Technological problems associated with use of insect pheromones in integrated pest management of stored products

Pasquale Trematerra[1]

Abstract

The use of pheromones is one of the most promising techniques aimed at the control of stored-product insects. The use of these substances may lead to a drastic reduction of chemical treatments, thus determining remarkable economic advantages and improvement of product quality In recent years, considerable progress has been made in monitoring and control of stored-product insects by using mass trapping, mating disruption and attracticide methods. In spite of these achievements, progress in the application of pheromones has been rather slow, and technology is still in its infancy

Dispensers can be characterized by release rates of active ingredients as a function of temperature and other environmental conditions, as well as by the change of these release characteristics as a function of time. Traps and lures presently on the market are found to vary greatly in efficacy, mostly due to varying degree of purity of the starting materials Industrial standards are needed to assure quality control of pheromones in Integrated Pest Management.

Introduction

With the introduction of insect pheromones in plant protection, an old dream has come true: Toxic' insecticides are being replaced with 'harmless' natural products. This is most apparent in the mating disruption which directly uses pheromone chemicals to control pests. But even when used to attract insects to a monitoring trap, as in hundreds of insect species worldwide, pheromones have made a significant contribution towards a reduction of pesticide use (Arn et al., 1997).

In spite of these achievements, progress in the application of pheromones has been rather slow, and technology is still in its infancy While producing material for application on a large scale, industry is still in great need to make formulations more effective and suitable for a wide range of pests and climatic conditions. It is not only the scientific knowledge that drives this process, but to a great extent also trial and error Users thus still find it difficult to obtain material of predictable quality for practical use.

Semiochemical product performance is considerably influenced by environmental factors. In developing any pheromone product, it is critical to research and understand the behaviour and biology of the target insect as completely as possible. Important factors include: time of day for mating; duration of female calling behaviour; quantity of female pheromone release rate; location of female calling within environment; male searching behaviour (Kirsch, 1997).

Pheromones are used commercially in two ways: (1) for indirect control (monitoring for quarantine and spray timing) and (2) as direct control agents. This latter application may be further divided into their use in mass trapping and in area-wide dissemination. Area-wide dissemination includes three strategies, two of which, disruption and attracticide are used commerially and bioirritation which saw limited use approximately 7 years ago in crops.

Pheromones currently comprise but a very small percentage of the insect control products available in the USA where there are approximately 50000 insecticide products based on 250 active ingredients (Maxey, 1991) and only in the order of 26 pheromone products based on 14 active ingredients Arthropods elaborate many different types of chemicals to be used as pheromones and other semiochemicals, but at present those of commercial interest are restricted primarily to lepidopteran pheromones and, in particular, to unsaturated alcohol, ester and aldeyde pheromones with 10 – 18 carbons in the aliphatic chain.

Pheromone use in the control of stored-product insects

Considerable progress has been made in the use of pheromones for monitoring and control of stored-product insects, since the identification of the pheromone of Attagenus unicolor (Brahm). Pheromones from nearly all of the most important species have been identified (Burkholder, 1982, 1984 and 1990; Burkholder and Ma, 1985; Trematerra, 1989 and 1997; Chambers, 1990;

[1]Department S A V A , University of Molise, Edificio Facoltà di Agraria, I – 86100 Campobasso, Italy

Phillips, 1994 and 1997; Levinson and Levinson, 1995; Plarre, 1998)

Monitoring

Their purpose is to achieve a more accurate control and to limit insecticides usage only when strictly necessary. Pheromone traps are generally effective when pest numbers are very low and so they can be used qualitatively to provide an early warning of pest incidence. They are useful to define areas of pest infestation, particularly where the overall distribution and life cycle are poorly understood

Typical recommendations provide for the placement of a grid-work of traps and their monitoring for the capture of insects at regular time intervals. If one or more traps in a particular area captures a higher number of insects, then an increased density of traps should be deployed in that area in order to localize the source of the pests (Burkholder, 1990). Further developments in the use of pheromone-baited traps could ameliorate their application in pest management schemes. New trap designs are being realized which appear promising in the improvement of detection limits with some insect species (Mullen, 1992; Quartey and Coaker, 1992; Trematerra et al , 1996). Wright and Cogan (1995) list the factors, known to affect trap catch, that should be addressed during the design, execution and reporting of trapping studies.

Optimization of traps and lures will allow the realization of new computer-based methods aimed at the organization and interpretation of data and will make it easier to face pest attacks properly. Warehouse managers could then maintain in their own facilities long-term databases on insect activity and easily detect changing trends in pest numbers in a relatively short time. In addition to estimating relative numbers of insects by observing changes in trap catches over time, pest managers may also employ new techniques to estimate absolute numbers of insects in a facility.

Wileyto et al (1994) have developed a trapping-marking-re-trapping method to estimate population sizes of insects using pheromone traps With this method population estimation may provide a more realistic numerical value. This can be used with greater confidence than uncalibrated trap catches for making pest management decisions

Mass Trapping

Early attempts of mass-trapping were conducted by using pheromone blends of many target insect species; designs of traps have been developed, generally on an empirical basis Various release mechanisms have been devised to distribute the pheromones at a controlled rate A major problem is the quantification of the number of traps necessary per unit area to achieve an effective control. Mass trapping with pheromones, or simply catching as many insects as possible to reduce overall numbers, has immediate appeal but has gained limited success In the case of female-produced sex pheromones, those most commonly used in storage systems, only males are trapped Hence, any attempt to suppress the population by trapping males would require a sufficient number of trapped males so that nearly all females would go unmated.

Theoretical considerations of mass trapping males take into account the density of males in the population and the potential number of matings a male is able to secure in its lifetime (Lanier, 1990; Roelofs et al , 1970). If a male can mate with ten females in a lifetime, as is the case for Plodia interpunctella (Hubner) (Brower, 1975), then up to 90% of the male population can be trapped without affecting the number of mated females as well as the subsequent larval generation.

Proper experiments of mass trapping are not easy to conduct due to inadequate controls or poor replication, although various studies have been reported (Levinson and Buchelos, 1993; Trematerra, 1994). Mass trapping both sexes of a population using aggregation pheromones should be more effective than mass trapping only females. Aggregation pheromones produced by males are known from several beetle species that infest stored products, but few studies have been conducted to suppress populations of these insects by mass trapping

Mating disruption

This method is assumed to be achieved by permeating the area under treatment with a synthetic pheromone so as to reduce mate finding or aggregation, the result being mating suppression The limitations and theoretical bases of mating disruption are similar to those for mass trapping of males: a substantial proportion of male population has to fail to locate females, and success is more likely under relatively low population levels.

Although several successful experiments have been reported using mating disruption with stored-product pyralid moths (Sower and Whitmer, 1977; Hodges et al , 1984; Trematerra and Capizzi, 1987; Prevett et al , 1989), no commercial applications of this method are currently available. However, mating disruption is a potentially effective pheromone-based control method for storage moths and requires further consideration. The response of females in the presence of high concentrations of pheromones must be considered. In addition, more data is necessary in order to reduce the quantity of pheromones used and to reduce the risk of their residues in food The use of sex pheromones for mating disruption of Lepidopteran pests of agriculture has, over the last decade, become an important component of Integrated Pest Management packages in a number of crops.

Attracticide method

The attracticide concept-based method involves using a

pheromone, or other attractive semiochemical, to lure insects to an area or a specific point source whereby they contact a toxicant or are destroyed or disabled by other means. Attracticide control is in some way analogous to mass trapping, although many more insects are affected because the attracticide is broadcast over a large area and the killing effect is not limited to individual traps. The more common concept of an attracticide involves the formulation of an insecticide with a feeding stimulant and a long-range attractant, either in liquid droplets or in some encapsulated or solid matrix, that can be applied evenly over large areas Target insects orient to the formulation where they feed on or contact the insecticide and then die.

In agriculture the attracticide method has been used with success against tephritid fruit flies, cotton boll weevils and codling moth. In stored-products there are many promising results on the use of the attracticide concept in flour mills and warehouses in the control of Ephestia kuehniella Zeller (Trematerra, 1994 and 1995; Suss and Locatelli, 1995) Another method utilizes pheromones in an inoculation device that contains a pathogen (Burkholder, 1981; Vail et al., 1993).

Some Problems Associated with Use of Pheromones

Traps and trapping programs

Trap design is crucial in developing trapping systems (Barak et al , 1990) Before mating, most male or female insects respond to their pheromone in combination with supplementary key stimuli. This sequence of sensory stimuli can be utilized in the design of attractant traps to be employed in the manipulation of storage pests Using identical lures differences in trap effectiveness was shown to be based on either the traps' visual clues or their accessibility by the pest insects (Plarre, 1998).

Trapping procedures vary depending on whether the objective is monitoring or control In survey and detection programs, the foremost concern is the sensitivity of the system Similarly, when trap catch is used to time phenological events such as the onset of adult emergence, trap saturation may be of no concern. On the contrary, in other trapping programs, saturation can pose serious problems. When a trap catch is used as an indicator of population density, the limited capacity will make it difficult to develop predictable relationships between trap catch and density. In mass trapping applications, superior trap efficiency necessary for management would appear to eliminate sticky traps, except at very low pest densities.

The precise position of a trap within a habitat can significantly affect the levels of trap catch Placement of traps in warehouses is dependent in part on the size of the room and on available supporting posts or other places where there is little or no traffic In general, the traps should be placed away from open doors or windows in order to avoid attracting insects into a facility from outside. Traps may be placed outside of a warehouse to catch migrant insects and thus intercepting them before they have a chance to move inside.

Quality and performance of pheromone dispensers

Semiochemicals products performance is a dynamic between the choice of formulation, the age of the formulation, the rate of release and population pressure (Trematerra and Zanetti, in press) Production of a pheromone product requires pairing chemical synthesis with controlled release development Solutions need to be found in the following areas: synthesis; stabilization and longevity (pheromone molecules are environmentally labile and need to be stabilized from photochemical, thermal, oxidative and hydrolytic degradation, and from isomerization and racemization); blend quality (purity, composition)

Pheromone products are developed through the integration of pheromone chemistry with selection of the correct polymers Consumers of pheromone products increasingly demand from their suppliers products which conform to certain specifications and quality standards; it is incumbent on the semiochemical industry to establish high levels of product specification, quality and performance so that barriers to entry are sufficiently high to exclude the amateur, or worse still, the unscrupulous operator The pheromone industry is coming of age and standards need to be established to protect both the consumers and the credibility of the industry.

With a few notable exceptions, for the most part the companies involved in pheromone development have either been small start-up companies or largely independent subsidiares of larger companies. Often in these organisations there has been a youthful and enthusiastic research team keen to see this technology developed. As the pheromone industry matures, it is in danger of attracting the attention of supplies of products of dubious quality since the barriers to entry are not as onerous as they are for conventional insecticides (Casagrande and Jones, 1997)

Importance of field tests

Adeguate characterization of release rates of dispensers should become a part of the standard protocol of dispenser evaluation trials in order to introduce hard facts rather 'guesstimation' into the interpretation of field trial results (Millar et al , 1997). Information available to field researches with regards to performance characteristics of the dispersers that they are evaluating has often been sketchy at best Information which has been available has often been obtained from artificially aged rather than field aged dispensers. Finally, many release rate measurements

have been calculated indirectly, for example by subtracting the amount of pheromone remaining in a dispenser from the initial amount present. This fails to take into account degraded pheromone, which would not be detected or quantified by gas chromatography, resulting in actual release rates being lower than calculated

Conclusions

In recent years, considerable progress has been made in monitoring and control of stored-product insects by using pheromones Different tolerance thresholds should be established for the various groups of insects depending on their economic impact and on where they are found. For example, a limited number of insects can be tolerated at times in a storehouse containing raw materials, but in food-processing plants and storehouses containing finished products the threshold must necessarily be zero

I believe that pheromones, and indeed all semiochemicals, will play a major role in future integrated pest management programs than they do at present. However, we must obtain a sound ecological understanding to accompany the advances in the fields of chemistry, biochemistry, physiology and genetics (Weatherston and Minks, 1995; Plarre, 1998).

Semiochemicals are shadowed with the expectations asked of conventional pest control materials These products need to compete with chemicals in registration requirements, efficacy standards, cost structure and ease of application. Industrial standards are needed to assure quality control of pheromones in pest management. Dispensers can be characterized by release rates of active ingredients as a function of temperature and other environmental conditions, as well as by the change of these release characteristics as a function of time Lures presently on the market are found to vary greatly in efficacy, mostly due to varying degree of purity of the starting materials.

In order to assure a continuous supply of lures of comparable quality and to allow comparisons between lures of different origin, Arn et al. (1997) propose to adopt the procedure of batch certification It consists of two principles: (I) any chemical or blend prepared for insect monitoring is given a batch number which is carried over to all dispensers made from it; (II) each batch is field-tested by experts and the results made publicly available

Batch certification will lead to a gain of confidence in the trapping results obtained with pheromones. Attempts to relate trap catch with population density can begin to be fruitful as soon as the batch of chemicals are used in different tests in the same. Certification is of critical importance for quarantine pests in which it is often impossible to confirm biological activity without going to another continent. In insect monitoring and detection, the procedure will require a closer co-operation of suppliers and scientists

References

Arn, H , Brauchli, J., Koch, U. T., Pop, L., and Rauscher, S 1997. The need for standards in pheromone technology. Bulletin of International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section, 20 (1), 27 – 34.

Barak, A V., Burkholder, W. E , and Faustini, D. L. 1990 Factors Affecting the Design of Traps for Stored-Product Insects. Journal of Georgia Entomological Society, 63 (4), 466 – 485.

Burkholder, W E 1981. Biological suppression of stored-product insect pests. In: Papavizas, G. S., ed , Biological Control in Crop Protection. BARC Symposium, Allanheld, Osmun, Totowa, 391 – 399

Burkholder, W E. 1982 Reproductive biology and communication among grain storage and warehouse beetles. Journal of Georgia Entomological Society, 17 (4), 1 – 10.

Burkholder, W E. 1990. Practical Use of Pheromones and other Attractants for stored-product Insects In: Ridgway, R L , Silverstein, R M , and Inscoe, M. N , ed., Behavior-modifying Chemical for Insect Management. New York and Basel, Marcel Dekker Inc , 497 – 516.

Burkholder, W. E., and Ma, M. 1985. Pheromones for monitoring and control of stored-product insects. Annual Review of Entomology, 30, 257 – 272.

Casagrande, E., and Jones, O. T 1997. Commercial exploitation of mating disruption technology: difficulties encountered and keys to success Bulletin of International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section, 20 (1), 11 – 17

Cuperus, G , Noyes, R T., Fargo, W S., Clary, B L., Arnold, D C , and Anderson, K. 1990 Management practices in a high-risk stored-wheat system in Oklahoma. American Entomologist, 36, 129 – 134.

Hagstrum, D W , and Flinn, P W. 1991. IPM in grain storage and bulk commodities In: Krischik, V., Cuperus, G., and Galliart, D., ed., Management of Grain, Bulk Commodities, and Bagged Products Oklahoma State University, Cooperative Extention Service, Circular E – 912, 183 – 187

Kirsch, P. 1997 Amazing daze: confusion brings change. Bulletin of International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section, 20 (1), 249 – 256.

Lanier, G N 1990. Principles of attraction-annihilation: mass trapping and other means In: Ridgeway, R. L , Silverstein, R M , and Inscoe, M. N., ed., Behavior-

modifying chemicals for Insect Management New York and Basel, Marcel Dekker Inc , 25 – 45.

Levinson, H. Z. 1983. Integrated manipulation of storage pests involving insectistasis. Mitteilungen der Deutschen Gesellschaft fur Allgemein angewandte Entomologie, 4, 102 – 103.

Levinson, A , and Levinson, H. 1995 Reflections on structure and function of pheromone glands in storage insect species Anzeiger Schalingskunde, Pflanzenschutz Umweltschutz, 67, 99 – 118.

Maxey, F. 1991. Agricultural chemicals. In: U. S. industrial out-look 1991 Washington, DC: US Department of Commerce.

Millar, J. G. , McElfresh, J S , and Rice, R. E. 1997 Technological problems associated with use of insect pheromones in insect management Bulletin of International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section, 20 (1), 19 – 25

Phillips, T W. 1994 Pheromones of stored-product insects: current status and future perspectives. In: Highley, E. , Wright, B J , Banks, H J , and Champ, B R. , ed , Proceedings of the 6th International Working Conference on Stored-product Protection, Canberra, Australia, April 1994. 1, 479 – 486

Phillips, T. W 1997 Semiochemicals of Stored-product Insects: Research and Applications. Journal of Stored Products Research, 33, 17 – 30

Plarre, R. 1998. Pheromone and other Semiochemicals of Stored Product Insects A historical review, current application, and perspective needs Mitteilungen aus der Biologischen Bundesanstalt fur Land-und Forstwirtschaft, H. 342, 13 – 83

Trematerra, P. 1989 Survey on pheromone uses in stored-product pests control Angewandte Zoology, 2, 129 – 142.

Trematerra, P 1997 Integrated Pest management of stored-product insects: practical utilization of pheromones Anzeiger Schalingskunde, Pflanzenschutz, Umweltschutz, 70, 41 – 44

Trematerra, P. , and Zanetti, P In press Activity of commercial pheromone dispensers in the capture of the tobacco beetle, Lasioderma serricorne F. (Coleoptera Anobiidae) Bulletin of International Organization for Biological and Integrated Control of Noxious Animals and Plants, West Palaearctic Regional Section.

Vail, P. V , Hoffmann, D. F. , and Tebbets, J S. 1993 Autodissemination of Plodia interpunctella (Hubner) (Lepidoptera: Pyralidae) granulosis virus by healthy adults. Journal of Stored Products Research, 29, 71 – 74

Weatherston, I. , and Minks, A. 1995. Regulation of semiochemicals-global aspects. Integrated Pest Management Review, 1 (1), 1 – 13

Wileyto, E P. , Ewens, W J. , and Mullen, M. A. 1994. Markov-recapture population estimates: a tool for improving interpretation of trapping experiments. Ecology, 75, 1109 – 1117.