Fig. 5c) and type II (Fig. 4, c11; Fig. 5d), Basiconic sensilla type I (Fig. 4, b1; Fig. 5e) and type II (Fig. 4, b11; Fig. 5g), and Styloconic type sensilla (Fig. 4, s; Fig. 5g).

The distribution and the external morphology of different types of sensilla are similar irrespective of sex. Most abundant and scattered uniformly on the funiculus are trichoid sensilla type I (Fig. 5a); they are slender with a tapered tip, lacking basal sockets, and usually located beyond the microtrichia. The length of these sensillae range from 12.9 to 20.0 μm. Surfaces appear smooth at low magnification. However, under observed high magnification they have nobules (Fig. 6a) and unclear pores.

The trichoid sensilla type II (Fig. 5b) are much shorter and less numerous than are the trichoid type I, with lengths from 7.1 to 10.9 μm. They are slightly curved, taper tipped, and distributed all over the funiculus.

The clavate sensilla (Fig. 5c) have a basal socket and swell distally to form a club-like structure. According to size, these sensilla are classified into two types: clavate type I and clavate type II (Figs. 5c and 5d). The type I sensilla is larger averaging 7.5-12.0 μm in length and 0.5-1.0 μm in diameter at their clubs and most densely distributed near the proximate part of the funiculus. Type II sensilla are much smaller and more slender than type I. Curved in appearance they are 5.5-6.9 μm in length and less than 0.5 μm in diameter at the club. The type II sensilla are the sensilla located nearest the proximate part of the funiculus.

The basiconic sensilla are shorter and have a blunter tip than clavate sensilla. Basiconic sensilla can be distinguished into two types: basiconic type I and basiconic type II (Figs. 5e and 5f). The

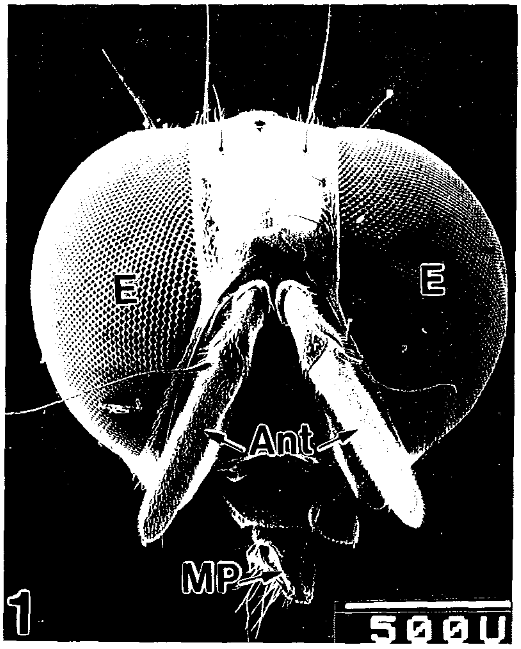

Fig. 1. A Scanning Electron Micrograph (SEM) of the head of *Dacus dorsalis* male. Ant: antenna, E: compound eye, MP: mouth part.

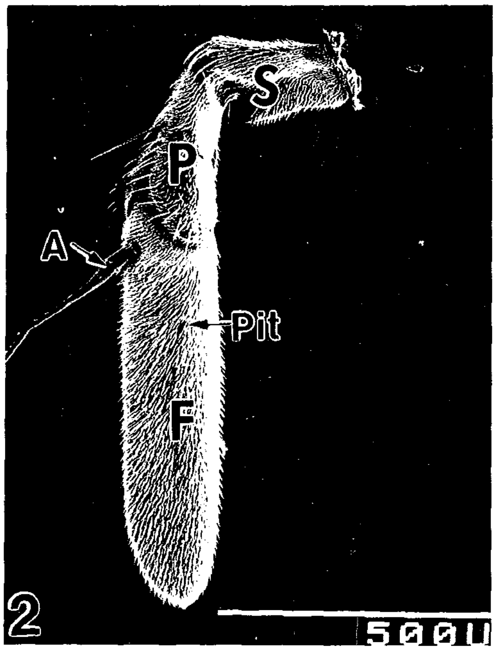

Fig. 2. SEM of the external surface of the right antenna showing the position of arista (A) and the sensory pit on the funiculus (F). P: pedicel, S: scape.

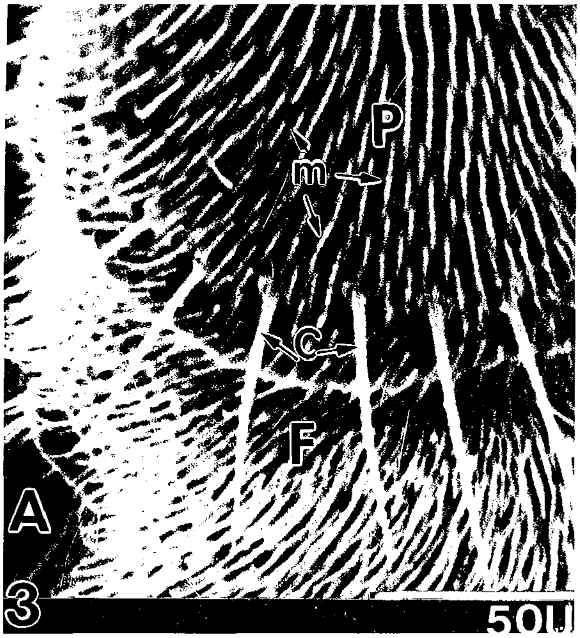

Fig. 3. SEM of microtrichia (m) and chaetae (C) on the pedicel (p). A: arista, F: funiculus.

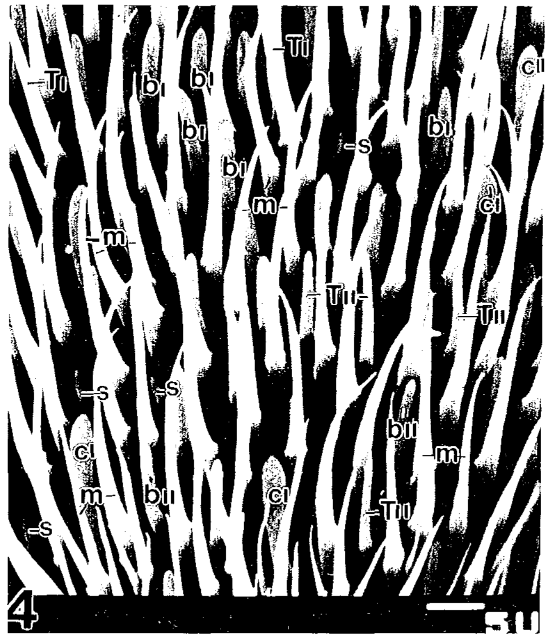

Fig. 4. SEM of the antennal funiculus sensillas distribution on the proximate region of *D. dorsalis* male. b1: basiconic sensilla type I, b11: basiconic sensilla type II, c1: clavate sensilla type I, c11: clavate sensilla type II. m: microtrichia, s: styloconic sensilla, T1: trichoid sensilla type I, T11: trichoid sensilla type II.

former is 6.3-10.7 μm in length and 1.0-2.0 μm in width; the later, slender, 6.3-8.3 μm in length, and 0.5-0.7 μm in diameter. Most of these sensilla are distributed on the proximate part of the funiculus, few on the remainder of this segment.

Under scanning electron observation, the trichoid type I sensillum surface appears to have nobules (Fig. 6a); the trichoid type II surface (Fig. 6b), the clavate (Fig. 6c), and the basiconic sensilla (Fig. 6d) appear to have many pores; the pores on the clavate sensilla, most distinct.

The styloconic sensilla, referred to as grooved sensilla in other cyclorrhaphous Dipterans (Ross and Anderson 1987, Itoh et al. 1991), are the smallest of all sensilla and microtrichia on the funiculus; 2.4-3.6 μm in length. Hidden among other sensilla and microtrichia, these sensilla appear to have several grooves distal region and ridges, a smooth basal region, and a very distinct socket at the base (Fig. 5g and Fig. 6e).

Quantification of sensillum presented on the left and right antennae of males and females are given in Table 1.

Table 1. Quantity of each type of sensillum on the funiculus of male and female *D. dorsalis* (n = 2)

Types of sensilla	Number of sensilla			
	Male		Female	
	External surface	Internal surface	External surface	Internal surface
Trichoid type I	513	382	487	387
Trichoid type II	156	151	118	141
Clavate type I	32	49	44	50
Clavate type II	35	33	27	33
Basiconic type I	62	146	64	62
Basiconic type II	103	85	117	123
Styloconic type	243	206	327	230
Total numbers	1,144	1,052	1,184	1,026

DISSCUSSION

A morphological study by scanning electron microscope revealed, the antennae of male and female *Dacus dorsalis* do not show sexual dimorphism as do those of many cyclorrhaphous Dipterans and that the antenna are tri-segmented : scape, pedical and funiculus (Lewis 1971, Bay and Pitts 1976, Venkatesh and Singh 1984, Giannakakis and Fletcher 1985, Dickens et al. 1988, Ross and Anderson 1991, Itoh et al. 1991). The microtrichia and the chaetae on the scape and the

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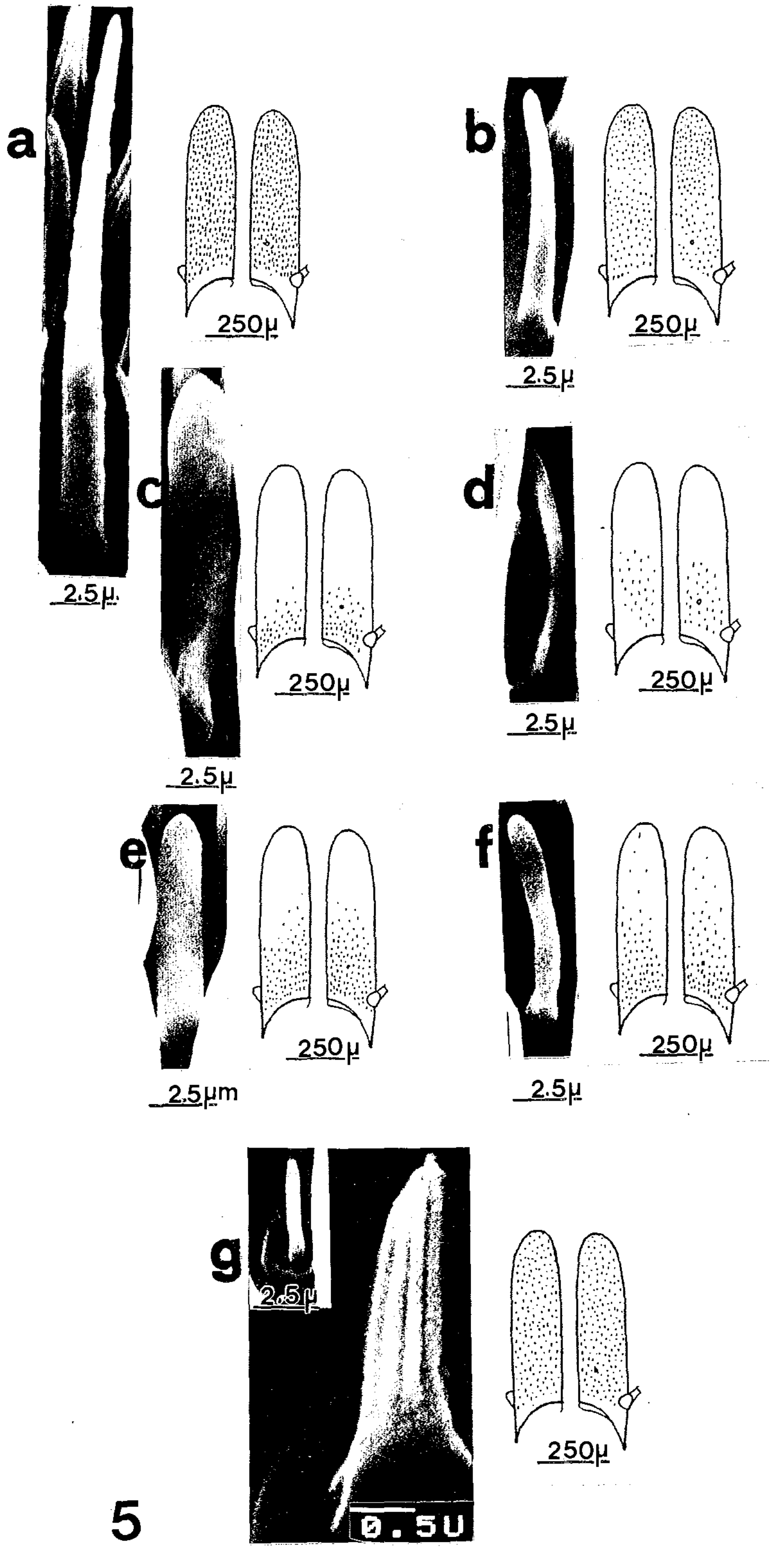

Fig. 5. SEM of each sensillum type (left) and its distribution (right) on the funiculus. a/ Trichoid sensillum type I, b/ Trichoid sensillum type II. c/ Clavate sensillum type I. d/ Clavate sensillum type II. e/ Basiconic sensillum type I. f/ Basiconic sensillum type II. g/ Styloconic sensilla.

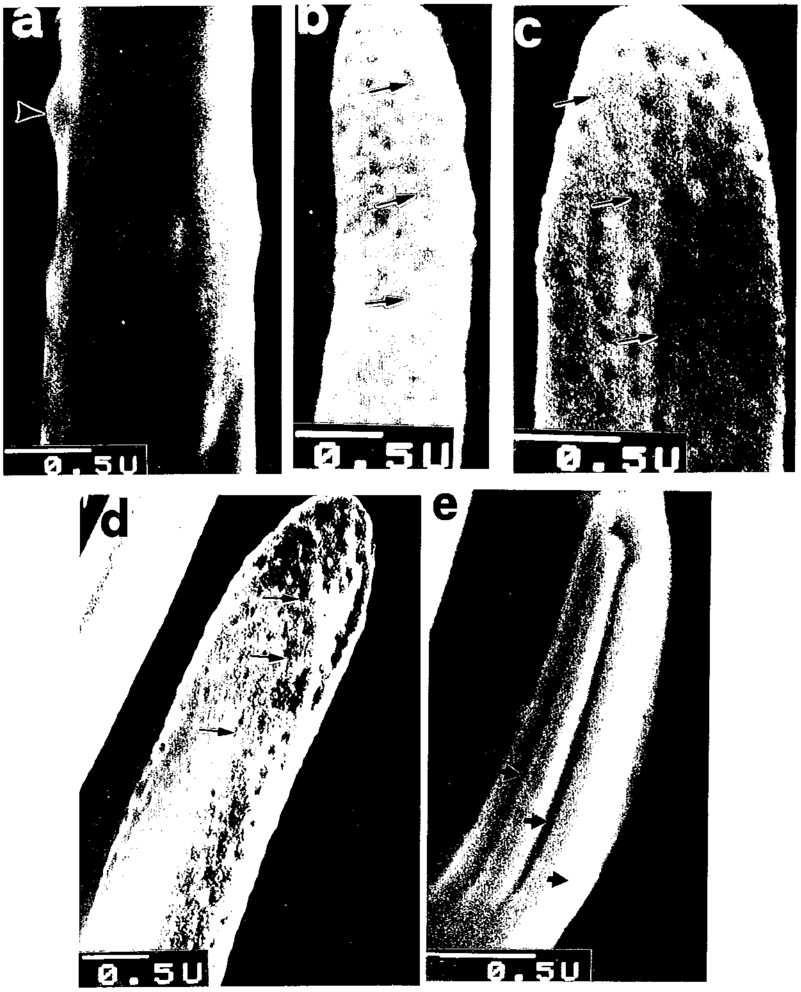

Fig. 6. High magnification SEM showing sensilla morphological characteristics. a/ Trichoid sensillum type I with nobules on the surface (Triangle). b/ Trichoid sensillum type II with pores (small arrow). c/ Clavate sensillum with pores (small arrow), d/ Basiconic sensillum with pores (small arrow). e/ Styloconic sensilla with grooves (short tail arrow).

pedicel are mechanoreceptors similar to those of *Dacus tryoni* (Giannakakis and Fletcher 1985) and the cuticular mechanoreceptors described by McLver (1975). Using electrophysiological recordings, Dickens et al. (1985) reported that the pedicel and scape sensilla of four tropical species of tephritid flies were also mechanoreceptors.

In this investigation, seven sensilla morphological types were observed on the funiculus of *D. dorsalis*, six have pores; one, longitudinal grooves. In *D. tryoni*, 5 types of sensilla can be distinguished through scanning electron microscopy: 2 types of trichoid, 1 type of clavate, 1 type of basiconic, and 1 type of styloconic sensilla (Giannakakis and Fletcher 1985). *Stomoxys calcitrans* has 6 funiculus sensilla types:1 trichoid type, 3 basiconic types, 1 clavate type, and 1 grooved type (Lewis 1971). *Musca autumnalis* has 1 trichodea type, 2 basiconic types and 1 grooved type sensilla (Bay and Pitts 1976). The *Drosophila melanogaster* funiculus appears to have 4 surface hair types; sensilla basiconica, sensilla coaloconica, sensilla trichodea, and uninnervated hairs or spindles (Venkatesh and Singh 1984). Sensilla in the funiculus sacculus *Drosophila melanogaster* are divided into 4 subgroups; grooved, basiconic, and blunt-tipped (distributed in 3 different cavities) (Itoh et al. 1991). The cabbage root fly , *Delia radicum* antennae appear to have 4 types of funicular sensilla: trichoid, basiconic, clavate, and grooved (Ross and Anderson 1987). Of Dipterans so far studied, types of sensilla vary in different species.

The trichoid types I, II distribution and the styloconic sensilla on the funiculus is uniform.

Similar to those of *D. tryoni* (Giannakakis and Fletcher 1985), the trichoid type I sensillum is more prolific than the other two sensilla in both sexes of *D. dorsalis*. Appearing predominately on the proximate part of the funiculus in *D. dorsalis*, the clavate sensilla distribution pattern is similar to those of *D. tryoni* (Giannakakis and Fletcher 1985), *Stomoxys calcitrans* (Lewis 1971) and *Delia radicum* (Ross and Anderson 1987); but the basiconic sensilla show different distribution.

The number of funicular sensilla is 1144 on the external surface and 1052 on the internal surface of the males; and 1184 and 1026 on the females observed. These findings are almost the same as those of *D. tryoni*, 1,148 on external surface 1,016 on internal surface in the males and values of 1,201 and 1,293 in the females. (Giannakakis and Fletcher 1985). It might be considered that both sexes have almost the same olfactory response to the host fruit volatile.

The male flies strongly respond to the attractant with methyl eugenol (Stainer 1952), which might be imitating a sexual odor, prompting speculation that it was possibly a food odor which only males require (Howlett 1915, Cunningham 1989). The females are attracted by the pheromone produced by males (Kobayashi et al. 1978, Lee et al. unpublished data). Both males and females of *Dacus oleae* emit the pheromone and reciprocal chemical communication may be reflected in the equally well-developed antennae of both sexes (Hallberg et al. 1984). The female of *D. tryoni* responds to male pheromone (Fletcher and Giannakakis 1973). Male moths, possessing large numbers of long, single walled sensilla, indicated a high sensitivity to the pheromones emitted by the females, whereas the females lacking these did not (Kaissling 1971). The chemical response mechanism of the sensilla still remains obscure. However, several authors believe that some proteins in the sensillum lymph serve to carry a hydrophobic odorant (Van Dan Berg and Ziegelberger 1991, Vogt 1987, Vogt and Riddifort 1986). The sensillum lymph of the male moth contains an abundant quantity of (10 mM) soluble polypeptides the pheromone binding protein (Kaissling and Thomson 1980, Vogt and Riddiford 1981). These pheromone molecules produce a sensory cell (Glenn 1993). It might be postulated for the antennal sensilla of *Dacus* flies that their sensillum lymph contains different kinds of proteins in male and female antennal sensilla. Those in the male bind methyl eugenol odorous molecules and the female bind pheromones.

Based on morphological observations, it may not be possible to identify sensilla functions; electrophysiological studies of each type of sensilla need further investigation. Lewis (1971) discussed the relative efficiency of the sensilla on the funiculus in *S. calcitrans* and *Aedes aegypti* (Davis 1976, McLver 1978); different types of sensilla receive stimulant molecules by diffusion or convection within the air layer closest to the antennal surface. Porous cuticular structures and the number of each sensillum are essentially devices through which odorous molecules may diffuse to the receptor membranes within the sensilla. The efficiency molecules are intercepted by a sensillum may depend upon its surface area and antennal location. Lewis (1970) stated that the more open the sensillum structure, the more readily molecules may permeate receptors sites. At any one location, small procumbent or unevaginated sense organs are not significantly less exposed to odorous molecules than long sense organs. The advantage of long sense organs is a larger interception surface area.

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東方果實蠅(*Dacus dorsalis* Hendel)觸角感覺毛形態之研究

李文蓉　章瑞駿　黃毓斌　林泰郎

利用掃描電子顯微鏡技術研究東方果實蠅*Dacus dorsalis*觸角感覺毛外部形態。東方果實蠅之觸角結構，雌蠅與雄蠅相同，包括有柄節(Scape)，梗節(Pedicel)和鞭節(Funiculus)三部份。柄節和梗節上著生有豐富的細毛(Microtrichia)和剛毛(Chaetae)。鞭節上具有七種不同型態之感覺毛(Sensilla)遮覆於細毛下方，這七種感覺毛可歸屬4類，它們是毛狀感覺毛(Trichoid Sensilla) I 型和 II 型，棒狀感覺毛(Clavate Sensilla) I 型和 II 型，突出感覺毛(Basiconic Sensilla) I 型和 II 型，以及時針感覺毛(Styloconic Sensilla)。這些感覺毛之外部形態特徵及其在鞭節上著生分佈情形和數目，均詳細研究觀察並報告於原文。

關鍵詞：鞭節, 外部形態, 掃描電子顯微鏡技術。