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Review

Influence of Semio-chemicals on Group Behaviors and Application in Insect Pest and Vector Management

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ABSTRACT

Semio-chemicals are released into the environment from the exocrine glands. These enable chemical communication, achieved by olfaction, gustation, oviposition and contact through hind tarsi of some species. Distinct receptor cells and sensilla amplify these signals within the active odor space to initiate both behavioral and physiological responses for corporate survival of the species. These chemical signals have been harnessed for eradication of most insect pests and vectors. Traps, insecticides, chemosterilants, sex repellents and attractants when synergized give potent control of between 60 – 99%.

Key Words: Semio-chemicals; Insect pest; Vector management

INTRODUCTION

Insects produce compounds that coordinate both behavioural and physiological responses. These compounds are released into the environment from the exocrine glands (Fig. 1) and are collectively called semio-chemicals. Two groups exist: pheromones, which affect members of the same species and allelochemicals, which affects individuals of different species (Masson & Mustaparta, 1990). The objectives of this review are to: expound how chemical communication is achieved in insects, identify certain behavioural responses to these chemicals on individuals and population levels and discuss successes achieved in harnessing these behavioural responses in the pest and vector management.

Mechanism of achieving chemical communication. Insects detect semio-chemicals by olfaction generally, gustation in Diabroticite beetles, fore tarsi in *Chrysolina* species and oviposition stimulants on the female ovipositors (Metcalf & Metcalf, 1992). Williams (1986) define receptors as "distinct cellular constituents that are capable of recognizing subtle differences in the chemical composition of ligands".

Sensilla responses occur in a variety of morphological forms like hairs, cones, sensory pits or pore plates (Fig. 2), which increases antennal efficiency. Increase molecular diffusion enables molecules to rebound on the antenna as many as 250 times. In the silkworm male *Bombyx muri*, the effective size of the sensillum is estimated to be 10 times the geometric size (Metcalf & Metcalf, 1992). Electro-antennogram (EAG) monitor depolarization of antennal receptor cells by summation of olfactory cells of the antennae to an odorant.

Behavioural responses of insects are classified as: kinesis, meaning non-directional responses in initiation or cessation of movement and increasing or decreasing linear rate of turning. Taxis are response towards or away from odorant.

Mathematical modeling of active odour space theory. Dispersion of semio-chemicals in nature involves distribution down wind over uneven terrain and with eddy current induced by vegetation. The active odour space is the 3-dimensional zone within which the perceiving insect respond due to receptor activation (Nordlund *et al.*, 1981; Dusenbery, 1989; Mbata *et al.*, 2000).

To approximate the maximum dimension of the "Active odour space", we calculate the Q/K ratio. The larger the Q/K ratio, the greater the maximum distance the signal is effective and the slower it fades.

$$Q/K = 1/2AC_yC_zUX_{max}^{2-n} \text{-------------------} \quad (1)$$

Where,

Q = emission rate of semio-chemical in mol. Sec^{-1}, K = behavioural threshold in mol. mL^{-1}, U = steady wind velocity ($cm.sec^{-1}$), $X_{max.}$ = maximum distance down wind in cm above K, n = index that varies between 0 - 1, with a vertical profile, C_y and C_z = horizontal and vertical dispersion coefficient.

Therefore dispersion in winds of neutral atmospheric stability over relatively leveled terrain can be modeled, using typical values of: n = 0.25, C_y = 0.4 cm and C_z = 0.2 cm. Inserting these values to (1) above.

$$Q/K = 0.126\ UX_{max}.\ 7/4 \text{------------------} \quad (2)$$

While the maximum height ($Y_{max.}$) and maximum width ($Z_{max.}$) of the coordinate can be calculated thus:

$$Y_{max.} = C_y \ \frac{\blacklozenge 2Q}{KB\ C_yC_zUe} \quad \text{and} \quad Z_{max.} = C_z \ \frac{\blacklozenge 2Q}{KB\ C_yC_zUe}$$

This modified equation is useful to estimate maximum distances for pheromone communication between males and females of an insect species.

Semio-chemical formulation, dispensers and classification. Formulation implies admixing semio-chemicals with carriers for ease of application, storage and improve efficiency. Plimmer (1983) listed the commercially available formulations as: micro-encapsulated pheromones used in Disperlure; hollow fiber dispenser like conrel(R) from celon(R) in Gossyplure; laminated polymeric dispenser like the 3-layered Hercon(R) for suppression of gypsy moth population.

Pheromones are grouped based on the functions each coordinates (Table I), while allelochemicals are grouped as: allemones, where only emitters of the chemicals benefits; kairomones, only recipient benefits; synomones, both emitters and recipient benefits and apneumones, are emissions by non-living materials. Others mediate between plants and phytophagus insect's habitat, food and host finding or have evolved as defense mechanism (Nordlund *et al.,* 1981).

Effect of semio-chemicals on natural insect population. Biological functions are frequently fulfilled by way of complex behaviour patterns composed of sequence of responses. Thus communication brings individuals together over long distances to mate, feed and nest, and perform other biological functions.

Wilson (1971) divided chemical communication functionally into: alarm and assembly for defense and foraging as in honey bee stings and queen substance for location of nest, acceptance, re-establishing contact with nest mates and induces assembly of worker bees to inhibit queen cell construction and reproduction (Atkins, 1980); recruitments of nest mates to perform specific functions like food retrieval and nest construction. Chemical trails, which aid navigation to and fro the nests, are species specific, highly volatile and fades readily. Prey recognition determined by abundance relative to area searched, others respond to specific hosts pheromones, *Myrmecia gulosa* reacts to formic acid, which is alarm pheromone of its host *Solenopsis fugax* (Bergstrom, 1979).

Males orientation to female sex pheromones. In cockroach *Periplanata americana*, females pheromone induces sexual excitation in males. With this, males become alert and restless (Roelofs, 1984). Dictyoptera males often starve for four weeks in the laboratory once excited. A mating stimulant from females induces courtship behaviour in *Haematobia irritans* (L.), these compounds have been identified and synthesized as Z-isomers of 5 tri-, 9-penta and 9-hepta-cosene (Bolton *et al.,* 1981).

The sex urge was high in stimulated *Rhodnius* males that they attempt to mate with each other in the absence of females. *M. domestica* (L.) demonstrated a directional response to sex pheromones, similarly nuptial flight in honey bees is induced by the female sex pheromones (Ahmad *et al.*, 1980).

Fig. 1. Major exocrine glands

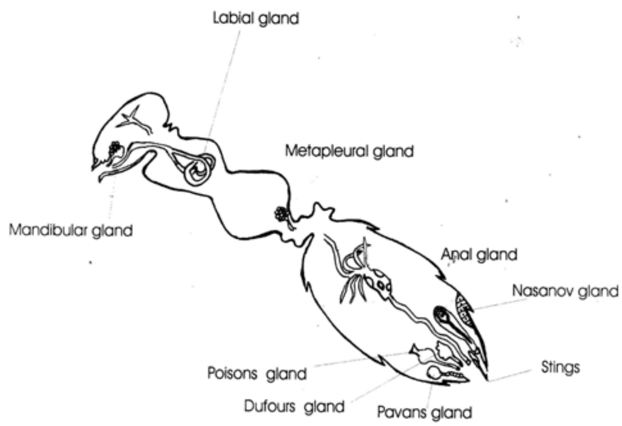
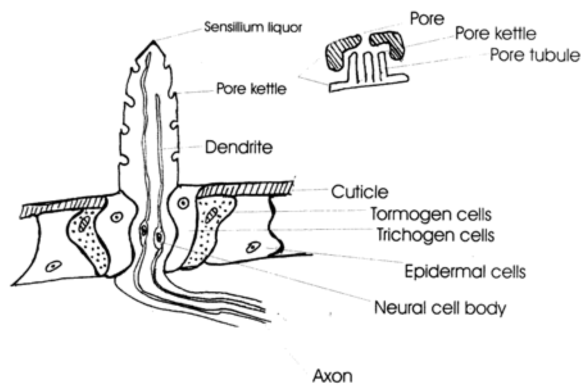


Fig. 2. Structure of olfactory sensilla



These sex attractants often mimic and disrupt communication and prevent mating in the stripped rice borer moth C*hilo suppresalis* (Walker), Douglas-fir tussock moth, *Orgyia pseudotsugata* (Mac.Dunnough), southern pine beetle, *Dondroctonus frontalis,* Zimmerman and the oriental fruit moth, *Grapholitha molesta* (Shorey, 1973; Roelofs, 1984). Oviposition Deterrent Pheromones (ODP) of most females act as male arrestant as in the fruit flies *C. capitata* and the apple maggot fly, *Rhagoletis pomonella* (Prokopy, 1983).

Application of semio-chemicals in pest and vector management. Natural chemical attractants, mating stimulants or repellents are often effective in incredibly small concentration. The effectiveness of these chemicals and ease of synthesis favour their use as lures. This offers high specific control methods that are environmentally friendly. The use of pheromones in population monitoring is feasible to decide on thresholds requiring control.

Traps are however useful in insect population studies commonly used traps include: conical and bio-conical traps for Tsetse fly rounds, delta-shaped, winged and rectangular traps, others are pitfalls, water, suction, trucks and light traps. Effectiveness of these traps is enhanced by: colors of various wave length (Dame & Jordan, 1981); pheromones, mostly giving synergistic effect (Atkin, 1980); spatial

Table I. Semio-chemicals available in scentary shops

S/No	Semio-chemicals (Nat./synth.)	functions	Pests affected
1	Muscalure	Attractant	*Musca domestica*
2	Trimed lure	Attractant	*Ceratitis capitata (wiedemann)*
3	Dimethyl carbamate and Dimethyl phthalate	Repellant	Mosquitoes
4	2-methoxy phthalate and Acetopheromone	Repellant	*Glossina morsitans* (Tsetse flies)
5	Anisyl-acetone	Aphrodesiacs	Melon fly *Didacus vertebrates* Bezzi
6	Iso-amyl salicylate	Aphrodesiacs	Tobacco horn worm
7	Amyl acetate	Sex repellant	The cockroaches, *Periplanata Americana*
8	Para-dicholorobenzene	Sex repellant	Carpet beetles and cloth moth
9	Pine tar oil	Oviposition deterrent	Flea beetles, leaf hopper and psyllids
10	Salannin (neem seed oil)	Feeding deterrent	Cowpea bruchids *Callosobruchus* spp.
11	70% ethyl-alcohol extract of virgin females	Excitation and sex stimulant	Click beetles *Limonias californicus (*Mann.)
12	0.4% Ether extract of females abdomen	Stabilization substance	Honey bees
13	Formic acid	Alarm pheromone and prey location	Ants, *Myrmecia gulosa*
14	Glycol	Trail marking	Many species of termites
15	Methyl chloride	Trail marking	Leaf cutting ants, *Atta taxena*

arrangement of these traps also enhances their efficiency (Mitchell, 1983). The use of insect attractant in pest control is under-exploited but result oriented. Lepidopteran males are lured with pheromones to traps impregnated with insecticides or sticky boards (Atkins, 1980) other traps are impregnated with chemosterilant or admixed with feeds. Mating with such sterile males results in no progeny (Langley & Hall, 1984).

These attractants are used to disrupt communication between sexes, thus preventing mating, with spectacular control result in 99% cabbage looper (Shorey, 1973; Kennedy, 1983). Baited traps in cotton fields gave 80% suppression of the boll weevil population preventing 90% of damage from the weevils attack (Kennedy, 1983). E and Z-isomers of the tussock moth and spruce bud pine borer pheromones, gave 84 and 91% control, respectively. Similarly the Japanese beetles were attracted by geraniol, eugenol, citral and citronella synergized to ease annihilation. Bombykol of the silkworm moth and sex pheromones of the oriental fruit flies gave 87% effective control in citrus orchard (Mc Govern & Ladd, 1984).

In stored products protection, sex pheromones play an essential role in the mating behavior of the stored product coleopteran. This can be harnessed with an aim of producing safer and more effective control measures. Both males and females produce pheromones in the stores. The primary role of which is sexual excitation as shown by the storage beetles, *Tenebrio molitor* L., *Trogoderma granarium,* Everts, *Acanthoscelides obtectus* (Say.), *Attagenus megatoma* (F.) and *Callosobruchus* species (Burkholder, 1983; Mbata *et al.*, 1999).

Three isomers of the black carpet beetles pheromones have been synthesized and tested. These pheromones (Megatomic acid) in a trap captured 60 - 80% of the released beetles in a trial. Effectiveness of these pheromones is achieved in low density population (Burkholder, 1970; Mbata *at al.*, 2000).

Problems and prospects of semio-chemicals usage. A major obstacle to successful implementation of mating disruption control includes: formulation and applicators, patenting of findings, identification of pests spectrum in crop fields and stores, commercial production, behavioural characteristic of target pest and large scale application (Mitchell, 1983; Plimmer, 1983). Despite these prospects of research development of semio-chemicals for insect pests control, commercial application of these methods are neglected due to synthetic insecticide craze after World War II (Metcalf, 1980).

CONCLUSIONS AND RECOMMENDATIONS

All these chemical signals are effective in the eradication of several pest-species, when enhanced by traps, insecticides, chemosterilants, sex repellent and attractants and lastly when synergized. Therefore, incorporation of semio-chemicals into the Integrated Pest Management (IPM) system would prove highly beneficial, since it is environmentally safe and cost effective control measures.

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