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Insect Pheromones 2017

Insect Pest Management; Semiochemicals; Pheromone Discovery; Monitoring; Mass Trapping; Mating Disruption; Regulation; Markets; Trends

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Executive summary

1. Introduction

The significant increase in world population over this century will require more food production and, consequently, key inputs such as fertilizers and pesticides. Environmentally sustainable technologies for pest management mean greater semiochemical use, which currently shows a compound annual growth rate (CAGR) higher than 15%.

Increased semiochemical use has been driven by more restrictive regulatory legislation for conventional pesticides, consumer demand for foodstuffs with minimum pesticide residues and a meaningful increase in pesticide resistance.

2. Insect pest management

IPM uses the best combination of cultural, biological and chemical measures to manage pests and is based on preventing pest build-up, monitoring crops and intervening when pests reach an economic threshold and control measures are necessary.

IPM benefits include better profitability, less severe pest infestations, fewer pest resistance problems. These factors also benefit crop protection companies.

Insect pheromones are environmentally friendly, safe to human health, species specific, easier to register and integrate well with IPM principles.

3. Semiochemicals

Semiochemicals include insect pheromones, which are produced by individuals of a species that affect the behaviour of other individuals of the same species.

Pheromones can be *Releasers*, which elicit an immediate response or *Primers*, which modify the physiological state of the receptor insect and can be divided into categories, including alarm or dispersal pheromones, trail pheromones, sex attractants (mating disruption and monitoring), aggregation and anti-aggregation pheromones and marking pheromones.

4. Pheromone discovery

Insect pheromones effects were first observed in the 1870s but it was only in 1959 that Adolph Butenandt, working since the 1930s, isolated Bombykol, the substance that female moths use to attract males of *Bombyx mori*.

Also in 1959, Peter Karlson and Martin Lüscher, working on the termite caste system, introduced the term “pheromone”.

In 1957, Dietrich Schneider had used electrophysiology to develop an electrical means of detecting pheromones through the large antennae of moth species and named this odour-prompted electrical response of an insect antenna an “electroantennogram” (EAG).

In the mid-1960s, Robert Silverstein and David Wood, working with pine bark beetles discovered that specific blends of chemical compounds acted as aggregation pheromones.

Throughout the 1960s and 1970s technical improvements significantly improved the speed and productivity of pheromone research including gas chromatography, mass spectrometry, and nuclear magnetic resonance, used in combination with EAG.

John Kennedy invented the wind tunnel with a moving patterned floor to simulate the changing territory beneath the insects’ flight path and found that moths use the same visual information when tracking pheromones. Since the 1970s, Kennedy’s wind tunnel and similar devices have proven invaluable to researchers trying to test candidate pheromones and blends.

In 1960, Morton Beroza suggested using sex pheromones to jam the insect long-distance mating communication system and in 1967, entomologist Harry Shorey was the first to show that pheromones could be used to disrupt the mating of cabbage looper moths in the field.

A pilot programme to control the codling moth in apple and pear orchards in Oregon and California reduced pesticide use by 80 % and damage was lower than in conventionally treated orchards.

Pheromones also are used as the bait in traps for pests in mass trapping, such as bark beetles.

Researchers are working to improve pheromone dispensers so that chemicals are longer acting, less costly, more potent, and easier to release as well as assessing trap quantities and distribution.

5. Pheromones in IPM – Monitoring

The use of semiochemical-based monitoring systems has resulted in a more rational and cost-effective use of conventional insecticides.

There are now pheromone lures available for over 1,500 species of insect pests but 80% are for 20% of the possible species.

Modes of use in monitoring and detection include early detection of insects, detection of low levels of infestation, details of insect distribution by locality, season and sources of infestation, optimum timing for insecticide application and assessment of the efficacy of control measures.

Major insect species being widely monitored include: forestry pests, top-fruit moth pests, grape pests, cotton pests and many fruit fly species.

Several cases of pest monitoring with pheromone traps are discussed.

6. Pheromones in IPM – Mass trapping

The mass trapping of insect pests where a pest species is attracted in large numbers to a trap which contains a species specific lure is one way to control a pest.

An extension of mass trapping is to eliminate the trap and replace it with an insecticide coated killing device so that trap catch saturation is avoided. Both mass trapping and lure and kill approaches show promise provided there are powerful attractants for both sexes of a species.

Several case studies of mass trapping are discussed, including the cotton boll weevil, palm weevils and bark beetles.

7. Pheromones in IPM – Mating disruption

Market demand, legislative pressures and significant technological advances in pheromone manufacture and controlled release have all contributed to increasing the use of sex pheromones for mating disruption.

Mating disruption is based on the release into the environment of a synthetic version of the natural pheromone, which becomes a potential replacement for insecticides when pest populations are low, the dispenser system is reliable and there is an area wide approach.

The result is less insecticide use and lower insecticide residues in fruit.

The technique is influenced by the type of pheromone dispenser and pheromone field concentration among other factors.

Various case studies of mating disruption are discussed including the codling moth, tomato pinworm, pink bollworm and oriental fruit moth.

8. The regulatory situation

The registration of a new pheromone is often difficult although recommendations from the OECD support less regulation of low risk materials such as moth pheromones. Registration requirements can involve an efficacy study, requiring multiple seasons and issues like time and the cost of new solution development are often underestimated.

Under FIFRA, pheromones labeled for use only in pheromone traps for monitoring, and pheromone traps in which those chemicals are the sole active ingredients, are not subject to regulation.

For control using mating disruption in the USA, a pheromone regulatory relief programme has given exemptions.

In Europe, other concerns including consumer protection have required efficacy tests and this has inhibited product development.

9. The insect pheromone market and future growth trends

Global semiochemical sales are estimated at US$430 million at the manufacturer's level, growing at a CAGR of more than 17% over the last five years. The geographic share of the market is estimated at: USA/ Canada 25%, LATAM 14%, Europe 30%, Asia/Pacific 27%, Rest of the World 4%.

World sales of semiochemical-based products for pest monitoring are estimated at more than US$100m at the manufacturer's level.

Limiting factors and threats include political (reduction in government funding), societal (cost and lack of understanding) and regulatory factors.

Consumers want to eat residue-free foods, are resistant to conventional insecticides, are eating more organic foods and believe in sustainable agriculture.

Technological trends include improvements in pheromone manufacture resulting in lower costs.

Governments are encouraging more sustainable agricultural policies including less complicated and faster regulatory procedures.

A substantial biopesticide industry has been created and large crop protection companies have been investing in it. The pheromone market will therefore probably see consolidation and mergers in the near future.

10. Company profiles and product lines

The pheromone market is composed of several large companies, which manufacture many different pheromones and various trap designs, such as Shin-Etsu and Pherobank, and many smaller companies, some of which act as distributors. The company profiles and product portfolios are presented and fully discussed.

- Farmers receive consistent messages from more than one source and all stakeholders follow the same agenda.

- Training government, private extension staff as well as CP product and seed distributors and retailers, who directly influence farmers and need to be able to provide practical advice about IPM.

- Developing education and training programmes for farmers, which may include field schools, mass and social media, newsletters, direct mail, videos and posters. A major aim of the training is to maximize product benefits and minimize their risks. Such training covers all aspects of handling and storing CP products, as well as when to use and when not to use them, including how to:

  – Identify pests and beneficial insects

  – Assess the risk of pest populations and potential crop damage

  – Manage pests according to IPM principles

  – Apply crop products safely and effectively if required

  – Avoid unacceptable risks to people and the environment

  – Minimize product residues on crops and monitor for pest resistance

  – Store products safely and properly dispose of empty containers

2.5 Benefits of IPM

IPM provides multiple benefits for society and the environment and is vital for the long-term future of the CP industry. These benefits include:

- Improved crop profitability due to better pest control measures and the appropriate use of crop protection products

- Stable, reliable and quality crop yields

- Less severe pest infestations

- Reduced potential for problems of pest resistance or resurgence

Increased consumer confidence in the safety and quality of food and fibre products means that CP companies that integrate IPM principles into marketing and customer support for their products also stand to benefit from:

3. Semiochemicals

3.1 Summary - Semiochemicals

Semiochemicals include insect pheromones, which are produced by individuals of a species that affect the behaviour of other individuals of the same species.

Pheromones can be *Releasers*, which elicit an immediate response or *Primers*, which modify the physiological state of the receptor insect and can be divided into categories, including alarm or dispersal pheromones, trail pheromones, sex attractants (mating disruption and monitoring), aggregation and anti-aggregation pheromones and marking pheromones.

3.2 Introduction

The OECD defines semiochemicals as: “chemicals emitted by plants, animals and other organisms, and synthetic analogues of such substances, that evoke a behavioural or physiological response in individuals of the same or other species” (source: http://www.oecd.org/chemicalsafety/pesticides-biocides/2507268.pdf).

The term "semiochemical" has been in use since 1971 and is derived from the Greek word "semeon," which means "sign" or "signal."

A study of semiochemicals must consider their functions since the same molecule could act as a pheromone for one insect species and as a kairomone or allomone for another.

Insects seem to use more chemical signals than other forms of communication. These signals, often called semiochemicals or infochemicals, serve as a form of "language" that helps to mediate interactions between organisms. Insects are often highly sensitive to low concentrations of these chemicals and a few molecules may be enough to elicit a response (Table 3.1).

Table 3.1: The advantages and disadvantages of chemical communication

Advantages	Disadvantages
• Not limited by environmental barriers • Effective over distances and around corners • Effective either day or night • Longer lasting than visual or auditory signals • Metabolically "inexpensive" because only small quantities are needed	• Low information content (presence/absence) • Not effective in an upwind direction

The perfect social signal should have the following characteristics:

3.5 Insect taste and smell

(source: https://projects.ncsu.edu/cals/course/ent425/library/tutorials/behavior/chemoreceptors.html).

Insects use their sense of taste or smell to detect the presence of semiochemicals. Specialized receptors may be located anywhere on the insect body, but are especially common on the feet, antennae, palps and ovipositor.

3.5.1 Taste

The sense of taste (gustation) is used for contact chemoreception detecting molecules that adhere to a substrate or to the outside of an insect's body, e.g. ants recognizing their nestmates by the taste and smell of hydrocarbon lipids present on the cuticle surface.

Gustatory receptors are commonly described as thick-walled hairs, pegs, or pits where the dendrites of several (usually up to five) sensory neurons are exposed to the environment through a single opening (pore) in the cuticle. Each neuron appears to respond to a different range of compounds (e.g. sugar, salt, water, protein, acid, etc.). Taste receptors are most abundant on the mouthparts, but may also be found on the antennae, tarsi, and genitalia (especially near the tip of the female's ovipositor).

3.5.2 Smell

The sense of smell (olfaction) is used for remote chemoreception detecting semiochemicals with low molecular weight that are volatile enough to become airborne, for example, a parasitic fly attracted by its host’s odour.

Olfactory receptors are usually thin-walled pegs, cones, or plates with numerous pores through which airborne molecules diffuse. Dendrites of sensory neurons branch profusely within these pores and may respond to very low concentrations of detectable compounds (e.g. sex pheromones). Some receptors respond to a wide range of substances while others are highly specific. Olfactory receptors are most abundant on the antennae, but may also be associated with the mouthparts or external genitalia.

3.6 Insect pheromones

The term "pheromone" is derived from the Greek words "pherein" (to carry) and "horman" (to excite/stimulate). The term was introduced in 1959 by Karlsson and Butenandt and by Karlsson and Lüscher simultaneously.

The difference between pheromones and hormones is that hormones are produced in an insect's endocrine glands and have an effect on the insect that produces them, whereas pheromones affect other individuals.

Adolf Butenandt had characterized the first such chemical, bombykol, a chemically well-characterized pheromone released by the female silkworm to attract mates.

Pheromones can be *Releasers*, which elicit an immediate response or *Primers*, which modify the physiological state of the receptor insect and can be divided into at least the following categories based on their effect:

The cotton boll weevil (CBW-*Anthonomus grandis*) is indigenous to Mexico and Central America and is a narrowly oligophagous species, which feeds primarily on cotton, *Gossypium hirsutum* L. Since its introduction into US around 1882, it is estimated that the boll weevil has been the most expensive insect in the history of American agriculture, costing US$15B for damage and control measures.

One approach to eliminate the CBW that has received considerable investment has been the use of male-produced pheromone, grandlure, in conjunction with traps and/or trap crops.

Once male boll weevils locate their host plant, feeding ensues, and the weevils release in their frass an aggregation pheromone, attractive to both sexes, which serves as both an aggregation pheromone, to attract other weevils to a food source, and as a mating pheromone, to help the two sexes locate one another. Research has shown that this pheromone is capable of attracting boll weevils from as far as 150 m. Grandlure is a synthetic version of the pheromone produced by male boll weevils and is composed of four compounds discovered between 1965-69.

Male or grandlure baited traps have been used to determine the feasibility of mass trapping the CBW for many years. Many trap designs have been evaluated from the 1960's but, the so-called Leggett trap, and subsequent design based on it, had shown to be more effective and selective.

The boll weevil trap has three parts: a body, a molded screen cone and a collection chamber. The yellow-green trap body mimics the plants the boll weevil lives in and feeds on.

An artificial pheromone contained in a polyvinyl-chloride dispenser is placed in the collection chamber to attract weevils along with an insecticide strip to kill weevils that enter the trap.

Weevils attracted to the trap land on the outside of the body and crawl to the inside of the cone. An opening in the top of the cone allows the weevils to enter the collection chamber.

An essential prerequisite for the most efficient operation of pheromone traps against boll weevils is the reduction of the overwintered weevil population. Diapausing (hibernating) adult weevils spend the winter in leaf litter and other protected sites close to the cotton fields. In the spring, emerging weevils move into the cotton fields in search of food. About 4 generation occur during the cotton growing season and then at the end of the season, the weevil leaves the fields to find shelter for overwintering. Therefore, in the spring, the most effective placement of traps is along the borders of the cotton fields, to intercept the emerging weevils as they search for cotton. As the cotton grows, traps placed in the fields become more efficient. In spring, trap baited attract both sexes of overwintered adults, and again in the autumn, weevils of box sexes respond, reducing the weevil population. The use of aggregation pheromones as a suppression strategy in a boll weevil management programme allows the use of lower doses of insecticides and increases the control effectiveness.

6.3.4.1 The National Boll Weevil Eradication Programme

This a federal-state-grower cost share programme to eradicate the CBW which was launched in the late 1970s by USDA/APHIS. Growers funds with some state support accounted for over 70% of the programme operation budget with less than 30% of funds provided by Federal cost share.

The boll weevil has been eradicated in the Southeast states of Virginia, North Carolina, South Carolina, Georgia, and Florida and also from Alabama, Tennessee, Missouri, Arkansas and Mississippi. The Far West is now boll

Mass trapping is regarded as an effective method for protecting stands of wind-damaged spruce, but is considered rather ineffective during large-scale outbreaks. Estimates concerning the effectiveness of traps for reducing *I. typographus* populations range from 0.2 to 80%, but most studies have shown that only a minor portion is captured despite substantial numbers being collected.

Mass trapping has been implemented during large-scale outbreaks in Sweden (270,000 traps), and Poland (50,000 traps), but in the latter case was just one of several direct control methods employed. Generally, high trap catches are not well correlated with activity on trees, but low catches usually coincided with little beetle activity. Mass trapping could be effective as an additional method of control during outbreaks, especially in the context of protecting living trees rather than reducing *I. typographus* populations. A potentially negative impact of mass trapping is that several members of the natural enemy community may be collected and killed.

6.3.6 Palm weevils

(Source: Molet, T. 2013. CPHST Pest Datasheet for *Rhabdoscelus obscurus*. USDA-APHIS-PPQ-CPHST) and http://www.cabi.org/isc/abstract/19971100293

Palm weevils in the curculionid subfamily Rhynchophorinae (*Rhynchophorus* spp., *Dynamis borassi, Metamasius hemipterus, Rhabdoscelus obscurus* and *Paramasius distortus* [=*Metamasius inaequalis*]) use male-produced aggregation pheromones for intraspecific, chemical communication. Pheromones comprise 8, 9 or 10 carbon, methyl-branched, secondary alcohols. (4*S*,5*S*)-4-Methyl-5-nonanol (ferrugineol) is the major aggregation pheromone for *R. ferrugineus, R. vulneratus, R. bilineatus, M. hemipterus* and *D. borassi* and a minor component for *R. palmarum*. (5*S*,4*S*)-5-Methyl-4-octanol (cruentol), (3*S*,4*S*)-3-methyl-4-octanol (phoenicol) and (4*S*,2*E*)-6-methyl-2-hapten-4-ol (rhynchophorol) are the main aggregation pheromones for *R. cruentatus, R. phoenicis* and *R. palmarum*, respectively.

Plant kairomones strongly enhance pheromone attractiveness but none of the identified volatiles, such as ethyl acetate, ethyl propionate or ethyl butyrate are as synergistic as fermenting plant (palm or sugarcane) tissue. Studying orientation behaviour of foraging weevils to semiochemical devices helped to design and test traps for weevil capture. Generally, 3 mg per day of synthetic pheromone (with non-natural stereoisomers being benign) plus insecticide-treated plant tissue constituted highly attractive trap bait.

6.3.6.1 Rhabdoscelus obscurus

The Dryophthoridae weevil, *Rhabdoscelus obscurus*, is considered a significant pest of sugarcane, palms, and banana and a secondary pest of corn. *R. obscurus* is native to New Guinea and the surrounding islands but has spread to almost all of the sugarcane growing areas in the Pacific including Hawaii. It is also present in Asia**:** Indonesia, Japan, Malaysia, Taiwan and Oceania.

The female lays eggs in sugarcane stalks and after hatching, larvae bore downwards into the stock towards the base. There are six larval instars and a prepupal stage. On palms, females lay eggs on the petiole and stem. After hatching, the larvae bore into the living tissue and produce frass-filled tunnels. This species can have multiple generations per year. The life cycle takes about 13 weeks.

the period of treatment and permeation remains continuous as long as external wind speeds and air temperatures remain the same.

- **Hercon´s** unique, proprietary laminated polymer technology is the foundation of its controlled–release product manufacturing capability. This technology allows formulation and mass–production of highly effective controlled–release products for many different applications using a wide variety of AIs.

The unique multi–layer structure of Hercon´s laminated polymer formulation system protects sensitive AIs from premature environmental breakdown caused by oxidation or photo–degradation. It also prolongs the useful life of AIs by controlling their rate of release so an efficacious amount is continuously made available. By selecting the appropriate film thickness and polymeric composition, product release characteristics can be varied to accommodate a wide range of AIs and use applications.

The laminated polymer technology permits high speed/high volume manufacturing of products having uniform high quality. The laminate structure produced lends itself to a wide variety of finished product forms, from small flakes suitable for aerial application (see DISRUPT® II GM), to postage stamp–sized dispensers for use as lures in insect traps (seeLURETAPE® Insect Monitoring Lures), and larger patches for the controlled–release of insecticides to prevent insect infestations in telecommunications and utility equipment (see INSECTAPE® Insecticidal Tape/Strip).

- **Scentry** manufactures No-Mate CM Fiber, which is applied aerially through the use of Scentry application pods mounted on helicopters or fixed wing aircraft. The fibre can also be broadcast by tractor mounted ground equipment.

The spirals are made of flexible PVC and filled with pheromone in a solid matrix. Unlike quid-filled dispensers of rigid polyethylene, the spirals slip onto tree branches, eliminating labour-intensive twist-ons. The spirals will not break and leak and they flex to accommodate tree growth. The solid matrix filling is highly stable, providing predictable, consistent release of more pheromone into the orchard in all weathers.

No-Mate spirals reduce hand application costs by 50% and contain more AI than other dispensers releasing 20%" more pheromone into the canopy.

NoMate spirals meet US National Organic Program standards, and can be used alone or in combination with insecticides.

- **Suterra** invented the Puffer®, which consists of an electronically controlled, mechanical device (cabinet), and an aerosol pheromone formulation (canister). The cabinet is used to dispense the pheromone in the canister, which provides mating disruption for the targeted pest.

Features and benefits include:

- The pheromone is only released when the electronically controlled device is activated, permitting complete control of the emission rate and timing.
- Emission frequency can be programmed every 15 minutes or every 30 minutes so that the release rate can be tailored to pest characteristics.

Table 7.3: Use of the pheromone-mediated mating disruption technique for oriental fruit moth in various countries

Country	Type of Dispenser	Density (no./ha)	Efficacy and extension
France	Polyethylene tube	1000	Both kinds of dispensers were the most effective and simple to use.
	Polyethylene bulb	500	
USA	Polyethylene tube	1000	The pheromone-treated peach and nectarine orchards in California and Virginia extended from 600 ha in 1987 to 4000 ha in 1990.
	Microcapsule	-	Male OFM captures were reduced by 77–98% in 35d, and the formulated pheromone significantly disrupted male orientation.
Japan	-	-	The effect of mating disruption was greater than trapping.
Korea	-	-	The effectiveness of the disruption technique was enhanced through sequential suppression year after year at the same site.
Australia	400mL microcentrifuge tube	-	In this extensive 3-year trial, use of pheromone treatment increased from 25 to 40 ha and confirmed that conventional insecticides could be replaced by mating disruption from the viewpoint of cost and efficacy. These successful tests encouraged use of mating disruption in over tens of thousands of hectares in the peach-growing districts in New South Wales and Victoria.
	Polyethylene capillary	500	Male OFM capture was reduced by 77–98%.
		100	OFM males preferred untreated orchards adjacent to pheromone-treated orchards.
	Polyethylene tube	-	Pheromone treatment reduced the capture of moths in pheromone-baited traps by an average of 98%, suggesting a high level of disruption
	-	-	Application of mating disruption barriers on pears during two consecutive seasons provided sufficient control of OFM on peaches, and this mating disruption barrier treatment was able to reduce the number of OFM caught in all experimental peach blocks. Extending the mating disruption treatment area for 54–60 m into the neighbouring pear block significantly reduced the edge damage in mating disruption-treated peaches in the first season and almost eliminated OFM damage in the second season.
	-	-	Mating disruption was a viable alternative to conventional insecticides.
China	Rubber septa	-	In Liaoning province, Eastern China, the percentage of infested fruits in the pheromone-treated orchards was reduced to 50% and 72% compared with the insecticides-treated orchards in 1981 and 1982, respectively; this technology was extended on a large scale.
		1050	In pear orchards of Shanxi province, Northern China, male OFM orientation was disrupted by 97.43% and the percentage of infested fruits was reduced by 74.72% in 2009.
		750	In pear orchards of Shanxi province, Northern China, male orientation was disrupted by 81.83% and the percentage of infested fruits was reduced by 56.43% in 2009.
		3000	In peach orchards of Shanxi province, Western China, after 37d, without insecticides, male orientation was disrupted by 93.46% and the percentage of infested fruits was reduced by 73.72% in 2007.

10.3 Agrisense, UK

www.agrisenseuk.co.uk

Agrisense offers a wide range of bio-rational products to protect residential, commercial and industrial assets. Their products are based on three main areas of expertise:

- Insect behaviour modifying chemicals (pheromones, attractants and repellents) and trap design.
- Controlled release technology for pheromones and other volatile compounds.
- Insect glue technology and application.

10.3.1 Product portfolio

- The Trappit™ CR range provides pest management professionals with roach monitoring products in three distinct profiles that are efficient and economic.
- Bed Bug products, including traps with lure technology.
- Moth Monitoring Traps (black-striped delta and funnel types) and Kits for *Ephestia* spp, *Plodia interpunctella* and *Tineola,* including lures. There is a comprehensive range of lures for stored product moths, including the Spectrum lures designed for use as part of the industry standard seasonal colour system, providing an easy visual auditing capacity.
- Beetle monitoring traps plus lures (for *Lasioderma serricorne*, *Tribolium confusum*, *T. casteneum*, *Attagenus* spp.)
- Wasp traps and baits with monitoring products in both disposable and reusable options containing an industry-leading attractant.
- Fly traps and attractants with indoor and outdoor monitoring products with efficient attractants and which are effective against various fly species.

10.4 Andermatt Biocontrol

www.biocontrol.ch

The company Andermatt Biocontrol was founded by Drs. Martin and Isabel Andermatt in 1988 and since then has become the leading company in Switzerland for biological based plant protection.

The key expertise of Andermatt is the production of baculoviruses and entomopathogenic nematodes, as well as beneficial insects for greenhouses and stored products.

Table 10.3: Insect pheromones and pheromone blends available from ATGC Biotech, India

Insect Target	Common name
*Anarsia lineatella**	Peach twig borer
*Anthonomus grandis**	Cotton boll weevil
*Batrachedra amydraula**	Lesser date moth
*Batrachedra pinicolella**	Pine cosmet
Carposina sasakii	Peach fruit moth
*Cryptophlebia illepida**	Koa seedworm
*Cryptophlebia ombrodelta**	Macadamia nut borer
Cydia pomonella	Codling moth
Earias insulana	Spiny bollworm
*Endopiza viteana**	Grape berry moth
Epiphyas postvittana	Light brown apple moth
Eucosma gloriole	Eastern pine shoot borer
*Grapholita molesta**	Oriental fruit moth
Helicoverpa (Heliothis) armigera	Old World bollworm
*Keiferia lycopersicella**	Tomato pinworm
Lobesia botrana	European grapevine moth
Maruva vitrata	Legume pod borer
*Ostrinia nubilalis**	European corn borer
*Paranthrene robiniae**	Western poplar clearwing
Phyllocnistis citrella	Citrus leafminer
Platyptilia carduidactyla	Artichoke plume moth
*Plutella xylostella**	Diamondback moth
Proeulia auraria	Chilean fruit leaf folder
Rhopobota naevana	Blackheaded fireworm
Spodoptera exigua	Beet armyworm
*Spodoptera littoralis**	Egyptian cottonworm
*Spodoptera litura**	Oriental leafworm moth
Synanthedon scitula	Dogwood borer
*Tineola bisselliella**	Webbing clothes moth
Tribolium castaneum	Red flour beetle
Tribolium confusum	Confused flour beetle
Zeuzera pyrina	Leopard moth
* pheromone blends also available as per client's request.	

With the acquirement of American Cyanamid's agrochemical division in 2000, BCP became one of the top three agrochemical companies in the world, together with Syngenta and Bayer.

DISRUPT MICRO-FLAKE® and DISRUPT BIO-FLAKE® Bark Beetle Anti–Aggregant products are based on Hercon´s proprietary pheromone controlled–release technology, effective in over 15 years of use in the US Forest Service´s Gypsy Moth Slow–the–Spread Program with aerial applications of over 400,000 acres throughout the United States to be treated annually with Hercon’s DISRUPT II GYPSY MOTH MATING DISRUPTANT.

DISRUPT MICRO-FLAKE® and DISRUPT BIO–FLAKE® VBN Bark Beetle Anti–Aggregant Flakes contain the AI, verbenone, effective as an anti–aggregation pheromone against mountain pine beetle and certain other species by preventing attack and build–up up of damaging population levels in susceptible trees and tree stands.

The BIO–FLAKE formulation is made of a biodegradable product that will naturally and rapidly degrade in the environment once the AI is gone.

DISRUPT MICRO–FLAKE® MCH Bark Beetle Anti–Aggregant Flakes contains the AI, methyl cyclohexenone, effective as an anti–aggregation pheromone against Douglas–fir beetle and certain other species.

10.15 Horizon Biosciences

www.horizonbiosciences.com

Horizon BioSciences is part of the Horizon Inc. family of companies, located in Boulder, Colorado, USA and is one of North America's leading wholesale supplier of products for forestry and urban foresters, selling to garden centers, horticultural suppliers, nurseries, retailers and professional foresters.

Horizon BioSciences carries a wide range of semiochemical and insect pheromone repellents baits and lures, bio pesticides, OMRI and certified organic pesticides, insect traps, insecticides, miticides, fungicides, herbicides and biological controls.

The company distributes a wide range of biopesticide technologies, including state of the art forest semiochemical products and pheromones designed to improve pest management.

Baits and lures

Tree baits concentrate bark beetle attacks enabling forest managers to better contain infestations for more effective beetle removal and retention of timber market value. Species specific beetle and moth traps monitor insect populations and aid a variety of control strategies. Pheromone and kairomone traps are also sensitive detectors of non-indigenous forest insect pests (See Table 10.9)

Verbenone repellents

Verbenone Pouches, Verbenone Flakes and Splat Verbenone Tubes and Paste, pheromone repellent for Mountain Pine, Southern Pine and Ips Beetles