Pheromones ~ clean weapon against insects?

Back in the 17th Century, European naturalists used to put virgin female moths into cages. These virgins would then attract males to their doom — which in this case was to finish up pinned out in the naturalists' moth collections.

One of Dr Rothschild's pheromone-dispensers, which he has used in peach orchards to control oriental fruit moths by confusing the males and thus preventing them from mating.

What these naturalists were doing was making use of a scent that the virgin moths give out to attract males for mating. Now, three centuries later, a not-dissimilar technique is being used in the orchards and cotton-fields of Europe, North America, Africa, and Australia, to detect the presence of certain insects that are regarded as being pests.

Today, use of such scents to the insects' detriment is on the verge of becoming big business in agriculture. Yet the science of studying these scents is little more than 20 years old. Current interest stems back to about 1959. In that year P. Karlson and M. Luscher, two German scientists, coined the name 'pheromone' for the perfumes — a compound word derived from the ancient Greek words *pherein* meaning 'to carry', and *hormon* meaning 'to excite or stimulate'. Two years later, the German chemist Butenandt, after 20 years of study, finally identified the substance with which the female silkworm moth attracts its mates. Now the perfumes that attract the mates of some 55 moth species have been identified.

Pheromones are quite common in the animal kingdom. They are by no means restricted to female moths. Neither indeed do they merely attract males to females. Rabbits use scents to mark their territories and establish their position in rabbit society (see *Ecos* 18), and when male dogs go through the familiar ritual of lifting their legs against trees, lamp-posts, or other upright objects they are, of course, laying a scent (or pheromone) to inform other dogs that they were in the neighbourhood.

Stinging attack

Among the insects, pheromones are widely used to maintain a social structure. Thus the queen bee gives off a substance that holds the swarm together. And if you have ever suffered from the painful experience of being attacked by bees, you might have wondered why it was that so many just homed in and stung you. The answer is simple. The first attackers had marked you with a pheromone, so their fellows merely 'zeroed in' on the scent. Ants and termites also use pheromones. When foraging they lay scent trails, which their fellows follow. They also signal danger with an 'alarm pheromone'.

Discovery of the relatively simple chemical structures of insect pheromones led, inevitably, to thoughts of how these chemicals may be used to control those insects that we regard as pests. In practice, using the pheromones for this purpose hasn't proved so easy. Nobody, for example, has yet come up with a way of using the alarm or the trail-forming pheromones of ants and termites.

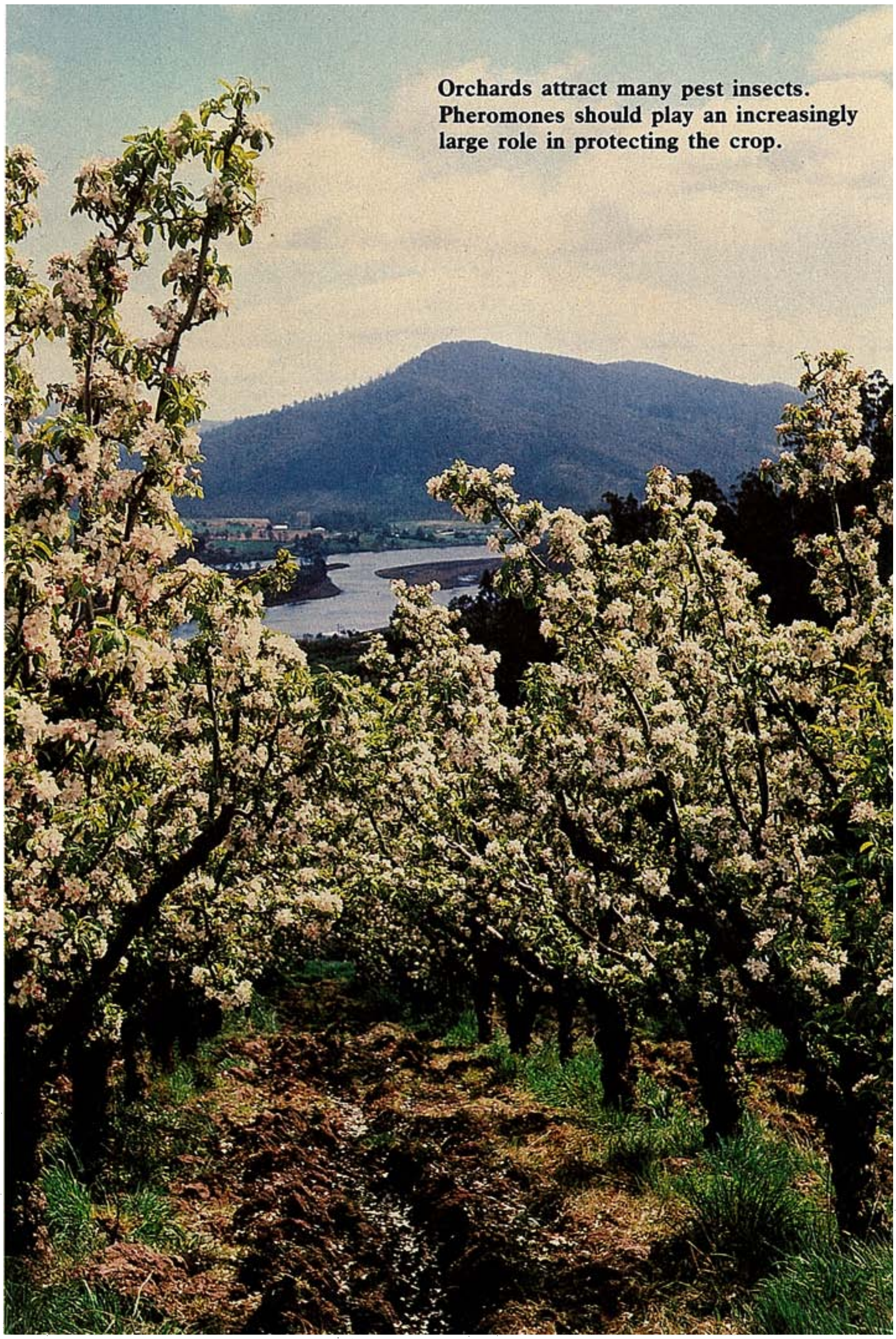
To date, with one exception, the only pheromones that look close to being used in any quantity are those that attract members of the opposite sex. The moths, being night flyers, depend more than most insects on chemical signals for bringing the sexes together. Not surprisingly, this is the group in which the most progress has been made.

The one exception is the boll weevil, that famous pest of cotton. Males of this particular insect give off a perfume that attracts other boll weevils, regardless of their sex. The scent serves to attract other adult weevils to sources of food, and for this reason it is known as an 'aggregation pheromone'.

Early hopes

Perhaps disenchantment with insecticides has done more than anything else to spur research into pheromones. Here, it seemed, was a way of controlling insects using chemicals that occur naturally. Thus the problems caused by unnatural synthetic insecticides accumulating in the environment should be avoided. In addition, in the early days, each insect species apparently had its own perfume. Thus when released into the air, each pheromone would only affect the one target insect. So using pheromones would avoid one major disadvantage of spraying broad-spectrum insecticides — namely, the insecticides may kill all insects with which they come in contact, regardless of whether the activities of their victims are a nuisance to Man or to his benefit.

Pheromones seemed to have yet another advantage over the insecticides


Orchards attract many pest insects. Pheromones should play an increasingly large role in protecting the crop.

in that only minute amounts of the chemicals would be needed to affect a very large number of insects. What's more, since these scents would only be effective when carried on air currents, it should be unnecessary for them to ever pass into the soil. Many researchers also felt that pheromone resistance (the equivalent of insecticide resistance) should not arise.

As so often happens, not all these expectations have withstood the test of time. We now know that a single pheromone may affect more than one species; indeed unrelated insects from different biological orders may react to the same chemical. Frequently also, the perfume does not consist of a single chemical. Instead, it may contain a blend of major and minor constituents. The sensors of each species may be fine-tuned to a particular combination. These days researchers talk not so much about pheromones as about 'pheromone complexes', and they refer to the substances in the blend as the 'pheromone components'. Thus, once again, a biological arrangement that appeared simple at first sight turned out to be much more complicated.

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Even the claim that insects cannot become resistant to pheromones has perhaps been given the lie. There is evidence that in the United States some populations of the cabbage looper moth, whose little caterpillar can make a considerable nuisance of itself in cabbage crops, may have already evolved a 'tolerance' to a sex attractant.

Over-enthusiasm

While pheromones may have been somewhat oversold in the first flush of enthusiasm after their discovery, they certainly will be useful. Indeed, the pheromones of some 47 species of insects that make a nuisance of themselves are now in use. But the days of the 'suck it and see' approach of identifying pheromones, synthesizing them, and then just seeing whether they can be used are probably over. Nowadays it is generally realized that if these substances are to be used effectively, much more knowledge will have to be accumulated on the way the target insects react to them. Also, research into methods of dispensing the pheromones has lagged behind.

Australian peaches — a favourite food of the oriental fruit moth. Controlling the moths with pheromones has proved cheaper than with insecticide.

Attraction; confusion

The fact that the sex attractants offer most hope for immediate application has already received a mention. Two main strategies seem to be emerging for using these attractants. The first uses the sex pheromones as baits in traps to stimulate males to approach what they perceive as females. The other, which is known as the 'confusion' technique, does the opposite. Flooding the environment with the female pheromone may so confuse the poor males that they cannot find the females. If this disruption can be main-

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tained for long enough, then the males will die without mating and, more importantly, so will the females.

Attracting the males to non-existent females has been used in two ways — for monitoring the size and geographical extent of certain pest populations, and occasionally for controlling them by 'mass trapping'. Usually the aim with mass trapping is to catch so many males that most of the existing females will not mate. Hence the insect population will

If not prevented by heavy doses of insecticides, native budworm larvae may badly damage cotton crops. Using pheromone-baited traps to show their presence can at least enable growers to spray only when they really have to.

at least be maintained at its existing level. (No scientist investigating the use of pheromones believes that they can be used to eradicate an insect population. The best that can be hoped for is to reduce the numbers to a level where the damage the insects do will be tolerable. In other words, the aim is control, not eradication.)

The snag with the mass trapping technique is that a few males can usually fertilize many females, so relatively few males will be needed for the population to maintain itself. It will often be necessary to trap more than 90% of the males, a feat that frequently proves impossible. Research workers generally seem to feel that mass trapping will probably prove the most effective against small isolated pest populations.

The technique has not been tried in Australia, as no pest insects seem to be particularly suitable candidates. Researchers do appear to have had considerable success in California against the western pine beetle. A variant of the technique, which involves trapping out both sexes, has also been successfully employed against the cotton boll weevil — using a synthetically produced version of the weevil's aggregation pheromone that was mentioned earlier. This perfume mixture of four components is sold under the trade name of 'Grandlure'.

In the United States and Switzerland mass trapping has also been tried against codling moth — a pest of apple and pear orchards in many countries, including Australia — but to no avail.

Perfumes show they're there

Using pheromone-baited traps for monitoring purposes has yielded success both overseas and in Australia. The technique does nothing to control the various pest insects, but using it does

Light-brown apple moths, male and female. The female leads.

enable growers to cut down on the quantities of insecticides they spray. Normal 'prophylactic' spraying routines involve spraying at fixed dates regardless of whether a large insect population is present. Pheromone-baited traps can reveal whether a particular undesirable insect really is present, and they may also suggest in what numbers. Armed with this knowledge, growers can use insecticides only when they will be most effective.

Dr George Rothschild of the CSIRO Division of Entomology has directed most of the research into making practical use of pheromone traps for monitoring pest populations that has been done in Australia. He has used the technique to check on codling moth populations in New South Wales apple orchards, and for monitoring the activities of the various species of bollworm that attack cotton crops around Narrabri, in northern New South Wales, and in southern Queensland.

In his studies with the codling moth he has tried to correlate the numbers caught in traps baited with a male-attracting pheromone with damage to fruit. So far, his results have proved disappointingly variable. Nevertheless, in orchards in which he has placed one trap for each hectare, weekly catches of more than two males per trap have usually indicated that more than 2% of the fruit will be damaged. Dr Rothschild feels that he will have to learn rather more before he can confidently predict the best times for spraying.

Checking out cotton pests

In the cotton-fields Dr Rothschild has come up with a number of uses for monitoring traps. For example, at pres-

A codling moth larva disturbed in its home. Checking for the presence of adult moths should also allow a reduction of insecticide spraying.

ent 'scouts' make spot-checks for infestations of the cotton bollworm and native budworm — two species of *Heliothis* moths that may attack the cotton. The scouts do so by counting the eggs on selected plants, but unfortunately it is not possible to know which species the eggs belong to, and the control measures needed differ for the two species. Dr Rothschild has had some success in separating infestations of the two moths by using different pheromones in traps.

Both the cotton bollworm and the native budworm may migrate over considerable distances, which means that mass trapping would have little chance of controlling them. The major problem is that the baited traps attract only males, so the female population remains intact. An invasion of relatively few males will permit rapid fertilizing of most of the females (and some already fertilized females may, of course, also enter the crop).

Aided by the officers from several State Departments of Agriculture, Dr Rothschild has also been able to use pheromone-baited traps for mapping the distribution in northern Australia of two other pests of cotton — the pink bollworm (*Pectinophora gossypiella*), and its close relative the pink spotted bollworm (*P. scutigera*).

Dr John French of the CSIRO Division of Building Research has used a rather similar technique using an aggregation pheromone for detecting the spread of elm bark beetles in urban and rural plantings of the elm tree in south-eastern Australia. (In Europe and North America the elm bark beetle spreads the fungus that causes the devastating Dutch elm disease. Although, as Dr French's studies showed, the elm bark beetle is probably present in all those parts of south-eastern Australia where large numbers of elms exist, the fungus has not reached Australia.)

In other countries, the technique has been successfully used to monitor populations of a number of insects regarded as pests, including those of summer fruit tortrix moths in apple orchards in the Netherlands, spruce budworms in Canada, and oriental fruit moths and the codling moths in Washington State, U.S.A.

Pheromones are now used to check out these insects

flies
- oriental fruit fly
- Mediterranean fruit fly
- melon fly
- house fly

butterflies and moths
- European corn borer
- peach tree borer
- lesser peach tree borer
- oriental fruit moth
- lesser apple worm
- codling moth
- grape berry moth
- European pine shoot moth
- smaller tea tortrix
- summer fruit tortrix
- red-banded leaf-roller
- eastern spruce budworm
- carpenter worm
- peach twig borer
- pink bollworm
- gipsy moth
- African armyworm
- fall armyworm
- cluster caterpiller
- tobacco budworm
- cabbage looper
- *Spodoptera littoralis*
- oblique-banded leaf-roller
- omnivorous leaf-roller

beetles and weevils
- boll weevil
- *Dendroctonus* sp.
- smaller European elm bark beetle
- ambrosia beetle
- *Ips* sp.
- Japanese beetle

wasps and bees
- yellow jacket

scales
- California red scale

Pheromones may not yet be used for controlling insects, but they are now being widely used for detecting pest species — as this list of 36 species around the world that are now being monitored using pheromone-baited traps shows.

Jamming the senses

The confusion technique (flooding the environment with pheromone so that it jams communication between the sexes) has shown considerable promise both in Australia and overseas, particularly against moths. However, there are good reasons why it will not work with all species that depend on pheromones to attract members of the opposite sex. Males of some species, for instance, are merely attracted to the vicinity of the females by the pheromones these emit. They actually locate the females by sight. In such cases, flooding the environment with pheromones may merely stimulate the males to look for nearby females, and it's not inconceivable that with the extra female-hunting activity mating will actually increase.

Obviously, a detailed knowledge of the mating behaviour of target insects will be needed before it will be possible to predict whether the confusion technique will work. Sadly, our present knowledge about the detailed behaviour of pest species is so limited that for most we don't even know where they mate. If you don't know if your orchard pest mates on the ground or in the tops of the trees, it is difficult to know how to best release the pheromones to have the desired effect!

What's more, because many sex-attractant perfumes consist of a blend of several chemicals, it may be extremely difficult to obtain exactly the right blend, and without that blend the males may still find the females. For a while it looked as though this situation might apply with the light-brown apple moth, which is an Australian native. In southern parts of the continent, and in orchards located at higher elevations further north, this insect is regarded as something of a pest by the apple and pear industries.

In Dr Rothschild's trials, using the pheromone even proved more economical than spraying parathion.

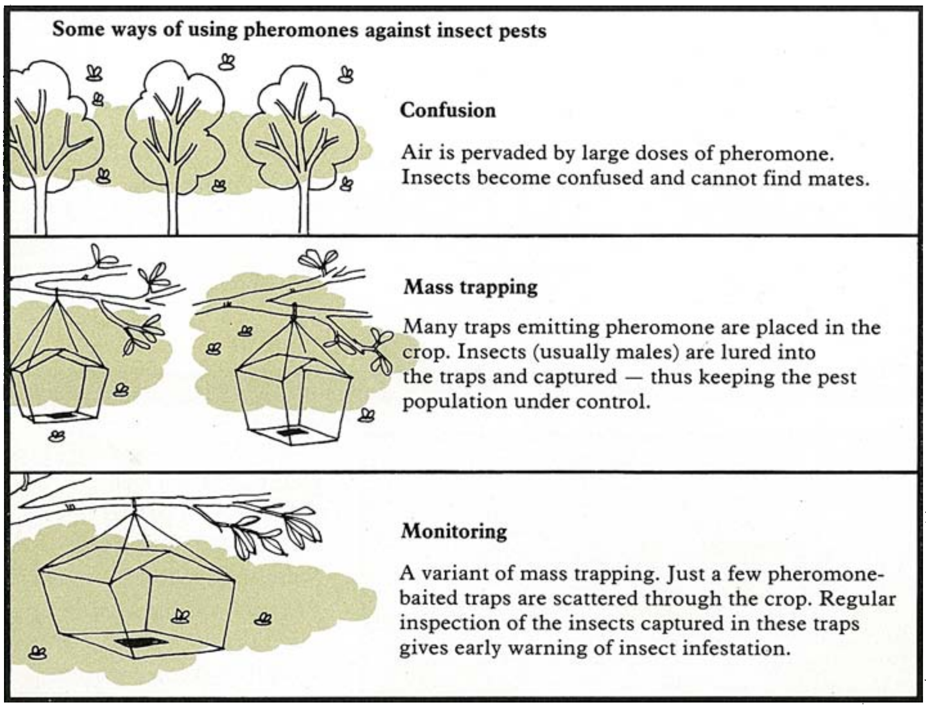
Dr Tom Bellas, a colleague of Dr Rothschild at the CSIRO Division of Entomology, has now discovered the chemical nature of the sex attractant emitted by females of this species and can make it artificially. Laboratory studies carried out by Dr Roger Bartell and Ms Louise Lawrence, two other colleagues, have shown that while its two components usually occur in the scent gland of the female in exactly the same proportions, male moths will nevertheless react to a broad range of mixtures.

In the case of the light-brown apple moth it seems that there are at least two different strains (they look different), which live in different geographical locations. The perfume blends emitted by the females of these two strains may well differ — indeed, it appears that the perfumes of the two strains may even contain different chemicals. Such a finding would not be that surprising, since scientists studying pheromones now suspect that geographical variation within the perfume blends of a species may be quite common.

Candidates for confusion

Such complications may suggest a rather bleak future for the confusion technique. In fact it appears to hold out considerable promise for controlling several common insect pests in many parts of the world. Currently, the best candidates for control in this way seem to be the gipsy moth, the plum fruit moth, the oriental fruit moth, and the pink bollworm moth.

As in the United States, the oriental fruit moth makes a considerable nuisance of itself in Australian peach orchards, and Dr Rothschild has had considerable success in controlling this insect — mainly at Cobram, Vic., Leeton,



N.S.W., and Renmark, S.A. — using the confusion technique. His trials compared the effectiveness of pheromones with that of currently used insecticides.

Dr Rothschild dispensed the pheromone from sealed polythene tubes, each of which contained 50 mg that slowly evaporated through the seal out into the air of the orchards. By cutting down the numbers of tubes in successive trials, he found that he could obtain effective control by placing two dispensers in every eighth tree in the orchard. Thus every eighth tree carried dispensers containing 100 mg of pheromone, which means that the pheromone in all the dispensers in each hectare of the orchard totalled 2·5 grams. These dispensers released pheromone into the orchard air at a rate of about 6 mg per hectare each hour.

By comparison, routine spraying with insecticides to obtain slightly lower levels of control involved spraying parathion on six different occasions at a rate of 910 g of active ingredient per hectare.

Environmental pros and cons

It's the fact that such small amounts can effect control when released into the environment that makes pheromones such an attractive proposition from both the economic and the environmental points of view. In Dr Rothschild's trials, using the pheromone even proved more economical than spraying parathion. Similar rates of application have been found to disrupt mating of other pest species in other countries.

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Where mass trapping rather than confusion has been successful, amounts of pheromone used per hectare have been as low as 0·1 g, or roughly one ten-thousandth of the quantity of chemical commonly applied to each hectare when using conventional insecticides. In addition, being substances whose molecules contain plenty of double bonds, pheromones break down easily.

Nevertheless, it should not be forgotten that, although they occur naturally, pheromones are chemicals that are being released into the environment in greater than natural amounts. The United States Environmental Protection Agency (EPA), whose standards are usually followed by other countries including Australia, therefore demands that when pheromones are to be used for insect control (rather than monitoring), they should be subject to the same stringent tests as normal pesticides.

To date, only one pheromone appears to have been registered by the EPA for use commercially as a control agent — namely that of the pink bollworm, which is synthesized and marketed by the Conrel Company under the trade name of 'Gossyplure H.F.'. The H.F. stands for 'hollow fibres', since the pheromone is contained in very small hollow plastic fibres, from which it evaporates into the surrounding air. The adhesive-coated fibres are small enough to allow them to be dropped from aircraft, or to be distributed onto cotton plants mechanically from a tractor.

It's interesting that the EPA has given approval for the pheromone to be used only in this way. Thus both the chemical and the formulation (the method of application) have had to be approved.

Holding the pheromones in hollow fibres is but one way of dispensing them. Other methods are now being investigated, but considerable technical difficulties still remain when it comes to dispensing pheromones on a commercial rather than an experimental scale. Much also remains to be done to improve the design of traps for mass trapping and for monitoring. Nevertheless, the Zoecon Corporation, a Californian company, does now market kits for monitoring boll weevils in cotton — marketing pheromones for monitoring does not require the approval of the EPA.

More about the topic

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