CHEMICAL ECOLOGY AND PEST MANAGEMENT

Tessa R. Grasswitz
Harper Adams University College, Newport, Shropshire. UK.

Keywords: Semiochemical, pheromone, allelochemicals, kairomone, synomones, allomones, behaviour, pests, invertebrates, vertebrates.

Contents

Summary

The field of chemical ecology has its origins in the first identification of an insect sex pheromone nearly fifty years ago. Since then, our knowledge of the role of chemical cues in mediating the interactions between and within species has significantly increased. Nevertheless, from a commercial point of view, the most valuable contribution of chemical ecology remains the insect sex pheromones and their role in pest management. Here, the commercial uses of sex pheromones are discussed, together with an evaluation of the actual and potential roles of a variety of other semiochemicals which affect the behaviour of both invertebrate and vertebrate pests. Given the increasing need for more selective, ‘biorational’ approaches to pest control, there are compounds in virtually all classes of semiochemical that could be explored and developed for practical uses in support of more sustainable agricultural production systems.

1. Introduction

Chemical ecology has been defined as the study of the structure, origin and function of naturally-occurring chemicals that mediate interactions between individuals of the same species (i.e., intraspecific interactions) and/or between individuals of different species (interspecific interactions).

The chemicals concerned [termed 'semiochemicals' (from the Greek *semeion*, a mark or signal)] are divided into pheromones (which mediate intraspecific interactions) and allelochemicals (which mediate interspecific interactions). Both major groups of chemicals are subdivided further on the basis of their function. Sex pheromones, for example, are chemicals which mediate interactions between the sexes of the same species; most are produced by females and attract males, although some examples of male-produced pheromones are also known. Other types of pheromones include trail pheromones (which guide social insects to distant food sources), aggregation pheromones (which attract individuals of both sexes), alarm pheromones (which alert other members of the same species to the presence of danger), oviposition-deterring pheromones (which deter females from laying eggs in the same resource as another female), and so on. Pheromones may elicit an immediate behavioural response ('releaser' pheromones), or may mediate more long-term, physiological changes ('primer' pheromones). Most sex pheromones are not a single compound, but rather a blend of several compounds, each of which must be present in the correct concentration and ratio to elicit the appropriate behavioural response. Each sex pheromone blend is generally unique to a particular species.

Allelochemicals are divided into kairomones (which mediate interactions which are adaptively favorable to the receiving organism but not to the emitting organism), allomones (which mediate interactions which are adaptively favourable to the emitting organism but not to the receiving organism), synomones (which mediate interactions which are adaptively favourable to both receiving and emitting species), and apneumones (which are substances emitted by a non-living material that evoke behavioural or physiological responses that are adaptively favourable to the receiving organism but detrimental to a second species found on or in the non-living material).

Thus kairomones include plant odours which are used by herbivorous insects to locate their host species, and compounds produced by herbivorous insects which are used by predators and parasitoids to locate or recognize their prey or host. Allomones include, for example, both secretions used for defense and attractant compounds used by certain predators to attract their prey. Synomones include floral odours which attract pollinators (such odours are mutually beneficial if a food 'reward' (nectar or pollen) is associated with the flower), and volatile compounds produced by plants when attacked by herbivorous insects that attract predators and parasitoids of the attacking herbivores.

Note that semiochemicals are classified in relation to their role in specific interactions, and that the same chemical may act in different ways depending on the interaction concerned: thus pheromones, for example, may also act as kairomones if they attract predatory or parasitic species to the emitting organism.

Chemical ecology is a relatively young discipline. Semiochemicals of all types 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. This first identification took many years and the extracts of approximately half a million female moths. Since then, however, advances in chemical techniques and equipment have made it possible to identify compounds from ever smaller amounts of material, and the field has progressed rapidly as a result.

2. Semiochemicals and Their Application in Insect Pest Management

At present the most widely used semiochemicals in pest management are the insect sex pheromones, particularly those of lepidopteran pests, which were amongst the first to be identified and synthesized. As pest management tools, pheromones have the useful attributes of species-specificity, potency, and low toxicity. They are not, however, direct substitutes for conventional insecticides, being used not as ‘killing agents’ *per se*, but rather as monitoring tools (to improve the timing of conventional chemical controls), or as ‘indirect’ means of pest population reduction through disruption of the pest’s mating system, or by mass-trapping and other related techniques.

Commercially, sales of semiochemicals (mainly pheromones) represent a very small fraction of the current global market for pest control products. However, the estimated annual growth rate in pheromone sales (approximately 11%) is about five times that of conventional pesticides, and one estimate predicts that pheromone sales will rise from approximately 1% of the global pesticide market to 20% by 2010. At present, about half of the total sales of semiochemical-based products are in the form of pheromone lures and traps for monitoring purposes, while most of the remainder are for mating disruption products.

2.1 Sex and Aggregation Pheromones

2.1.1. Insect Sex Pheromones As Monitoring Tools

As monitoring tools, pheromones may be used to detect the migration of a specific pest into a particular area, as a post-application means of assessing the effectiveness of other control measures, or to improve either the timing of more labour-intensive monitoring methods (such as visual plant searches) or the timing of control tactics such as pesticide sprays.

For use in monitoring systems, the unique pheromone blend of the target insect is typically applied to an inert matrix (such as a rubber septum) which forms the attractive ‘lure’ in a trap of some kind. The most effective trap design will vary according to the target insect, although several standardized designs have been found to work well for a number of different species (Figure 1). The trap must allow free diffusion of the pheromone, and must incorporate some method of retaining any insects attracted by the lure: a glue-covered sticky board, which can be removed and replaced as required, is often used. The efficiency of the trap will decline as the sticky surface ages and becomes saturated with insects, debris and so on. For this reason, traps must be inspected and serviced regularly if the sensitivity of the system is to be maintained.

If the traps are to be economically viable, the pheromone lure must be optimized to deliver an effective concentration for a period of several weeks, and the traps must be placed at the correct height, density and orientation to be most effective. Correctly used, pheromone traps can be several times more efficient than hand sampling, especially for detecting pests at low population densities.

Pheromone monitoring traps are now available for a wide variety of pests, mostly Lepidoptera, although some are available for species from other orders, including Coleoptera and Diptera. By far the majority of monitoring traps use female sex pheromones, and hence trap adult males. However, it is very often the larval stage of the pest that is the most damaging, and against which control tactics are generally targeted. If the aim of the monitoring system is to improve the timing of insecticides aimed at larvae, then the numbers of trapped adult males must be related to the probable egg hatching dates and likely numbers of larvae. The most sophisticated monitoring systems therefore combine trap catch data with in-field temperature monitoring and computer-based models of insect development rates to predict the optimum application date for pesticides. The earliest forms of these models relied on crude daily maximum and minimum temperature data, but the development of continuous in-field data-loggers at relatively low prices now provides more accurate and area-specific information than was previously possible. Nevertheless, the accuracy of any model-based predictive tool is still ultimately dependent on the quality of the developmental model used to construct it.

Figure 1. A typical pheromone trap used for insect monitoring purposes. The lower surface is coated with adhesive to trap insects attracted to the pheromone lure. (Image reproduced by kind permission of Trece Inc., USA)

Thus, at their crudest level, pheromone traps provide a rough indication of insect activity, but with additional information can be used as much more sophisticated decision-support tools.

-
-
-

Bibliography

Carde, R. and Bell, W. (Eds.)(1995). Chemical Ecology of Insects. 2nd edition. Kluwer Academic Publishing. [Good general text]

Hardie, J. and Minks, .K. (Eds.) (1999). Pheromones of non-Lepidopteran insects associated with agricultural plants. CABI Publishng, Wallingford, U.K. [Comprehensive treatment that includes responses of natural enemies to herbivore pheromones]

Haynes, K. F. and Millar, J. G. (Eds.)(1998). Methods in chemical ecology. Volume 1. Chemical methods. Chapman and Hall, London. [Good treatment of techniques and methodology]

Haynes, K. F. and Millar, J. G. (Eds.)(1998). Methods in chemical ecology. Volume 2. Bioassay methods. Chapman and Hall, London. [Companion volume to above; again, good treatment of techniques and methodology for a variety of species]

Thomson, D. R., Gut, L. J. and Jenkins, J. W. (1999) Pheromones for insect control: strategies and successes. In: Hall, F. R. and Menn, J. J. (Eds.) Methods in Biotechnology. Vol. 5: Biopesticides: use and delivery. Humana Press, Inc. NJ.

Biographical Sketch

Tessa R. Grasswitz

Researcher and lecturer. Specialisms include insect behaviour, biological control and chemical ecology, with particular emphasis on parasitoid and hyperparasitoid behaviour in the context of multi-trophic level interactions.