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Olfaction in Coccoidea (Hemiptera)

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ABSTRACT

The insect olfactory system has become a very important model of sensory function, morphology and development. The understanding of the molecular mechanism of insect olfaction will help in the development of insect attractants and repellents for controlling insect pest and vector populations for a wide range of pathogens. This essay aims to explain the importance of understanding how insects 'smell' and how the chemical signals are recognized is useful for many things, but especially for modern pest control in agriculture.

Keywords : Olfaction , Coccoidea

INTRODUCTION

Coccoidea (Insecta: Hemiptera), commonly called “cochineal insects”, “mealybugs”, or “scale insects”, are hemipterous insects belonging to the Suborder Sternorrhyncha (Gullan and Martin, 2003). They constitute a homogenous and specialized group of small phytophagous insects a few millimeters in length, characterized by a high degree of adaptation to the parasitic life and showing extreme sexual dimorphism. During this period of 250 years, the number of described scale insects has increased from 24 species (Williams, 2007) to some 7,700 species in more than 1,050 genera (Ben- Dov *et al.*, 2006). In general, the highest diversity of genera and species are found in the tropics, subtropics and in climates with high temperatures. They can be found in different parts of their hosts or even be restricted to a specific organ. Some species are cosmopolitan, whereas others are either present in specific environments or limited to specific geographical regions. Some species can have a wide host range including species from different plant families (polyphagous), be restricted to a few hosts (oligophagous) or can even be restricted to a single host (monophagous).

Scale insects (Coccoidea) are of particular important pests among insects that feed on crops, fruit, ornamentals and indigenous plants (Arruda *et al.*, 1996). They cause damage to plants directly by sucking their sap, and indirectly by injecting toxic salivary secretions, transmitting pathogens, attacking ants, and encouraging the development of sooty-mold (Lara, 1992 and Zucchi *et al.*, 1993). Besides their impact on the commercial value of ornamental plants and fruit quality, these insects also affect urban landscape. In fact, a number of scale insects are well known as quarantine pests although they are frequently difficult to detect at quarantine inspection until they cause significant damage to crops. Scale insects are notoriously difficult to control, even with conventional insecticides. Because of the wax covering the insect's body, many insecticides are ineffective. In some cases only the crawler stage may be killed

which means an insecticide must be applied at a specific time in the life cycle of the scale insect. Another problem with the use of insecticides is that scale insects have demonstrated their ability to develop resistance to many of the insecticides used to control them. Interestingly, insect resistance to insecticides was documented, when scale insects demonstrated resistance to an inorganic insecticide. As early as 1912, California red scale resistance to hydrocyanic acid was detected (Quayle, 1938). In the 1970s, California red scale populations in some citrus-producing areas of South Africa developed resistance to organophosphate insecticides, including dimethoate, parathion and methidathion, and to a carbamate insecticide, methomyl (Nel *et al.*, 1979).

Due to a variety of side-effects of the chemical insecticides, including pollution of the environment and resistance phenomena of the target insects, there are urgent demands for alternative strategies in modern pest management, i.e. for controlling insect populations. For most animals the sense of smell is of critical importance as major sensory modality which allows to continuously monitor the chemical environment. Perception of odorous cues-mostly volatile compounds - from the environment is an essential prerequisite for survival and reproduction in the animal world; thus allowing to identify and locate appropriate food sources, mating partners and oviposition sites. It is the olfactory system that performs the complex task of recognizing and discriminating a large variety of chemical compounds; moreover, the highly accurate and sensitive chemo-detectors allow the animal to detect certain chemical compounds at extremely low concentrations. In addition, the olfactory system is also responsible for sensing pheromones-chemicals involved in conspecific communication - some of which elicit innate behavior. In insects, the antennae are the main site for recognizing and discriminating odorous compounds from the environment. Accordingly, moth antennae have been an invaluable model system for investigating the structural organization and physiological functions of the insect olfactory systems which allowed pioneering approaches to illuminate some of the principles of odor perception.

In general, the process of odor perception is accomplished by specialized olfactory sensory neuron cells housing in sensillar hair structures. These cells convert the chemical signal into an electrical response and convey the olfactory information via their axons to the antennal lobes, the first relay station in the brain. Experimental evidence based on molecular biological and biochemical studies indicate that detection and recognition of odorous compounds by olfactory sensory neurons (ORNs) is due to distinct molecular entities, the olfactory receptors (ORs). Olfactory receptors are members of the “seven-transmembrane domain” receptor family; this is in line with the concept that upon interaction with appropriate odorants or pheromones the activated receptors trigger G-protein-coupled second messenger reaction cascades which in turn induce the chemo-electrical signal transduction process of the antennal neurons. How the second messenger cascade finally leads to the generation of a receptor potential in chemosensory neurons of insects is still elusive. Thus, the receptors not only recognize the ligands but also elicit the transduction process.

In Coccoidea, the antenna is basically a tactile organ. It appears to be in more plesiomorphic condition, with respect to shape, segmentation, and sensilla, than that of any other hemipteran group figure (1). In spite of the enormous progress in understanding systematic and evolution of scale insect, we still have a huge gape and lack of knowledge about positional and functional of sensory organ in scale insect. Although DNA barcode coverage has growing rapidly for many insect orders, there

are some groups, such as scale insects, where sequence recovery has been difficult. Recently, Park and his group in (2011) have established for the first time the feasibility of developing a comprehensive barcode library for scale insect. This will lead to create an effective system for identifying scale insects and reveal taxonomic situations worthy of deeper analysis.

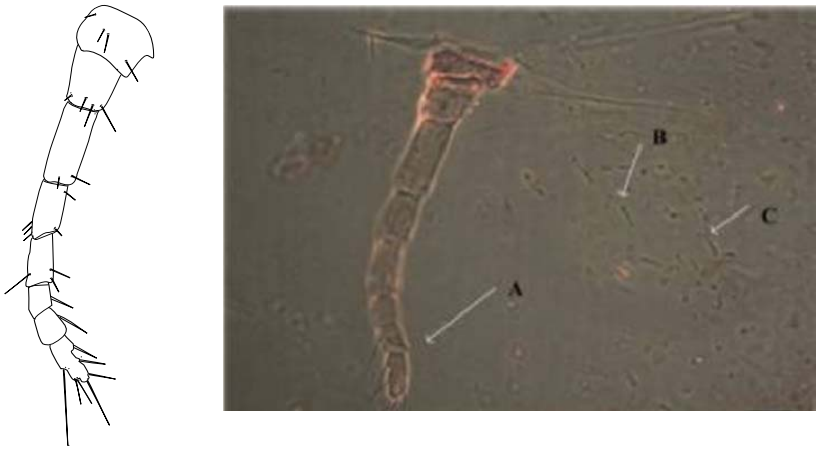

Fig. 1: Microscopic Photo (5 um) of a slide mounted specimen of female *Pulvinaria tenuivalvata* A: Antennae (see the sensory setae) and B&C: ventral tubular ducts

RESULTS

Olfaction and Pest Control

Although previous studies have been succeed in identifying the olfactory receptors of insect (Krieger *et al.* , 2002, 2004; Nakagawa *et al.*, 2005 and Grosse-Wilde *et al,.* 2007), the olfactory receptors of Coccoidea is not yet known. More detailed information will certainly improve our knowledge about the molecular basis of insect chemical communication but in addition may also open new avenues for control of pest insects, since in particular the reproductive behavior of insect is governed by specific odorous compounds, pheromones. Thus detailed knowledge about the specific receptors for their pheromone-ligands may allow to design and synthesize efficient agonistic or antagonistic compounds, tools for a natural, non-toxic pest control.

Furthermore, once the chemical ecology of a pest is understood, we may be able to take advantage of this knowledge and devise control tactics that are environmentally friendly, develop species specific survey methods and enhance the effectiveness of natural enemies. This is an exciting aspect of modern day pest management that will play a significant role in our quest for sustainable forestry practices.

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ARABIC SUMMARY

حاسة الشم فى الحشرات القشرية

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أصبح نظام حاسة الشم فى الحشرات نموذج مهم جدا من ناحيه الوظائف الحسية، والمورفولوجيه والتطور. ان فهم الآلية الجزيئية لحاسة الشم فى الحشرات سوف يساعد في تطوير مركبات جاذبة وطارده بهدف السيطرة على الآفات الحشرية والنواقل لمجموعة واسعة من مسببات الأمراض. هذا المقال يهدف إلى توضيح أهمية فهم كيفية (الشم) فى الحشرات وكيفيه التعرف على الاشارات الكيميائية لما له من اهميه خاصة فى المكافحه الحديثه للافات الزراعيه.