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# Chemical ecology and pest management: A review

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**Abstract**
The origin of chemical ecology started from its first identification of an insect sex pheromone nearly fifty years ago. From commercial point of view, the most valuable contribution of chemical ecology remains the insect sex pheromones and their role in pest management. However, the progress of integrated pest management (IPM) strategies is escalating since many problems appeared with the use of synthetic pesticides. Semiochemicals are informative molecules used in insect-insect or plant-insect interactions are more and more considered within IPM strategies as alternative or complementary approach to insecticide treatments. In fact, these species-specific compounds do not have any adversely affectation of beneficial organisms and do not generate any threat to resistance against insect pest as detected with insecticides. Since their complex biological activity, their dispersion in the environment to be protected or monitored needs the elaboration of slow-release mechanisms certifying a controlled release of the biologically active volatile composites. Hence, the IPM strategy of applying all the available control measures with thoughtful intent to protect the significance of each will be necessary. Semiochemicals, and particularly insect sex pheromones, are very useful part of detection, monitoring, and control programs for agricultural crops.

**Keywords:** Semiochemicals, sex pheromone, alarm pheromone, oviposition-deterring pheromone, allomone, kairomone

## Introduction
The term "semiochemical" derived from the Greek word "semeon," which means "sign" or "signal" and it is used since 1971. Depending on the function of a semiochemical, this group of chemicals can be further divided into two classes: pheromones, and allelochemicals. From its beginning as a field, chemical ecology has always had a strong interdisciplinary flavour. Both major groups of chemicals are further subdivided on the basis of their function. Allelochemicals can be divided in to signals that benefits that benefit the receiver (kairomones), the emitter (allomones), or both (synomones) (Norduland *et al*., 1981) [18].
In pheromone, sex pheromones, for example, are chemicals which mediate interactions between the sexes of the same species; mainly produced by females and to attract males, whereas some examples of male-produced pheromones are also known. Other types of pheromones include alarm pheromones (which aware other members of the same species to the presence of menace), trail pheromones (which guide social insects to distant food sources), aggregation pheromones (which attract individuals of both sexes), oviposition- deterring pheromones (which discourage females from laying eggs in the same resource as another female), and so on. Pheromones may bring out an immediate behavioural response (‘releaser’ pheromones), or may mediate more long-term, physiological changes (‘primer’ pheromones). Mainly sex pheromones are not a single compound, but rather a blend of several compounds which must be present in the proper concentration and ratio to obtain the proper behavioural response (Norduland *et al*., 1981) [18]. All types of semiochemicals may be biologically active at very low concentrations, a fact that has often made their isolation and identification technically challenging. The first semiochemical to be chemically characterized was the sex pheromone of the silkworm moth (*Bombyx mori*) in 1959.
There is an environmental concern and public demand for decline in the use of toxic insecticides for pest control. Semiochemicals have enormous potential to give substitute results, because they are moderately non toxic to vertebrates and to beneficial insects, are generally used in small amounts, and are often species specific.

**Semiochemicals and their potential in insect pest management**

Right now the most intensively used semiochemicals in insect pest management are the sex pheromones, mostly those of lepidopteran insects, which were among the first to be recognized and synthesized. Regarding pest management is concerned, pheromones have the significant attributes to species specificity-approximately, potency and low toxicity. The semiochemicals are not, however, direct alternatives for chemical insecticides, being used not as 'killing agents' *per se*, but perform as monitoring tools (to improve the timing of conventional chemical controls). The goals of using semiochemicals in pest management are (Reddy *et al*., 2005) [23]

- To monitor pest populations
- To determine if control is permitted
- To alter behaviour of the insect pest or its enemies to the detriment of the pest.

**Advantages of using semiochemicals are**

- They have adverse effects only on target pest
- They are relatively non-toxic and required in low amounts.
- They are non-persistent and environmentally safe.
- They appear difficult for insects to develop resistant against.

Right now, about half of the semiochemical-based products are in the form of pheromone traps and lures for monitoring reasons, whilst the majority of the remainder are for disruption of mating products.

**Sex Pheromones for monitoring pest populations**

Witzgall *et al*. (2010) [27] reported that one of the most widespread and a successful practical application of semiochemicals is in detection and monitoring of pest populations. Semiochemical baited insect monitoring traps can provide a best solution to solve this problem. The design of the trap will vary according to the target insect, even though numerous standardized designs have been establish to work well for a number of different species. The trap develop in such a way to allow free dispersal of the pheromone, and must incorporate some method of retaining any insects attracted by the lure: a glue-covered gummy board, which can be eliminated and reinstated as required, is often used.

Though the traps are to be economically feasible, the concentration of pheromone lure must be optimized to carry for a period of several weeks, and the pheromone traps must be positioned at the optimum height, density and orientation to be most successful. Properly used, pheromone traps can be more efficient than hand sampling, mainly for detecting pests at low population densities. For monitoring, pheromone traps are now available for a wide range of insect pests, mostly Lepidoptera, even though some are available from other orders, include Coleoptera and Diptera. Majority of the pheromone monitoring traps use female sex pheromones, and hence trap adult males. However, it is often that the larval stage of the insect that is the most harmful, and against which control strategy are generally targeted. If the aim of the monitoring system is to improve the timing of insecticides intended at larvae, then the trapped adult male's number must be related to the probable egg hatching dates and likely numbers of larvae Witzgall *et al*. (2010) [27].

**Sex Pheromones for mass trapping**

Mass trapping is another eco-friendly method of pest control and it is species specific semiochemical baited monitoring traps, with the aim of suppressing or eradicating populations of target pests by capturing as many as individuals as possible. To accomplish this, traps have to confine a large proportion of the pest population in an area, before mating and oviposition, and retain or kill captured individuals. The lure which will be used for mass trapping must be more efficient than natural sources of attraction such as food or mates / oviposition sites and perfectly maintain the effectiveness throughout the whole period of adult insect reproductive activity to reduce damage to a minimum. Additionally, the yield profits and the cost of traps, and the labour involved to install them, must be economically feasible to alternative control methods for this approach to be feasible (El-Sayed *et al*., 2006). In addition to, many cases of the attempted use of mass trapping to manage a range of insect pest Lepidoptera, Coleoptera, Homoptera and Diptera and classic studies have been itensively reviewed by El-Sayed *et al*. (2006) and Witzgall *et al*. (2010) [27].

Some of the successful examples of mass trapping are banana weevil, fruit fly. The banana weevil, *Cosmopolites sordidu*s, was managed by mass trapping using baits prepared from host plant pseudostems, until the aggregation pheromone was recognized and proved to be more efficient (Alpizar *et al*., 2012) [1]. Food odours including hydrolysed proteinaceous baits were expanded to catch a broad series of tephritid fruit fly species and are still in use in lure (El-Sayed *et al.*, 2009) [9, 10].

**Sex pheromone for mating disruption**

Mating disruption intends to interrupt chemical communication by organism and disrupt normal mating activities by dispensing synthetic sex pheromone, thus disturbing the organism's chance of reproduction (Carde and Minks, 1995) [8]. This can be achieving by using both attractive and non-attractive pheromone mixed together. Mating disruption can be successful if the large areas are treated or if the area treated are separated such as in a mountain valley. In recent time, pheromones are used in IPM has been reconsidered by Witzgall *et al*. (2010) [27] and mating disruption was reviewed by Rodriguez and Stelinski (2009). The area under this method has risen almost exponentially from the 1990s, and it is stated that the crop are being controlled for specific pests using mating disruption worldwide was 770,000 ha in 2010 (Ioriatti *et al*., 2011; Witzgall *et al*., 2010) [12, 27]. There are some reports, from that they reported three species with highest land area under mating disruption technique were the gypsy moth (*Lymantria dispar*) in North American forests, the codling moth (*Cydia pomonella*) in apple and pear trees worldwide and in EU and Chile the grapevine moth (*Lobesia botrana*) (Witzgall *et al*., 2010) [27]. A recent study has revealed the efficacy of pheromone-based mating disruption techniques of a part of the dipterans family, the swede midge (*Contarinia nasturtii*) in field assessment of small scale and in commercial scale fields' broccoli and cauliflower. The damage of crop was decreased by 59% in broccoli and by an average of 91% in the large scale experiments (Samitez *et al*., 2012) [25]

**Alarm Pheromones**

Alarm pheromones appear to be the second most commonly produced class of chemical signals used by insects, after sex pheromones (Barbier, 1982). Alarm signaling has developed in different arthropod taxa in which the characters are adjoining enough to each other to rapidly communicate.

Gregarious and social insects, including Hymenopterans and Hemipterans, have developed a diverse array of chemical compounds that function as releasers of alarm behaviour. Indeed, alarm pheromones appear to be highly adaptive for species in which individuals form collectives that can show a group reaction to traumatic stimuli (Blum, 1985) [6]. In eusocial species, for example, they allow colony resources to be rapidly and efficiently deployed in reply to exact risks. The alarm pheromones of insect are usually tiny molecules of low molecular weight and simple structure (e.g., terpenoids or aliphatic ketones and esters). They are thus extremely volatile and disperse hastily after release as befits signals that function over short time frames and at localized spatial scales (Payne, 1974) [20]. Various organs can be involved in their production, including mandibles, stings and anal glands. Even though commonly containing mixtures of several compounds, alarm pheromones tend to be less specialized than other types of pheromones and the minority are species specific (Blum, 1985) [6]. This non-specificity relatively may be an advantage to species that are able to detect alarm signals of other insects sharing vulnerability to a common threat.

**Oviposition-Deterring or 'Marking' pheromones**

Both parasitic and phytophagous insects are known to deposit chemical signals following egg laying that modify the behaviour of conspecifics who consequently keep away from depositing future eggs into formerly used host resources (Nufio and Papaj, 2001) [19]. These signals have been termed oviposition-deterring pheromones, marking pheromones, or epideictic pheromones (Roitberg and Prokopy, 1987; Nufio and Papaj, 2001) [24, 19]. It is believed that these signals have evolved under then selection pressures of limited host resources for development of brood and inform the receiver of a formerly utilized, sub-optimal resource, thus reducing competition among offspring (Prokopy, 1981a) [21]. Frequently, the behavioural consequences of oviposition inhibiting pheromones are a declining in time fatigued by gravid females on previously-utilized resources and a reduction in oviposition attempts (Prokopy, 1981a, b) [21, 22]. Oviposition-deterring pheromones have been described or identified among numerous insect taxa including the insect orders Coleoptera, Diptera, Hymenoptera, Lepidoptera, and Neuroptera (Prokopy, 1981a; Roitberg and Prokopy, 1987; Landolt and Averill, 1999) [21, 24, 15]. So we can say, the ecological significance of oviposition-deterring pheromones has been investigated by determining the association among the deposition of oviposition-inhibiting pheromone and larval distribution patterns amongst utilized hosts.

**Kairomones and their application in insect pest management**

Kairomones comprise plant odours which are utilized by herbivorous insects to recognize their host species, and compounds produced by herbivorous insects which are used by predators and parasitoids to locate or identify their prey or host. The parasitoid involvement of volatile chemicals from plants in the host-seeking behavior of *Trichogramma pretiosom* and wild *Trichogramrna sp.* in controlling *Helicoverpa zea* (Altieri *et al.*, 1981) [2]. These chemicals can be used to manipulate the behavior and increase the field performance of *Trichogramma* (Lewis *et al.*, 1975, 1979) [17, 16].

Chemicals previously recognized as kairomones used by parasitoids have been found in important quantities in food plants of host insects. Different plant species contain varying concentrations and ratios of these chemicals. Studies of insect feeding with chemically labelled kairomones show that these cues are concentrated and released unaltered by the host insect (Hendry *et al*., 1976) [11].

**Allomones and their application in insect pest management**

Allomones are the chemicals of defensive secretions released by many insects which are poisonous or deterrent to predators. They also serve plans as defence mechanism against herbivores and reduce the competition with other plants.

Plants produce a many varieties of allomones to protect themselves from phytophagous insects and other herbivores. It is likely that majority of secondary plant metabolites are biosynthesized to deter predation. Most toxic alkaloids, cynogenic glycosides, cardiac glycosides and other toxic plant products. Most living plants have some degree of resistance to natural enemies due to the presence of secondary plant compounds (allelochemicals). It is well known that plants are utilized as food sources by many pest and plants, therefore, have developed many barriers against herbivores (Janzen, 1981) [13] including competitive production of morphological characteristics (e.g. spines), biomass and plant secondary compounds which act as protective agents against herbivorous insects.

Numerous studies show that insect parasitoids are attracted to stimuli associated with their hosts (Weseloh, 1981) [26], and the majority of these stimuli appear to be of chemical origin. Volatile chemicals that attract parasitoids from longer distances can be released by the hosts themselves (e.g., aggregation and sex pheromones).

**Semiochemicals as activator of Plant defense**

When plants are treated with certain semiochemicals, both direct and indirect defence can be enhanced that function as activators of plant protection. The plants having ability to respond to semiochemicals that are connected with insect or pathogen attack permits them to well tune their metabolism according to likelihood of exposure to biotic stress factors. As an example, discharge of herbivore encourage volatiles from neighbouring plants can guide to activation of defence pathway that create a plant more resistant to insect pests attack (Baldwin *et al*., 2006; Karban *et al*., 2000) [3, 14]. A plant activator that is *cis*-jasmone, or (Z)-jasmine whose activity were first noticed at Rothamsted when parts of blackcurrant volatiels that repelled the summer form of lettuce aphid, *Nasonovia ribis-nigri*, were being recognized. The compound is structurally alike with jasmonic acid and it was checked as a plant treatment and was observed to have intricate effects on interactions between pest insects and crop plants (Birkett *et al*., 2000) [5].

An experiment was conducted with *cis*-jasmone then focused on the dealings between the grain aphid *Sitobion avenae* and wheat, *Triticum aestivum*. Wheat plant treated with low level of *cis*-jasmone as an aqueous suspension became less attractive to aphids but more attractive to their parasitoids in laboratory bioassays. Simulatenously in the field, similarly treated plants had lesser aphid infestations (Bruce *et al*., 2003) [7]. It shows that part of this result is due to enhanced parasitism of aphids by parasitoids.

**Conclusion**

Semiochemicals are species-specific chemicals that change insect actions, but are non-toxic to insects. In low doses also they are extremely active and are used to bait traps or confuse a mating population of insects. Semiochemicals can play a significant position in integrated pest management for structural, landscape, agricultural, or forest pest problems in India. Allelochemicals are known to serve important roles at all steps in the host-searching sequence of parasitoids, it is clear that multidisciplinary research work in the area of ecological chemistry is needed and will provide tools for sustainable methods for control of many insect pests.

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