A Study on the Sensory Structure, in Relation to Some Behavioral Ecology of the Oriental Hornet (*Vespa orientalis* L.) (Hymenoptera: Vespidae)

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Abstract: In the apiary of Assiut University, the oriental hornets, *Vespa orientalis* L., were trapped and collecting every three days by using modified wooden traps to know their fluctuation and population during their active season. Also, detect the differences on the morphology, ultra-structure, and behavior between the different casts (queen, daughter worker and male) of *V. orientalis*. In the present study, the fluctuation showed that hornet population began with a slight increase number during September which comprised about (12.3%). In October, a big jump occurred (52.5 %) in their number. By the first week of November, the number started to decrease (26.7%) and then disappeared at the second fortnight of November. Antenna plays an important and vital role during host finding and acceptance behavior in insect life. Like many insects, oriental hornet *Vespa orientalis L.*, use antennal chemo-receptors to detect the hosts during its active seasons. Scanning electron microscope (SEM) studies showed five types of sensilla (Chaetica, trichoidea, basiconica, placodea and coeloconica) were distributed on the antenna of the three different casts of the hornet. These function of sensillae possibly as chemo-, and tactile receptors, responding to movements of the antennae.

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Key words: Oriental hornet, *Vespa orientalis L.*, population fluctuation, morphology, sensilla, sensory structure, behavior.

1. Introduction

Wasps may be divided into the social wasps and the solitary wasps. Social wasps include the hornets, the yellow jackets and the large, mahogany-colored wasps known as the paper wasps. They live in communities consisting of males, females and sterile workers. The solitary wasps, including the mud daubers, potter wasps and digger wasps, produce no workers and build individual nests.

Adult wasps are largely carnivorous, or meat eaters and some also eat vegetable matter, such as overripe fruit. As a rule, young wasps are fed entirely on other insects or insect remains. Several species have economic importance, because they are among the pollinators of commercial crops, and some of them feed on such destructive caterpillars as the corn-ear worm and army worm. A species that is native to Africa is known to prey on the eggs of the rhinoceros beetle, an insect that causes immense damage in coconut-growing regions. Many parasitic varieties, which lay their eggs in the body or egg of the host, are useful in the control of some harmful pests such as aphids, codling moths, and bollworms. On the other hand, Oriental hornet, *Vespa orientalis L.* cause many damage on the hives of useful bees in the Assiut's region. It is considered recently the major pest and more dangerous for Egyptian beekeeping in Upper Egypt. Furthermore, it attacks and causes serious damages in many fruits orchards especially grapes, and dates before and after harvesting [1, 2]. The hornets are hovered near bee hives, attack and captures bee guard at hives entrances. Then they also catch forages from flowers [3, 4]. Sometimes, the hornets enter bee hives and carry off both larvae and pupae and fly back to their nests to feed their colony. Then, they cause weakness to the hives, and minimizing bee's productivity. The activity of hornets is low in winter, spring and summer. While it increases to reach maximum population in the autumn, particularly during October. It starts to fall down during November, and disappears in December [5- 7].

The aim of this paper is to throw a light to study the following aspects which play an important role in controlling the most dangerous pest for Egyptian beekeeping in Upper Egypt. Also, to highlight further researches and methods related to biological and chemical controls:

1- Determine the fluctuation of the oriental hornet population in Assiut region during active season.

2- Enhance the importance of those potential chemoreceptor organs, represented on the antenna of the three different casts (queen, worker and male) and try to relate their presence with the invasive behavior of this oriental hornet.

2. Material and Methods

2.1 Insect culture

In the apiary of Assiut University, the oriental hornets were trapped and collecting by using three modified wooden traps as follow: each trap was made of wooden bars and wire screen (45×65×80 cm), and attached to the top of the hive's box. It contains some died brood and honey combs to attract the hornet's individuals. All individuals were collected and recorded every three days to know their fluctuation and population during their active season (Sept-Nov 2006).

2.2 Scanning electron microscopy

The antennae of the different casts, queen, daughter worker and male (drone) of the oriental hornet, *V. orientalis* were taken out and fixed in Khal's solution. These preparations were dehydrated in ethanol series, followed by critical point drying and mounted on SEM stub, with double –sided sticky tape, on up- side down view to allow views on lateral, dorsal and ventral surfaces. Each stub was then sputter coated with gold- palladium for 5 minutes. Coated specimens were viewed on the screen of JEOL JSM T220 SEM, at voltage between 10 and 15 kV, at higher magnifications for identifications of sensillar types. Five specimens for each cast are photographed, and then sensilla are identified and compared. The scanning electron micrographs of this study are arranged in plates. Each plate represents the micrographs of each cast; plate 1, plate 2, plate 3, for queen, daughter worker and male, respectively. The terminology and nomenclature of all types of sensilla in this study are based on, but not identical with the studies of [8, 9].

3. Result and Discussion

3.1 The fluctuation of the oriental hornet, *V. orientalis* population:

In general, at the apiary of Assiut University region, the active season of oriental hornet started to appear in the last week of August until November. First of all, the results in (Figure 1) shows fluctuation in oriental hornet population from the first of September till the thirteenth of the November. The fluctuation showed that hornet population began with a slight increase in the trapped number during September which comprised about (12.3%) out of all hornet population. In October, a big jump in their number occurred (52.5 %), especially during the fourth week of that month. At the end of the last day of October, population recorded its peak activity (60.5 %). By the first week of November, the number of hornet started to decrease (26.7%). Then, it decreased sharply during the second week of November (0.5%) and started to disappear at the second fortnight of November. This part of the present study is confirmed by many authors in Egypt [1, 2, 5, 6, 7]. All of them mentioned that the hornet activity is very low in winter, spring and early summer. Then, gradually increase to reach the peak of abundance in autumn especially during October, decrease in November and disappear in December.

3.2 The morphology & ultra-structure on the antennae of the different casts of the oriental hornet, *V. orientalis*:

In the present study, scanning electron micrographs on the antennae of the three different casts (queen, daughter worker and male) of the oriental hornet show the appearances of five types of sensilla. Three types of sensilla, tricoidea, chaetica and basiconica are presented into two forms; (T1, T2), (Ch1, Ch2) and (B1, B2), respectively. On the other hand, scolopidia and coeloconica sensilla are classified into one form (Sc-Coe) on the antennae.

Sensillum chaeticum Ch1 has a peculiar shape; is large, short and with irregular longitudinal ridges on its surface. Sensilla basiconica B1 show unusual characteristic features. This form appears like a bend giant tree with some attached roots and pointed tip, and also with circular ridges on its surface. The structural features of the first form B1 are unusual in the sense that some of its characteristics are similar to those of sensillum chaeticum Ch1. One could assume that, this peculiar type becomes characteristics to vespidae insects. Also, T1 considered the second most common sensilla on the antenna of that oriental hornet. On the other hand, scolopidia and coeloconica sensilla scattered in very few numbers on the antennal segments.

The study contains tables (1 and 2) which represent the presence and abundance of the eight forms of sensilla, and the average number of each sensillum of the five types found on the first and second segments of the three casts of oriental hornet, respectively. Three micrographs of (1500×) magnifications have been chosen for counting the numbers of different types of sensilla on the three different casts. On the other hand, in table (2), it was noticed that ch1, co are very rare on the antenna of both male and queens. That doesn't mean they absent, but it could be explained that they are represented in a very few individuals in that frame according to the (1500×) magnifications.

As hypothesized that by [10], active insect that search out a specific food source or habitat using odor perception, tend to have a greater number of olfactory receptors than do generalist of very small insect that respond to environmental stimuli in more passive way. On the other hand, there are a relation-ship between behavioral ecology and sensory structure [11].

The Oriental hornet, *Vespa orientalis*

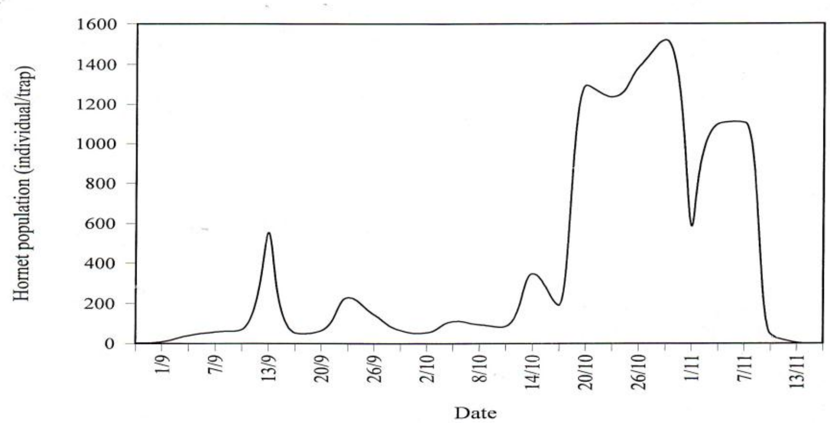


Fig. 1. Fluctuation of the oriental hornet population in Assiut region during active season (Sept. - Nov. 2006)

Table (1): The average number of the five types of sensilla (eight forms) found on the first and second segments of the oriental hornet (1500x magnification power).

Cast / Sensilla	Males	Workers	Queens
Scolopidia	1	0.98	0.62
Basiconica 1	0.75	1	0.68
Basiconica 2	0.69	0.50	1
Trichoidea 1	1	0.06	0.33
Trichoidea 2	1	0	0
Chaetica 1	0.24	0.75	1
Chaetica 2	0	0.2	0.46
Coeloconica	0	0	0

Sensilla trichoida (T)

Sensillum trichoideum is a setiform sensory hair. Two forms of this type have been identified on the antenna of *V. orientalis* L. The first form T1 is long stout hair. On the other hand, the second one T2 is shorter, and with a little pit curved end.

The two forms (T1, T2) are very most common on the head, antennae, eyes, tarsi, and mouth parts of the three casts. Although the first form of trichoid sensilla is the most common all-over the bodies. On the other hand, form two was the only one present on that (peculiar) island-shape structure on the antenna of the male. Form two has also been noticed on the antenna of both queens and workers of that hornet.

It is well known that among all insect sensilla, the trichoid in general have the greatest length and the thickest wall and function as olfactory receptors [12]. In contrast, the present study on the head, antennae, eyes, tarsi, and mouth parts of the three casts of the oriental hornet, trichoid sensilla present into two forms, neither of them is the greatest length or the thickest wall. Sensilla trichoidea act either as a contact chemo-recptors or as mechano-receptors [13]. Also, as reported by Azza Awad [14], the two forms on the external genitalia of the different casts of the oriental hornet. She assumed that, the features and topography of both form could be mechanoreceptors in function. Our opinions in this study about the trichoids, which function as mechano-receptive structure, are the most agreeable. However, thin walled and thick-walled sensilla and tactile receptors have been found on the antennae of various parasitic Hymenoptera [15]. These studies, in agreement with our results did not find any pore system on sensilla trichoidea and therefore no olfactory function could be attributed to this sensillar type.

Sensilla basiconica (B)

Sensilla basiconica show some kind of differentiation in its morphological features, presenting new structural data of sensory receptors in relation to specialized ecophysiology of the hymenopterous insects. It is considered as the most common type which characteristics to vespidae insect. Two forms also present this type of sensillum. The structural features of the first form B1 of this sensillum are similar to those of sensillum chaeticum Ch1 (a cone-like structure). This form is present on the antennae of the three casts. On the other hand, the second form B2 is quite similar to sensillum trichodeum T2. In addition, this type appears like a bend tree with some attached roots and pointed tip, and also with circular ridges on its surface. The later form is distributed on the antennae of three casts, more than the former.

Basiconica sensilla have an important sensory role in host location process [16]. They added that, the basiconic pegs are suggestive of gustatory function. Their role would be to respond to kairomones involved in host location, also to recognize a suitable host when one is encountered during probing and to mediate oviposition. basiconic pegs also appear to have a second role, thermo-hygro receptors on the antennae of a variety of insects [13]. In contrast to those suggestions, the present results revealed two forms of this type of sensilla. The first form B1 shows some morphological features and some of its characteristics are similar to those of sensillum chaeticum Ch1. On the other hand, the second form B2 is slightly shorter, thinner and quit similar to sensillum trichodeum T2. Agree with [14], who suggested that might considered this structure to be mechano-receptors and the purpose of these sensilla is to detect the external stimuli, such as those involved in monitoring the movement of the ovipositor during penetration into a substrate and also on antennae as external radar. The grooved surface with circular striations on sensilla basiconica B2 in the present study, enhance the significant difference from those described by other authors, and indicate the mechano-receptive functions of this structure. Our results for this type of sensilla agrees to some extend with those reported by [17]. He described basiconic sensilla of the muga silk worm with slight longitudinal striations on its surface. He also added that, the general morphology of those sensilla has some similarities with that of sensilla trichoidea. Sensilla chaetica were found by SEM on the glossa, labial palps, antennae and tarsi of the workers of honey bee were also denied the presence of sensilla basiconica on the antenna and glossa of the workers [18]. Disagree with them in this study, sensilla basiconica are the most abundant type of sensilla on the antennae of the three casts of *V. orientalis* L**.**

Sensilla coeloconica (Coe)

In this study, these sensory pit pegs sensilla appear in short or moderate pegs like-structure housed in cuticular oval pits. This coeloconicum sensillum is found only in few numbers on the antennae of males, while nothing could be noticed on the antenna of workers or neither queen.

Sensilla coeloconica located in sunken depressions and surrounded by a doughnut- shaped ring [19]. This type are also found in many Hymenopterans belonging to several families and have been described by different terminologies such as "small sub-terminal sensilla"; "multi-porous grooved sensilla"; "Bulb sensilla" and "smooth basiconic sensilla". An olfactory function of this sensillar type in Trichogramma nubilale suggested by OLSON & ANDOW [20]. But in several insect species, this sensillar type as thermo- or hygro-reception [13]. As described by Altner [21], coeloconic sensilla like pegs protrude above the surface of the cuticle, and he considered it as chemo- or thermo-receptors. In that case, the moderate long setae Co on the males and workers of the oriental hornet V. orientalis, assumed to have the same function. However, in that case, the structure may simply reflect a relatively short peg set in relatively deep socket. This could be due to the role of the antennae of males, or that of maxillary palps of the workers as a structure used to penetrate into substrate, hence they do not protrude far above cuticular surface. In addition, the deep socket gives the peg extra protection by preventing them from bending too far and possibly breaking off [22]. This hypothesis may agree with the present study, since Co on the males of V. orientalis appear as short pegs like - structure housed in cuticular oval pits.

Sensilla scolopedia (Sc)

Results of this study reveal the presence of only one form of that sensilla scolopidia on the antennae of the oriental hornet *V. orientalis*. This is considered the second type which appears more dominant as well as basiconica B2 sensilla, and also becomes characteristics to vespidae insect. Sensillum scolopidium (Sc) is noticed distributed and very common on the antennae of the three casts of the oriental wasps. The form Sc appears as simple cuticular scar or invaginated rod bearing no setae or peg. This cuticular scar is long and narrow on the antennae of the males. On the other hand, it is long but wider, may be oval like in shape on the antennae of queens and workers.

Many authors reported that type of sensilla on Dipteran insects like [10, 23, and 24]. [25] reported two forms of this sensillum on the larvae of *Aedes caspius* and *Culiseta longiareolata* and also, explained the presence of sensilla scolopidia on Anopheline and Culicine mosquitos as thermo-function organs. Since [26], this type of sensillum Sc, has been found in one form on the antenna of that Vespidae insects that may disagree with the hypothesis of Azza Awad [14], who found four forms of scolopedium sensillum on the external genitalia of that hornet. That could be explained the only function of that sensilum on the antenna of *V. orientalis* as thermo-receptors**.**

Sensilla chaetica (Ch)

Depending on the variations of length and shape, two forms represent this type of sensillum in this study. The first form Ch1 is large and short cone like-structure with irregular longitudinal striations or ridges on its surface. The structural features of the first form Ch1 of this sensillum are unusual and some of its characteristics are similar to those of sensillum basiconica B1 (a small cone-like structure). The second form Ch2 is long, but quit thinner than the first form and also with longitudinal striations or ridges on its surface. The later could be separated from trichoid sensilla T by its thick-walled and bristle like structure. No pores have been notice neither on tip nor on surface of both forms of this type.

This sensillum appears on head, labial and maxillary palps, glossa and paraglossa, and all over the leg with its large spine. On the other hand, it is not so common on the antenna of that hornet. The first form Ch1 has only been noticed in few numbers, on the antennae of queens and workers. At the mean time, this form was absent and unnoticeable on the antennae of males.

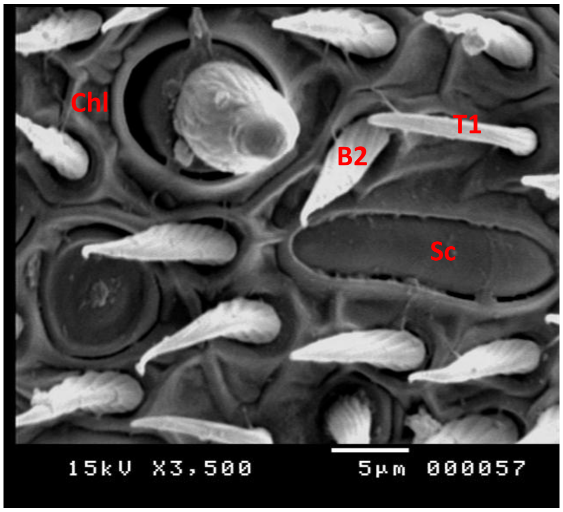
This study agrees with the opinion of many authors, which said that attention has been only focused on the importance of potential olfactory receptor organs on nearly all species of that wasp [19]. Also, Quicke [27] added that little consideration has been given to the role of chemo- and mechano-receptors on the antennae and ovipositor of those wasps and may be important in host discrimination and association. Again, Ochieng *et al*. [19] reported that sensilla chaetica may serve as mechano-function in *Microplitis croceipes*. On the other hand, Tawfik and Awad [28] reported the presence of two forms of sensilla chaetica on the antenna of the desert locust, *Schistocerca gregaria*. They considered the first tactile form as an organ of touch. While the second form with one pore on its tip was reported as chemo-function organ. So, that is may also indicate the dual olfactory and mechano-function of this sensilla and support the theory of sensillar plasticity in social and gregarious insects. Since, in this study, the sharp and pointed setae Ch2 are similar to the mechano-receptors sensilla trichoidea T1, and the first form of chaetica sensilla Ch1 is large and short cone like- structure with irregular longitudinal ridges or striations on its surface and have no pores. Therefore, from the morphological point of view, present result might go with all previous opinions and studies about mechano-function of sensilla chaetica.

Some authors have studied various properties of the cuticle of the oriental hornet wasp, such as the photoelectric properties [29-31]. Subsequently, they studied the effect of xanthines and colchicine on those properties [32, 33] and the temperature dependence on the electric resistivity [34]. Additionally, they studied the conditions which effect the electric capacitance [35] and furthermore, the luminescence of the hornet cuticle [36]. They added; there is solid evidence that the temperature in the nest of hornets (Vespidae) is constantly set to 29 °C [37-42]. It may also be presumed that thermoregulatory sensors are distributed throughout the hornet cuticle and all over the body of their casts. [14], pointed to those characteristics sensilla found in two forms on the-external genitalia of the oriental V. orientais L. She was also assuming that, this type of sensillae (form 2) may play a big role in the sense of movement as a tactile sensillae. On the other hand, one could consider the first form as thermo-regulators receptors.

In that case, this could explain the presence of type two on the male, while first form is absent. Both forms are noticed on the antennae of the workers and queens of that hornet.

So, for all the previous reasons and discussions, this study tried to focus on sensilla found on the antennae of the different casts of V. orientalis L. Again, it could be a trial to figure out the relation-ship between morphology, and ecophysiology and behavior of that oriental hornet.

Plate 1. Queen of *Vespa orientalis*



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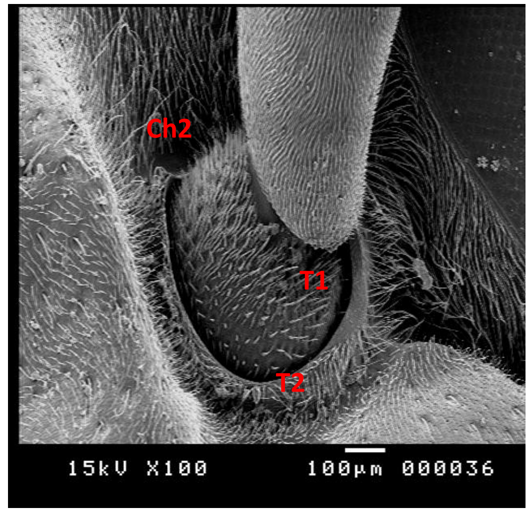

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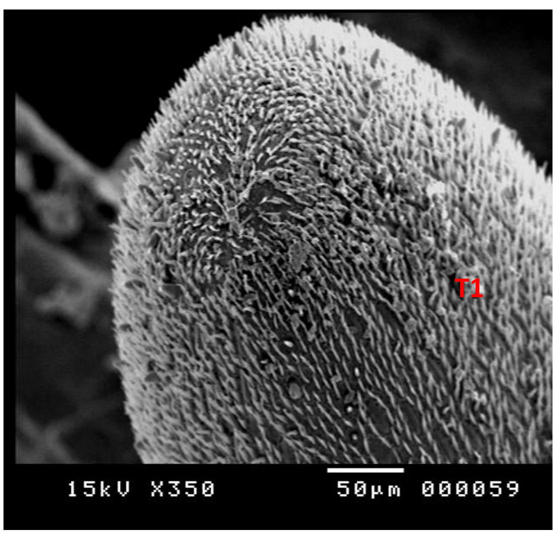

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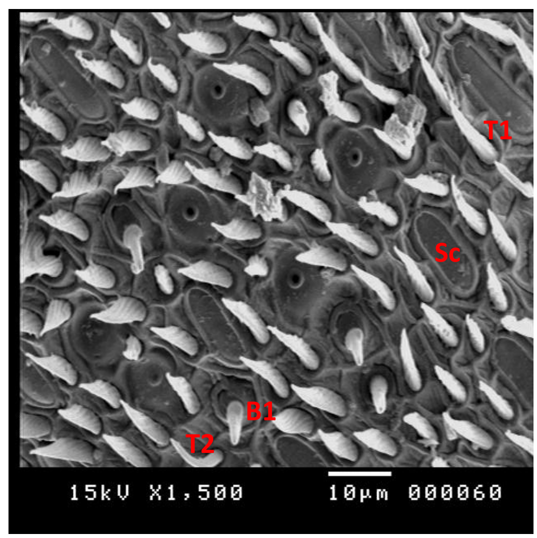

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Plate 1, shows the antenna of the queens of *Vespa orientalis L.*

Micrograph 1- high magnification for the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Micrograph 2- the pedicel of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1) and T2.

Micrograph 3- the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Micrograph 4- high magnification for the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Plate 2. Male of *Vespa orientalis*

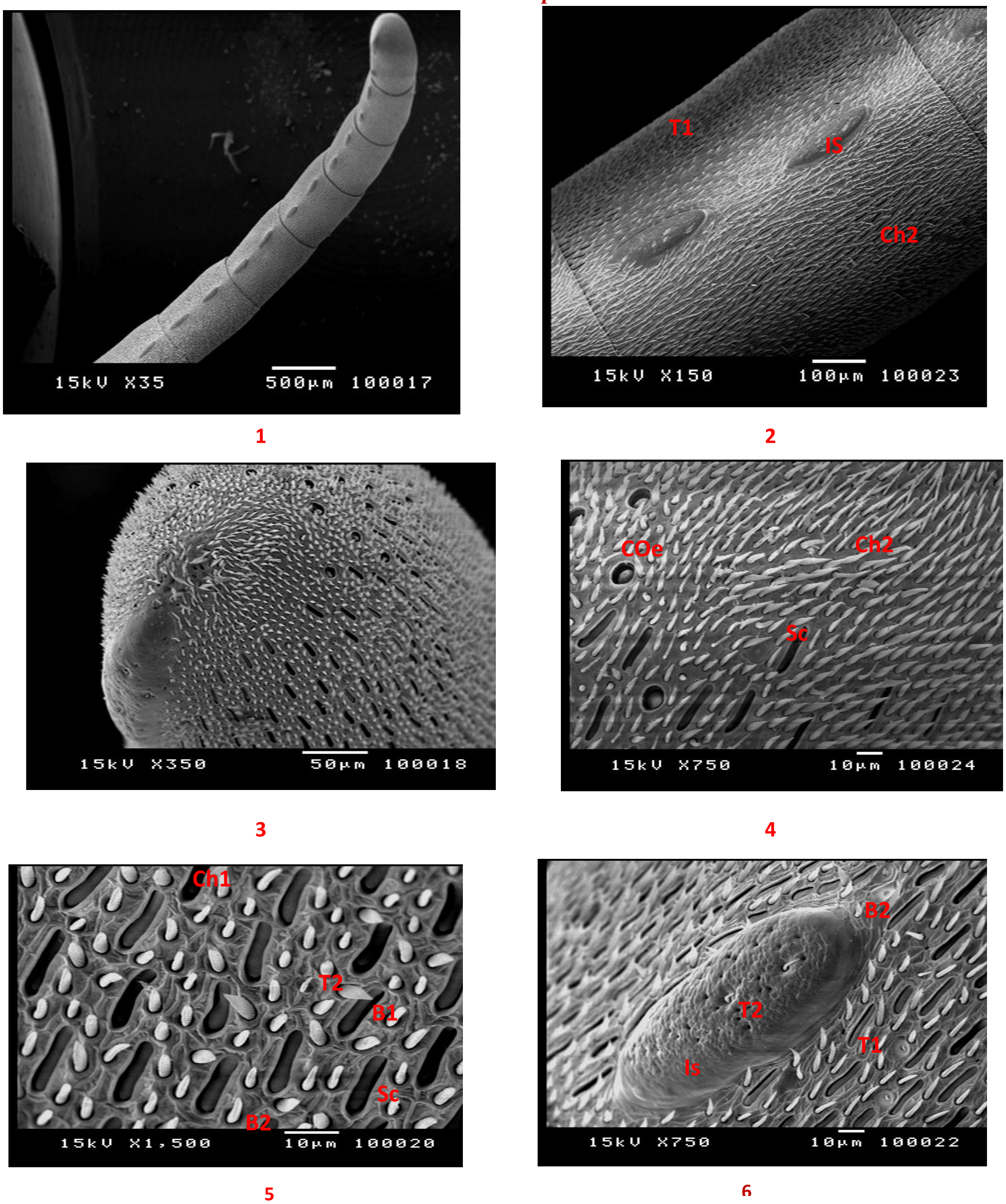


Plate 2, shows the antenna of the male of *Vespa orientalis* L.

Micrograph 1- low magnification shows the antennal segments with two islands like structure on the ventral side of each one.

Micrograph 2- the antennal segments with two islands like structure on the ventral side of each one.

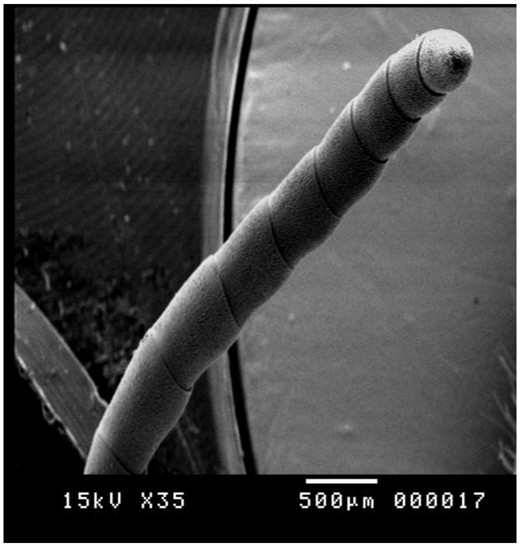
Micrograph 3- the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Micrograph 4- shows the presence of coeloconica sensilla(coe), with the elongate and oblong scolopedea sensilla (sc), trichodea sensilla (T1), and basiconica sensilla (B2).

Micrograph 5- high magnification for the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Micrograph 6- shows the presence of trichoidea sensilla (T2) on the island like structure.

Plate 3. Workers of *Vespa orientalis*



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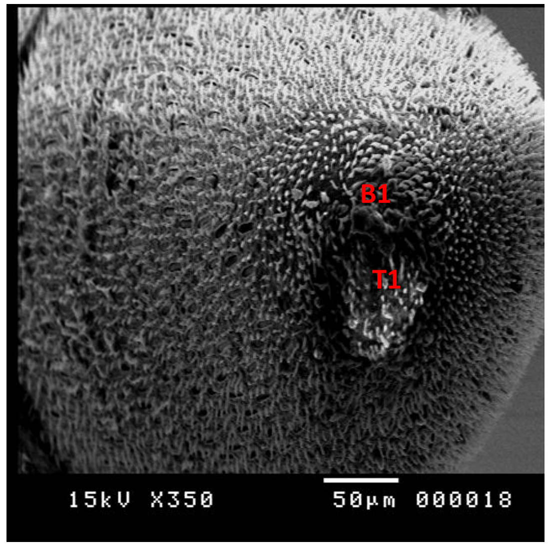

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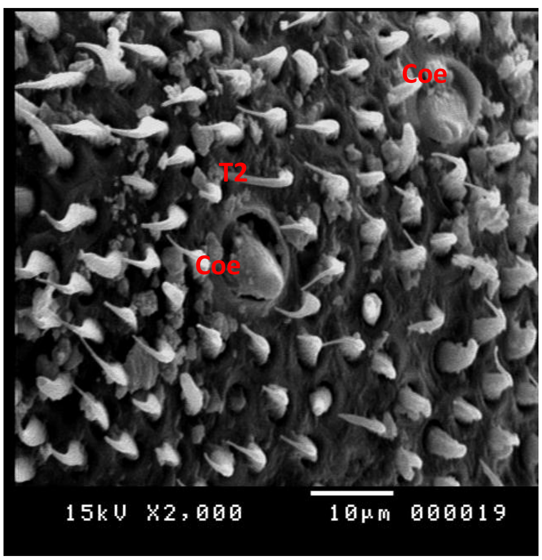

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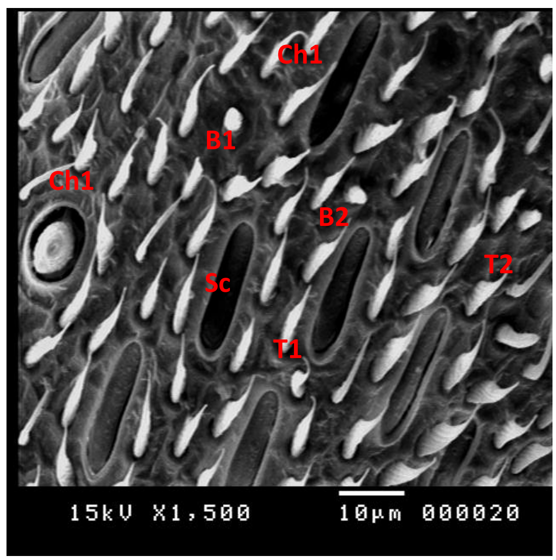

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Plate 3, shows the antenna of the Workers of *Vespa orientalis*

Micrograph 1- low magnification shows the antennal segments.

Micrograph 2- high magnification for the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), and basiconica sensilla (B2).

Micrograph 3- high magnification shows the more banded basiconica sensilla (B2), chaetica sensilla (ch1) and the very rare coeliconica sensillum (coe), and trichoidea sensilla (T2).

Micrograph 4- high magnification for the tip of the antenna shows: chaetica sensilla (ch1), trichodea sensilla (T1), basiconica sensilla (B2), and scolopedea sensilla (sc).

Table (2): The presence and abundance of sensilla on the three casts of *Vespa orientalis*

Cast / Sensilla	Queen	Male	Worker
B1	Moderate	Moderate	Moderate
B2	Dominant	Dominant	Dominant
T1	Dominant	Dominant	Dominant
T2	Moderate	Moderate	Moderate
Ch1	rare	Few	Few
Ch2	Moderate	Moderate	Moderate
SC	Wide oblong	Elongated oblong	Oblong
Coe	Very rare	Few	moderate

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