C1

INSECTS LINKED TO ELECTRONICS MAKE POWERFUL SENSORS

Jan N.C. Van der Pers

SYNTECH / VDP Laboratories, The Netherlands

The chemical senses of insects are characterized by an extremely high sensitivity and selectivity and are key factors for the insect's behavior. A variety of electrophysiological and behavioral bio-assays have been developed to use this features for scientific and practical applications. At present, the sensory information can be recorded at three levels: 1) at the peripheral sensory level using Electroantennography (EAG) and Single Sensillum Recording (SSR); 2) in the central nervous system by means of electrophysiological recording in brain tissue; 3) at the output level by observing and recording the insect's behavior.

EAG and SSR alone and coupled to high resolution gas chromatography (GC-EAD and GC-SSR) are indispensable laboratory techniques for the detection and identification of behavior-modifying chemicals. Recent advances in microelectronics and the application of signal processing with computers facilitated further development of the EAG and SSR from a restricted laboratory technique to portable EAG and SSR devices. Other advances can be seen in devices for simultaneous recording of EAG signals from multiple preparations and EAG sensors combined with miniature anemometers. Recordings from chemosensory responses in the brain are, however, still exclusively laboratory methods aimed at providing more information about the signal processing in the insect's brain. Both the peripheral recording by EAG and SSR and recording in the brain reflect partly processed information, whereas the insect's behavioral response is the conclusion of total processing. Therefore, recording at the behavioral level may provide essentially different and probably more relevant information for the researcher.

Traditionally, behavior responses are studied by direct observation or video recording and subsequent analysis. Both techniques are time-consuming and may be biased by the observer. Direct coupling of the insect to an electronic device designed to respond specifically to characteristic behavior would be of great advantage. A selection of novel devices are presented for recording overall activity, partial movements and locomotion behavior. These devices are based on optical and microwave sensors combined with electronic signal processors. Their possible applications in chemoreception research will be discussed.

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ODOR SOURCE LOCATION USING A DISCRIMINATING INSECT ANTENNAL BIOSENSOR ARRAY COUPLED WITH A WIND-DIRECTION INDICATOR

Thomas C. Baker*, Kye-Chung Park, Junwei Zhu, and Sam Ochieng

Department of Entomology, Iowa State University
Ames, Iowa 50011, U.S.A

Insect antennae offer a sensitive way to detect the presence of odor plumes in the field, and to monitor their fine structure both in the laboratory and field, as first demonstrated by Baker and Haynes (1989). Interest in using insect antennal biosensors to quantify ambient concentrations of odor in the field and relate them to effective levels of disruption of pheromone communication has grown in recent years as more successful commercial mating disruption products have come on the market (Sauer et al., 1992; Suckling et al., 1994; Suckling and Angerelli 1996). The Controlled Biological Systems Program of the Defense Advanced Research Projects Agency (DARPA) has funded projects aimed at detecting and locating sources of anthropogenic compounds, such as those emitted by unexploded landmines or by toxin manufacturing facilities. Our laboratory was funded by DARPA to design a discriminating antennal biosensor array having high sensitivity to compounds of interest from the groups listed above. We have designed such a biosensor and measured its sensitivity to a variety of anthropogenic compounds such as 2,4-DNT, 2,6-DNT, and 3,4-DNT, common contaminants of the soil around unexploded landmines. Recently we have found a way to couple our antennal biosensor to a wind-direction sensor and allow an operator to steer with high reliability towards an odor source and locate it within a short period of time from tens of meters away.

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ELECTROANTENNOGRAPHIC RESPONSES OF THE ORIENTAL TOBACCO BUDWORM, *HELICOVERPA ASSULTA*, TO PLANT VOLATILE COMPOUNDS

Kyung Saeng Boo* and Seung Joon Ahn

Graduate School of Agricultural Biotechnology
Seoul Natl. Univ., Korea

Electroantennograms(EAGs) from *Helicoverpa assulta* were recorded in response to host plant extracts and some synthetic volatiles. Linalool, hexanal, acetophenone, 1-hexanol, butyric acid, eugenol and terpineol elicited relatively large EAG responses among 29 synthetic volatile compounds tested. In general, females' EAGs were greater than those observed from male moths. When the relative EAGs of mated and unmated adults were compared, the unmated female elicited greater EAG responses than the mated, but the mated male showed larger responses than the unmated. In response to primary alcohols, aldehydes and acetates with a range of between C_1 and C_{10} carbon chain-length, EAGs were significantly greater for a

particular carbon chain-length(s), with responsiveness to primary alcohols peaking at C_4 and C_5, aldehydes at C_8 and C_9 and acetates at C_6. And the responsiveness with a ranking of alcohols > acetates > aldehydes was recorded in a range of between C_1 and C_6, but over C_7, with aldehydes > acetate > alcohols. The leaf extracts of *Capsicum annum*, one of major host-plants, evoked significantly larger responses than other parts of the plant. These electrophysiological data are expected to help in finding kairomones attractive to *H. assulta* and explaining our latest observations that female showed more active calling behavior and produced a large amount of sex pheromone in the presence of its host-plant, *C. annum*.

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STRENGTHS AND WEAKNESSES OF FIELD ELECTROANTENNOGRAMS AS BIOSENSORS

D.M. Suckling[1*] and G. Karg[2]
[1]HortResearch, PO Box 51, Lincoln, New Zealand and
[2]PPS GmbH, Darmstadt, Germany

Mating disruption of moth pests has achieved several notable successes, but information on the sensory environment of the insect has been generally lacking until relatively recently. Field electroantennogram (EAG) systems have been developed, to detect both the mean and variance in pheromone concentrations. Field EAG systems offer measurements with higher temporal resolution than other current methods. The increasing portability of EAG systems allows repetitive measurements over a short time, and measurements at different sites or treatments. Information processing remains relatively slow, with approximately two days of data analysis for each day in the field, in our experience. Estimates of mean atmospheric concentrations have broadly agreed with expectations, although not in all cases. The use of a proprietary field EAG device by researchers inexperienced in the subtleties of electrophysiology carries risks of misinterpretation, and other measures of efficacy remain important. For studies of plume structure, field EAGs can offer information about how the disruptant pheromone dose is received by the target insects, and highlights the influence of key variables. The high sensitivity of the antenna to pheromones enables information to be gained concerning the three-dimensional distribution of pheromone in mating disruption trials, which is otherwise not obtainable.

The major drawbacks of the approach are the need for dose response and other underpinning information, the non-linearity of the detector outside a certain concentration range, the potential in some species for a lack of sensitivity due to interaction of pheromone and host-plant detection, the variance between individual antennae which requires reasonable replication, and the effort required in data processing. For other applications of field EAGs as biosensors, the antennal specificity for certain odourants such as pheromones, or lack of specificity and lower sensitivity to others odourants (e.g. general plant volatiles) can also be limiting.

AUTOMATIC BEHAVIORAL MONITORING THROUGH TRAINING WITH ARTIFICIAL NEURAL NETWORKS TO DETECT CHARACTERISTIC PATTERNS OF RESPONSE BEHAVIOR OF AQUATIC INSECTS AFTER SUBLETHAL TREATMENTS OF INSECTICIDE IN SEMI-NATURAL CONDITIONS

Hyun-Min Kang[1], Inn-Sil Kwak, Mi-Young Song, Sung-Kyu Lee[2]
Yoo-Shin Kim[1] and Tae-Soo Chon*

Division of Biological Sciences
Pusan National Univ., Pusan, 609-735 Korea
[1]Division of Electrical Engineering
Pusan National Univ., Pusan, 609-735 Korea
[2]Toxicology Research Center
Korea Research Inst. of Chemical Technology
Taejon, 305-600 Korea

A multilayer perception network was used to train the locomotive tracks of aquatic insects after being treated with an organic phosphate insecticide, diazinon. The fourth instar larvae of *Chironomus* sp. were placed in an observation cage (6cm X 7cm X 2.5cm) at temperature of 18^0C (light condition(10LL: 14DD)).

The activity and the locomotive tracks of each test insect, pre- and post- treated with sublethal concentration (0.01 ppm) of diazinon, were individually observed for four days (1 day before treatment, 3 days after treatment) by using an auto remote sensing system. Irregular locomotive behavior and the characteristic "ventilation" movements occurred more frequently to the organisms treated with the insecticide. The backpropagation algorithm was implemented to the multilayer perceptron network to train the input data of the locomotive tracks of the organisms. The patterns of behavioral response were accordingly extracted through the training process, and the network was able to detect the characteristic patterns of treatment when new data for the locomotive tracks were provided to the network. This computational patterning on the locomotive tracks could be an alternative for "*in situ*" biomonitoring tool for detecting the presence of toxic chemicals in the environment.