Morphology and Distribution of Thermo- Hygro-Ir- and Chemo-Receptors for Females of Family Diaspididae (Hemiptera: Sternorrhyncha)

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ABSTRACT

The comparative study of the female body structures of many species of Diaspididae has been done using Leica microsystems. Several types of sensilla were described for three species namely: Parlatoria zizyphi, Lepidosaphes ficus and Lepidosaphes beckii. Four thermo-hygro-sensory species as sensing organs for temperature and humidity, namely plachodea in lepidosaphes beckii, sensilla basiconica and styloconica in Parlatoria zizyphi, sensilla caeloconica in lepidosaphes ficus and tuft organ in lepidosaphes ficus; One type of gustatory receptor is a styloconica in Parlatoria zizyphi; infrared receptors (IR), also in Parlatoria zizyphi; olfactory organs such as sensilla placodea in Parlatoria zizyphi. Measurements of sense organs in different species were done using ocular micrometer. Also, dimension measurements of each sensillum of temporary and permanent females mounts were done. According to these comparative studies, the general regulation of sensilla was assumed to be Diaspididae. Eight sensory phenotypes were identified, with an attempt to use these data at the systemic level. The results of this study provide an important basis for linking morphological characteristics of sensory organs to insect behavior and should stimulate the development of effective quasi-chemistry-based control strategies against species belonging to the diaspididae.

Keywords: Diaspididae, IR, Thermo-hygro-receptors, gustatory receptors, olfactory receptors.

INTRODUCTION

Insects are particularly interesting models of flexible sensory control. Although early descriptions often depicted insects as simple robots, "depriving them of any part of intelligence", careful observation since then has revealed that insects' locomotor patterns are, in fact, remarkably adaptable (Kirby and Spence, 1822).

Hemipterans, distinguished by their piercing, sucking mouthparts, constitute one of the most diverse and economically important insect orders (Weintraub and Beanland, 2006). Within this group, Sternorrhyncha (aphids, psyllids, scale insects, and whiteflies) play a very important ecological and economic role as plant pests and virus vectors (Eastop, 1977, Hühnlein et al., 2016).

Insects regulate their body temperatures through a process known as thermoregulation. Historically, insects have been categorized as thermophiles (animals whose body temperatures vary and depend on their environment) rather than isotherms (animals that maintain a constant internal body temperature regardless of external influences). The ability of insects and other animals to maintain a consistent temperature (either above or below ambient temperature), at least in portion of their bodies, by physiological or behavioural mechanisms is known as temperature regulation, or thermoregulation (Heinrich and Bernd, 1993). Some insects are endotherms (animals that produce heat internally by biochemical processes), whereas others are ectotherms (animals whose primary source of heat is from their environment). Because they are not all uniformly endothermic, these endothermic insects are best classified as heterothermic. When heat is produced, different body sections maintain distinct body temperatures. For instance, before taking flight, mites develop heat in their thorax, but their abdomen is kept relatively chilly (Heinrich and Bernd, 1981).

Insect survival is mostly impacted by moisture because it changes their water content. It might not be hazardous to be exposed to dry or wet circumstances if humidity can be kept within specific bounds. By looking for an appropriate environment, insects are able to maintain a constant water balance. Experiments in numerous species have shown that responses to moisture selection depend on the presence of future sensitivities to moisture. This sensory is visible from the outside as tiny ice wedges that protrude from the antennae's surface or are set into crevices. It has two different kinds of moisture receptor cells that react to variations in humidity in opposing ways. Dry air causes a drop in the discharge rate of one type whereas wet air increases it. They were referred to as "wet" cells. The second type of cells, referred to as "dry" cells, have a higher discharge rate in dry air and a lower discharge rate in moist air. The "cold" heat-receptive cell type and both types of moisture-receptive cells coexist in the same way (Altner et al., 1982, Steinbrecht, 1999; Tichy and Loftus, 1996; Yokohari, 1999; Tichy and Gingl, 2001).

Different substances in environment can be detected by insects. Olfactory receptors may detect these substances as scents (smells) when they are present in gaseous form (in relatively low concentrations). They are regarded as tastes by gustatory receptors when they are present in solid or liquid form (often at higher concentrations). While the sense of smell typically entails the detection of substances in gaseous or airborne form, the sense of taste typically entails...
RESULTS AND DISCUSSIONS

The first sensory organs or foci on the female armoured scales were the prosoma, which symbolises the merger of the head region, and the postoma, which symbolises the connection of the end of the thorax and belly. The morphological properties of female armoured scales were studied at a high magnification level of 100-fold. There were found to be clusters of organelles and structures that resembled other insects' sense organs. The functional roles of these organs in past studies have not been elucidated, and they have not been explained by an unexpected repeat interpretation. Microscopy revealed that mechanical and chemical sensory organs were a set of foci and organs that resembled the sensory organs found in other insect species.

These insects, which are members of the Diaspididae, have a set of sensilla that have been identified; these sensilla have been enumerated in various parts of the insects' bodies and linked to sensilla in other insect species based on their location, related morphological traits, and determination of their functional significance.

a. Plachodea without pore as thermo-hygro receptor and mechanoreceptors

They were found in similarity in the prominent side lobes of Lepidosaphes beckii in the form of transparent circular discs as thermo-hygro receptors and mechanoreceptors, surrounded by a group of conical sensory bristles as the type of trichodea, these sensilla feel the environment surrounding the insect body as movement of wind or predators and sensation of heat and humidity (Figure 1). They are with dimensions of 0.093 ± 0.031 μm diameter (Table 1).

The presence of a pair of cells of the sensillum may give it a dual function. One of the two sensory cells may act as a mechanical receptor, and the other neuron acts as a receptor for heat and moisture, as shown in Figure 1, where by tracking the sensory organ, it was found a pair of nerve extensions that lead to two neurons.
Figure 8. It is possible that it senses the temperature and humidity of the atmosphere and the juice in the leaf of the plant. (Nabil et al., 2019) and (Abd-Rabou and Farag, 2014) studied on seasonal fluctuations of P. ziziphi who concluded that a directly proportional was found between temperature and the predicted population of P. ziziphi, which could provide a valuable tool in monitoring, managing and controlling pests spread in the coming future.

Fig. 2. Sensilla basiconica as Thermo-hygroreceptors sensilla in Parlatoria zizyphii

c. Styloconica as thermohygroreceptors and gustatory receptors

During tracing the sensory organs in P. zizyphii as in (Figure 3,a), it is found on the edges on both sides of the prosoma and the bottom of the atrial appendage on both sides four sensory organs combined at a distance of 13 μm away from the base of mouth parts and they are all of the styloconica type. The dimensions of one organ were 0.033 ± 0.031 μm in length and 0.064 ± 0.011 μm in width (Table 1).

Here the member of S. styloconica in P. zizyphii, as shown in (Figure 3,b), appeared in the form of ten domes with a single transverse opening in the shape of a crescent in the space between the bases of the styloid mandible or the arms of the tentorium. The dimensions of one of them are 0.29 ± 0.12 μm in width and 0.09 ± 0.02 μm in length. This organs are used by the insect to taste the plant juice before feeding (Table 1).

In addition, next to the first pair of stomata on both sides of the mouthparts, four members of S. styloconica are found in the form of domes with one round orifice (Figure 3,c). The dimension of the organ was 0.038 ± 0.013 μm diameter (Table 1 and Figure 3). These observed pores were not mentioned in previous researches as one of the sense organs, but they were identified as they responsible for the waxy secretion of the waxy cover (Takagi, 1990). However, it is not possible for a waxy secretion to occur in the path of the respiratory stomata, where it blocks the stomata and it is more precisely that its role as a sensory organ responsible for taste, especially which the openings responsible for the waxy secretion are on both surfaces of female bodies. This finding needs more studies to prove it.

d. Sensilla Caeloconica as thermohygroreceptors

Devices made of Sessilium coeloconica have the ability to absorb heat and moisture. The cuticular organ of sensation is a poreless, mushroom-shaped protrusion that is concentrically positioned within a shallow cuticular depression. The edge can have pores. Three or four receptor cells are possible. Unbranched sensory cilia on three receptor cells are filled with tightly packed microtubules that extend deep into the dermal apparatus and entirely fill its lumen. One of the three ramifications is "wet," another is "dry," and the third is "temperature." (Coeoconic literally translates as "peg in a hole"). Beekeeping research. And this is what we discover, which is consistent with Lepidosaphes ficus: at the end of the prosoma region on both sides, four sensory organs of the type Caeloconica S. were discovered, as shown in Figure 4, as it was thought that they play a part in determining the hibernation period by sensing the low temperatures in the surrounding environment, as it occurs in hibernation of species that belong to the genus Lepidosaphes. In their 1995 research of the Lepidosaphes ficus life cycle, Carrillo et al., 1995 discovered that this species was monovoltine, with hibernation taking place in the egg stage. The sensory organ has dimensions of 0.063 0.031 m and 0.044 0.011 m (Table 1). The thermo-hygroreception sense nerve. They are rigid, peg-like structures that are encased in the cuticle's hollow. All members of the Corixidae family have these sensilla, according to Agnieszka et al. (2020), but only one of them has a pore at the tip. They also have a nonporous surface.

Fig. 3. Different sensilla styloconica as thermohygroreceptors sensilla in Parlatoria zizyphii a, on the edges of both sides of the prosoma; b, between the bases of the styloid mandible; c, both sides of the mouthparts as gustatory receptors.

Fig. 4. Sensilla caeloconica thermo-hygroreceptors sensilla in Lepidosaphes ficus

e. Tuft organ as thermohygroreceptors

A pair of tuft members at the end of the pygidium region is found at both sides in L. ficos as shown in Figure 5 where three cavities are found, inside each of them a pair of

Fig. 5. Tuft organ as thermohygroreceptors sensilla in Lepidosaphes ficus

A pair of tuft members at the end of the pygidium region is found at both sides in L. ficos as shown in Figure 5 where three cavities are found, inside each of them a pair of
finger appendages on both sides, next to the second lobe at the end of the pygidium outward the position of the horns. The anal area of ordinary insects, as for its role, is to sense the heat and humidity of the female at the posterior region, where the place of laying eggs to feel the appropriate temperature where the female expects to laid eggs. These organs are very similar to the Tuft organs at the end of the antenna of the human louse Pediculus humanus. Insauroralde et al. (2019) identified Two tuft organs, one located at the dorso-lateral side of F2 and the other at the dorso-lateral side of F3. Each tuft organ consist of a deep and circular pit (3.54 ± 0.21 μm diameter) from which six pegs emerged and each with a mean length of 3.31 ± 0.18 μm

Similarly, the same six number of finger appendages were found in the current study at the end of the L. ficus and emerge from three deep oval cavities (Figure 5). The dimensions of the first cavity, which is the largest of them, are in-between the other two cavities (1.44 ± 0.21 μm in width and 2.56±0.42 μm in length). The second cavity on the left was 0.57 ± 0.11 μm in width and 1.76±0.35 μm length. The third one on the right is closed to second cavity in dimensions of 0.49 ± 0.12 μm in width and 1.46±0.32 μm in length (Table 1).

**Fig 5. Tuft organs as Thermo-hygroreceptors sensilla in Lepidosaphes ficus**

**Table 1. Morphometry (length and width) of sense organs present on females bodies of some species belonging to diaspididae.**

<table>
<thead>
<tr>
<th>Species diaspid</th>
<th>Species sense organs</th>
<th>Name of sense organs</th>
<th>Length</th>
<th>Width/ Diameter</th>
<th>Range</th>
<th>Mean ± SE</th>
<th>Range</th>
<th>Mean ± SE</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Parlatoria zizyphii</em></td>
<td>Thermo-hygro receptors</td>
<td>Basiconica</td>
<td>0.042-0.064</td>
<td>0.033 ± 0.011</td>
<td>0.047-0.05</td>
<td>0.049 ± 0.02</td>
<td>0.033</td>
<td>0.047</td>
</tr>
<tr>
<td></td>
<td>Thermo-hygro receptors</td>
<td>styloliconica</td>
<td>0.002-0.064</td>
<td>0.033 ± 0.031</td>
<td>0.053-0.075</td>
<td>0.064 ± 0.011</td>
<td>0.033</td>
<td>0.053</td>
</tr>
<tr>
<td></td>
<td>Gustatory receptors</td>
<td>Styloliconica 1</td>
<td>0.07-0.11</td>
<td>0.09 ± 0.02</td>
<td>0.17-0.41</td>
<td>0.29 ± 0.12</td>
<td>0.07</td>
<td>0.17</td>
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<td></td>
<td>Styloliconica 2</td>
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<tr>
<td></td>
<td>infrared receptors</td>
<td>infrared receptors</td>
<td>0.061-0.065</td>
<td>0.063 ± 0.021</td>
<td>0.39-0.43</td>
<td>0.041 ± 0.029</td>
<td>0.061</td>
<td>0.39</td>
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<tr>
<td></td>
<td>Offactory organs</td>
<td>Sensilla placodea</td>
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</tr>
<tr>
<td><em>Lepidosaphes ficus</em></td>
<td>Thermo-hygro receptors</td>
<td>Tuft organ (cavity 1)</td>
<td>2.13-2.95</td>
<td>2.56±0.42</td>
<td>1.23-1.64</td>
<td>1.44 ± 0.21</td>
<td>2.13</td>
<td>1.23</td>
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<tr>
<td></td>
<td></td>
<td>Tuft organ (cavity 2)</td>
<td>1.41-1.76</td>
<td>1.76±0.35</td>
<td>0.46-0.68</td>
<td>0.57 ± 0.11</td>
<td>1.76</td>
<td>0.46</td>
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<tr>
<td></td>
<td></td>
<td>Tuft organ (cavity 3)</td>
<td>1.14-1.78</td>
<td>1.46±0.32</td>
<td>0.37-0.51</td>
<td>0.49 ± 0.12</td>
<td>1.78</td>
<td>0.37</td>
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<tr>
<td></td>
<td>Thermo-hygro receptors</td>
<td>Caeloconica</td>
<td>0.34-0.92</td>
<td>0.063 ± 0.031</td>
<td>0.033-0.055</td>
<td>0.044 ± 0.011</td>
<td>0.34</td>
<td>0.033</td>
</tr>
<tr>
<td><em>Lepidosaphes beckii</em></td>
<td>Thermo-hygro receptors</td>
<td>Plachodea</td>
<td>0.062-0.14</td>
<td>0.093 ± 0.031</td>
<td>0.062</td>
<td>0.093</td>
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**SE, Standard error**

It is consistent with the findings of Schmitz et al. (2007) who discovered that IR receptors are housed in extra-antennal sensory organs, which can be located on the thorax or on the abdomen, that infrared (IR) radiation is present below the mouth parts in *Parlatoria zizyphii*. *Melanophila acuminata*, a pyrophilous beetle, has infrared receptors and the sensory neurons that go along with them that are descended from mechanoreceptors.

It might be because these insects require the use of infrared (IR) radiation sensing to determine whether their environment is suitable for their biological tolerance. It differs with the findings of Schmitz et al. (2007) who claimed that fire-loving (pyrophilous) insects depend on forest fires for their reproduction since it has a chance to leave the unsuitable environment that it despises, aside from foregoing egg-laying. These insects approach active fires and swarm into the burned area right after a fire. These insects have specific smoke and infrared (IR) radiation sensors for long-range navigation toward a fire as well as for short-range orientation on a freshly burned region, whereas the antennae are home to the olfactory receptors for smoke. Iron biomineralization has also been observed in honeybees (*Apis mellifera*), which forms the basis...
for magnetoreception. showed earlier that superparamagnetic magnetite was present in the iron granules produced by honeybees, and they agreed with the theory that external magnetic fields might cause the superparamagnetic particles to expand or contract in a way that is specific to their orientation, transmitting the signal via the cytoskeleton (Hu and Li, 1994).

Here, we find that armed scale insects may have (IR) to help them find the appropriate time for laying eggs, while in fire-loving insects, their guide is by infrared rays to reach them.

g. Sensilla placodea as olfactory receptors

Insect olfaction is the ability of chemical receptors to detect and identify volatile substances, which enables insects to forage for food, avoid predators, find mates (through pheromones), and choose homes for laying eggs. It is therefore the most significant feeling for insects (Carraher et al., 2015). Insects should ideally time their most significant behaviours, which depends on their fragrance and when they smell Kadenne et al. (2016). For instance, many insect species depend on scent to find food sources and hunt for prey; this is true of the sensory organs of smell used by Diaspididae.

At the end bodies of P. zizyphi females and according to microscopic examination there were openings known as Perivulvular pores and Prevalvular pores. Their functional role has been described as the possibility of secreting a substance to prevent egg agglomeration during egg laying (Takagi, 1990). On the other hand, according to its morphological shape, it is a sensory organ responsible for smelling as placodea. This organ consists of 4 groups around the genital opening (fig. 7). The two groups before the genital opening included 5-6 sensory organ and the two groups next to the genital opening include 9-11 sensory organ. The organ was a plate that includes 9-11 opening with mean dimension of the sensory organ of 0.51 ± 0.11 μm diameter.

Fig. 7. Sensilla placodea as olfactory sense organs in *Parlatoria zizyphi*

According to Onagbola et al. (2008); Li et al. (2020); and Visser. (1986), Diaspididae may be able to accurately detect and recognize various odors from their environment, which influences insect behaviour such as host choice and egg-laying decisions. In addition, Pratibha and Renee (2017) suggested that the insect ovipositor is an olfactory responsive organ to volatiles and carbon dioxide in gaseous form. This phenomenon is demonstrated in parasitic wasps connected to *Ficus* racemosa.

However, ovipositors have far fewer and smaller sensilla compared with antennae; this may explain an almost complete absence of studies on electrophysiology of ovipositors. The few conducted studies have been mostly recorded as gustatory sensilla (Rice, 1977; Cmjar et al., 1989; Van Lenteren et al., 2007; but see Kliner et al., 2016).

REFERENCES


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NC State - Agriculture and Life sciences https://genet. cals.ncsu.edu/