PHEROMONES: AS THE GLAMOUR AND GLITTER FADE—
THE REAL WORK BEGINS

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ABSTRACT

Sex pheromones have been proclaimed throughout the technologically advanced regions of the world as having great potential for managing insect pests through manipulation of their mating behavior; annihilation by mass trapping; and monitoring and surveys which facilitate control through early detection of pests allowing the timely application of pesticides. Yet, very little of this potential has been realized. How then can pheromones become a part of insect pest control schemes in tropical regions of the world where many countries with meager resources are struggling to introduce modern insect pest management practices? The key lies in education of the scientist-extensionist-farmer connection and a deep commitment to the development to one aspect of sex pheromones: trapping for monitoring and survey. The technological tools generally are available; the real work involves developing the relationships between pheromone trap catches with insect populations and plant damage thresholds.

RESUMEN

Las feromonas del sexo se han proclamado a través de las regiones avanzadas tecnológicamente como teniendo gran potencial para administrar plagas de insectos a través de la manipulación del comportamiento de apareamiento; aniquilación por medio de trampas; y el chequeo y muestreo que facilitan el control a través de detección temprana de plagas, así aplicando pesticidas oportunamente. Sin embargo, muy poco potencial se ha realizado. ¿Cómo pudieran entonces las feromonas ser parte de un plan para controlar plagas en regiones tropicales del mundo donde muchos países con pocos recursos están luchando para introducir practicas modernas para el manejo de plagas?. La clave se encuentra en la educación del científico-extensionista-farmero, y en un profundo deseo para el desarrollo de un aspecto de las feromonas sexuales: trampas para chequeos y encuestas. Los medios tecnológicos están generalmente disponibles, el verdadero trabajo implica el desarrollo de relaciones entre lo que se atrapa en las trampas de feromonas con las poblaciones de insectos y el umbral de daño de las plantas.

Pheromones constitute one category of the group of chemicals known as “semiochemicals,” i.e., messenger chemicals, and they are used throughout the Animal Kingdom for communication and regulation of behavior. Pheromones provide information about potential danger, territory, food, trails, aggregation, sex attraction, mating, and egg laying.

Insect sex pheromones are the most widely and intensely studied of all animal communication systems. During the past 20 years, sex pheromones and attractants have been identified for over 600 different species (Insoe 1982), and new identifications appear in our scientific literature with almost unbelievable regularity. This great leap forward in pheromone research has been propelled by the development of sophisticated analytical equipment and new techniques which now permit identification using minute quantities of material as low as the picogram level. As might be expected, the large number of pheromone identifications have spawned an even greater number of publica-
tions on pheromone biology, behavior, and potential for utilizing pheromones as tools to control or manipulate insect pests. It is the belief that pheromones can become a significant factor in insect pest control that continues to drive the "pheromone research machine."

I propose here that pheromones can, and indeed, are being used in selected cropping situations to improve insect pest management practices. The key here is "selectivity." Can pheromones be used as a component of insect pest control strategies in tropical environments? Indeed, they can, but as is true in the more temperate regions of the world, ingenuity, creativity, and simplicity are critical to the integration of these powerful tools into any insect pest control system.

USES FOR PHEROMONES IN INSECT PEST MANAGEMENT

Numerous proposals have been put forth on how pheromones may be used to control insects (Mitchell 1981 and papers therein). However, considering the thousands of papers that have been written on insect pheromones, the number of papers detailing actual utilization of pheromones for any purpose is disappointingly low. The reason for this are many and varied, not the least of which is that most people who have been and continue in pheromone research are involved in identifying pheromones and studying the basics of sex pheromone communication, rather than developing the "how" to put pheromones into practical usage. This does not necessarily indicate a disinterest in developing such information, but more realistically, reflects the work situation in which many researchers find themselves. They often are located in research facilities with little or no direct contact with actual cropping situations, and many also have no practical knowledge of the intricacies of insect pest control.

There are, essentially, three approaches to the use of pheromones in insect pest management: annihilation through mass trapping; disruption of sex pheromone communication; and monitoring with traps. I will not attempt to give an encyclopedic account of all the research which has been reported on each of these approaches. Rather, I will define briefly each approach, and give my opinion as to its potential for adoption as a viable pest control strategy in the tropics and elsewhere.

Mass Trapping—This involves the concentration of many traps in an area with the goal of capturing enough adults to significantly reduce the population. Trapping for annihilation is most effective against species with low birth rates and survivorship, which exist at low equilibrium densities and have density-dependent regulation and low dispersal rate (Barclay 1984). Unfortunately, many pests occur in outbreaks, and as such, their regulation is density-independent most of the time (Barclay & Van Den Driessche 1984). Consequently, suppression of insect pest populations using pheromone-baited traps probably is not a viable alternative to conventional control methods except, perhaps, in isolated situations, such as on an island or in an area newly infested by an introduced insect pest.

Recently, researchers have begun to explore the possibility of eliminating the trap by combining pheromone-pesticide formulations that can be broadcast en masse. The success of this annihilation technique likely will depend upon the use of a combination of attractants (pheromone, food) to ensure killing a large proportion of both males and females.

Disruption of Mating Communication—The air permeation technique for disrupting mating communication has been explored around the world by both public agencies and private enterprise for control of a wide variety of insect pests on numerous crops (Mitchell 1981 and papers therein). The premise of this approach is to distribute enough artificial point sources throughout an area such that an insect that relies on the use of a pheromone to locate a mate will be unsuccessful because the atmosphere is permeated
with pheromone. It has yet to be determined whether the insect’s inability to find a mate is due simply to confusion or because communication is disrupted as a result of habituation by the perceiving insect. Although much has been written on this approach, the full potential of the mating disruption technique for control of any insect pest has yet to be realized. The mating disruption approach to insect pest control shares the same inherent limitations which characterize the mass trapping approach. In addition, a successful mating-disruption control program is dependent upon a delivery technology that remains in a state of flux and which has not yet achieved an industry standardization critical to grower acceptance. However, the air permeation technique may yet become a useful component in some insect pest control strategies, but the success of this technique will depend upon a careful choice of the target pest. Mating disruption, resulting in subsequent reductions in population numbers and crop damage levels, is achieved only through a complex of events which may affect species differentially, depending upon the insects’ behavior and host crop condition. Thus, considerable research is needed before the atmospheric permeation technique will become a significant part of insect pest control strategy.

*Monitoring and Surveying*—The most immediate and primary use of insect sex pheromones is, and probably will continue to be, as tools to monitor and survey insect populations. Pheromone trap catch data can be used to make judgments on pest control strategy, a few examples of which I cite here.

Sex pheromone traps can provide a realistic estimate of the beginning and ending points of male emergence, flight activity, and migration (Riedl et al. 1976). The distribution and migration of several moth species, including the beet armyworm, *Spodoptera exigua* (Hübner), in California (Trumble & Baker 1984); Egyptian cotton leafworm, *S. littoralis* (Boisduval), in Cyprus (Campion et al. 1977) and Egypt (Nasar et al. 1984); and the black cutworm, *Agrotis ipsilon* (Hufnagel) in the United States corn belt (Levine et al. 1982, Krueter & Showers 1982) have been documented using pheromone traps.

In October 1983, a group of interested scientists, including the author, met in Guadeloupe, F. W. I., to develop a strategy for monitoring the movement of the fall armyworm (FAW), *S. frugiperda* (J. E. Smith), throughout the Caribbean Basin, using sex pheromone traps. Based upon the first year’s trapping results, pheromone traps provided a realistic estimate of adult activity peaks in those areas where the FAW resides year-round. Pheromone traps also detected migrant fall armyworm moths as they moved into previously uninfested areas throughout the Eastern United States and Canada.

Data derived from adult surveys can be used to model the development of migrant insect pests once they arrive in uninfested areas. For example, catches of male black cutworm (BCW) moths in pheromone traps give a more reliable indication of the onset of egg laying among migrant females than do catches of BCW moths in light traps. Establishing the start of egg laying is important because it allows the initiation of a temperature-based developmental model using degree days which can predict the presence of BCW larvae. In Iowa, BCW reach the damaging stage 300 Fahrenheit degree-days after the first significant pheromone trap catch. This period usually is about 5 weeks long, but it could be as short as 2 weeks. Because BCW eggs are difficult to find, the model provides far greater efficiency in the pest scouting program (Anonymous 1985).

Pheromone traps also can be used to estimate larval populations and damage levels in crops. Tingle & Mitchell (1981) obtained significant correlations between pheromone-baited trap catches of male tobacco budworm moths (TBW), *Heliothis virescens* (F.), and larval infestations and damage levels in tobacco in Florida. Similarly, Johnson (1983) found a direct relationship between the number of male TBW caught in pheromone traps and egg counts in cotton fields in South Carolina. Silvain & Ti-a-hing
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(1986) reported significant correlations between fall armyworm (FAW) larval counts in pasture grasses and adult males caught in pheromone traps in French Guiana and a warning system that enables timely and effective control has been developed (Silvain 1986). Chowdhury et al. (1985) found that pheromone trap catches of FAW males were significantly related to egg mass and larval densities in late-planted sweet corn. These reports provide excellent examples of how catches of male moths can be used effectively to monitor pest development in different cropping situations. This information can be used with other scouting techniques to enhance pest control practices through timing of pesticide applications.

Pheromone trap catch data can be used to discourage automatic spray programs and encourage growers to apply pesticides only when threatened with economically damaging infestations. A recognized method of controlling the boll weevil (BW), Anthonomus grandis Boheman, in the lower Gulf Coast of Texas, is to apply early-season insecticide treatments to reduce the number of overwintered adults before they can establish the nucleus of an F1 generation. Such treatments usually are based upon the intensity of previous years’ infestations. Benediet et al. (1985) developed a practical and inexpensive pheromone trapping index system (TI) that can be used to reduce unneeded automatic early season insecticide sprays. Their method uses cumulative weekly BW trap captures prior to the occurrence of squares (flower buds) sufficiently large for oviposition (one-third grown stage). The square damage used in their indexing system is the accumulative oviposition damage by overwintered BW during the first 2 weeks following appearance of one-third grown squares. Treatments are indicated when the TI ≥ 2.5. TI of ≤ 1 indicates no insecticide treatment is needed. A TI reading of 1.1 to 2.4 indicates that the treatment decision must be based on the presence of damaged squares or adult BW in the field and on field history. Rummel et al. (1980) previously showed that the trap index method was superior to field inspections for determining the need to treat overwintering BW in West Texas.

Moreno et al. (1985) and Moreno & Kennett (1985) have developed a model for predicting infestations of California red scale (CRS), Aonidiella aurantii (Maskell), in California citrus orchards using catches on pheromone-baited sticky traps. The CRS is best controlled with a single application of a scalicide applied after blooming and before the settling of crawlers on the new crop of fruit. The model assumes that some degree of fruit infestation must be accepted. However, their research has shown that navel orange trees in good physiological condition easily can withstand up to 40% fruit infestation (1 or more scale) without apparent damage to the trees at the end of the season. Through proper use of the pheromone trap and proper interpretation of male catches, an assessment of fruit infestation can be made before it occurs. Using this method, some growers have been able to spread the interval for scalicide applications for CRS control up to 36 months.

Gargiulo et al. (1985) developed a model using pheromone-trap data and degree-day summations to predict optimal timing for chemical control of the Nantucket pine tip moth (PTM), Rhyaconisia frustrana (Comstock), on Christmas trees (Pinus virginiana (Mill.). For each generation, the degree-days are summed commencing on the day of first catch in traps, and continues until a predetermined sum is attained. The day following this attainment is designated as the best date to spray. The choice of insecticide can influence the timing application. For example, optimum dates for spraying a contact insecticide like fenvalerate occurs 1 to 2.5 weeks earlier than for dimethoate, a systemic insecticide. The reason for this difference in timing is that the fenvalerate kills newly hatched PTM larvae, whereas dimethoate is generally most effective against the early larval instars feeding inside of needle mines, fascicle sheaths, and buds.

Management of Pesticide Resistance—One of the newest and most novel uses of pheromones is in the management of pesticide resistance. Suckling et al. (1985) used a
cluster of several pheromone caps strategically placed among suitable host plants to attract males of the lightbrown apple moth (LBAM), *Epinotia postvittana* (Walker), which then were collected during flights at dusk with sweep nets. The LBAM is a major tortricid pest of apple in New Zealand and Australia. Live traps were not used because the captured moths were in poor condition. Netted moths were treated topically with insecticides to determine the level of pesticide resistance, if any. Using this method, they were able to detect rapidly (within 48 h) the geographic distribution of resistant, susceptible, and possible mixed populations. Using pheromones as a method of collecting samples for insecticide testing to determine the distribution of resistant individuals in an area permitted rapid management decisions on what, when, and where a chemical should be applied. This monitoring method is now an integral aspect of the resistance management of the LBAM in New Zealand.

These are all excellent examples on how pheromones can and are used to manage insect pests. Nevertheless, each insect pest presents a unique set of circumstances which require careful study before pheromones can be put into practical use. How, then, does a person go about developing pheromones as a factor in their pest management scheme?

**YOU MUST HAVE DATA**

It is elementary, of course, to say that one must have data on which to base one's proposed use of pheromones in insect pest management. But, is it really? Here, I use DATA as an acronym: Development of Appropriate Technology for Agriculture. For those who have not done so, I recommend that you read and digest the article “Challenges to International Pest Management Research and Extension in the Third World: Do We Really Want IPM To Work?” by Grace Goodell (1984). Ms. Goodell points out the difficulties of transferring technology in Third World countries from scientists to extensionists and farmers. When such shifts are unsuccessful, and they are more often than we like to admit, such failures often are blamed on “socioeconomic” obstacles which the entomologist perceives as quite simple to resolve in comparison to his or her own challenges. While socioeconomic problems definitely do contribute to failures in technology transfer, all too often scientists unwittingly design their system for failure because they develop inappropriate technology. This often is as true for technology transfer in developed as in undeveloped countries. Whether we like to admit it or not, pheromone usage for insect pest control is “high technology.” The proper use of pheromones for maximum impact in control situations requires a relatively high level of technical knowledge and skill to collect the data and interpret the results so that decisions and recommendations can be made in insect control situations.

**USE THE KISS TECHNIQUE**

According to Goodell (1984): “Third World IPM programs often arrive at the farm level as shimmering misfits using sustained rat baiting, quantitative monitoring of trap catches [author’s emphasis], multicolored handbooks for pest identification, and lessons on graphing field populations [author’s emphasis]. As such, recommendations from scientists frequently run counter to the farmer’s best interests.” Insofar as the utilization of sex pheromones for insect pest control is concerned, Goodell’s observations are as appropriate to the developed as to the undeveloped world. For some unknown reason, many scientists seem to equate complexity with usefulness. On the contrary, the KISS technique—KEEP IT SHORT AND SIMPLE—would appear to be the most prudent approach in developing pheromones for use in insect control. For example, pheromone trap catch degree-day developmental models for the black cutworm and Nantucket pine
tip moth cited here are excellent examples of simple systems which can be used with a minimum of technical training. More complex models requiring extensive data collection and computer-assisted analyses surely will be relegated to the archives of scientific literature, but they will find little or no use in the field. It also is significant that the more successful of the pheromone model systems developed to date have used temperature, i.e., degree days, as the driving force.

**Eliminate the FUD Factor**

New insect management tools always are greeted with a healthy dose of skepticism. Pheromones are no exception. Farmers throughout the world have experience on their side when it comes to pest control practices. They, naturally, are fearful of changes, especially with gadgets and terminology which they may have never seen or of which they have never heard. They are uncertain if they should become a willing participant in an experiment with their livelihood; after all, they stand to lose the most if things do not go as advertised. This uncertainty often translates to doubt that the new approach—for example, the use of pheromone traps to schedule insecticide sprays—is worth the risk of shifting from an automatic spray schedule to one of wait-and-see. Elimination of the FUD factor—FEAR, UNCERTAINTY, DOUBT—is difficult to overcome under the best of circumstances; the less sophisticated the farmer clientele, the more difficult it will be. Education is the key here. Scientists must work hand-in-hand with extensionists and FARMERS if the value of pheromones as a pest management tool is to be realized. Goodell (1984) summarized the plight of the small farmer in the Third World thusly:

> Of all the various components of modern agriculture . . ., IPM is the most demanding. To the small farmer IPM remains the cutting edge of scientific farming. But as the traditional farmers strain to catch up with the challenging improvements available to them, they often find themselves in a no-man's-land between technological change for which scientists assume responsibility, and those aspects of change which depend on the limited resources of Third World extension programs.

Much of the same can be said for the developed world, especially where the use of pheromones is concerned.

**The Hard Work Begins**

Entomologists have numerous opportunities to develop unique ways of introducing pheromones into the management of insect pests. In some cases, pheromone traps can be used to survey insect pests over large areas to alert farmers to possible infestations from migrant and local pests. In other cases, pheromones can be used locally on a field-by-field basis to schedule spray treatments or even to release parasitoids for maximum effectiveness. In both instances, much data must be gathered on the biology of the pest and its relation to its natural enemies, and to wild and cultivated hosts. In many cases, plant infestations and crop damage data already are being gathered in the course of present insect pest management programs. The introduction of pheromone traps would be a natural extension of these programs. Simplified models developed from these data then could be used to improve pest management practices through more judicious use of pesticides and conservation of natural enemies.

Most pheromones identified to date have been for species native to the temperate and subtropical regions of the world. However, sex pheromones or attractants have been identified for more than 50 species which are of major importance to agriculture in the Caribbean Basin and Central and South America. These pheromones often can be purchased already formulated and ready for use in traps. Moreover, effective traps
have been designed and are available for most of these species. Persons seriously considering developing pheromones for use in context of their own insect control programs are encouraged to take advantage of the vast amount of research already done on pheromone formulation and trap design, and to use their talent, experience, and energy to commence gathering the necessary data to forge the link between pheromone trap catches and insect pest populations. This truly is a unique opportunity for the economic entomologists of the Caribbean and Central and South American regions (and indeed in North America also) to adapt a form of high technology to their areas at nominal costs; the major costs of identification, formulation, and trap design having already been borne to a large extent by their North American friends and neighbors.

END NOTE

Mention of a commercial or proprietary product does not constitute an endorsement by the USDA.

REFERENCES CITED


USE OF PHEROMONE TRAPS AS A WARNING SYSTEM AGAINST ATTACKS OF SPODOPTERA FRUGIPERDA LARVAE IN FRENCH GUIANA

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ABSTRACT

Experiments in French Guiana since 1979 have shown that it is possible to use pheromone traps in improved pastures, to enable not only a follow-up of the seasonal