Special report

Integrated insect control may alter pesticide use pattern

by Worthy

Chemical pesticides have a lot wrong with them. Pests can become resistant to them. Their effectiveness is temporary; repeated applications are necessary. Their residues can be permanent, lingering in the harvested crops. They can disrupt natural controls, causing even worse pest outbreaks. They can harm nontarget organisms—man and his domestic animals, wildlife, honeybees and other pollinators, and the crop plant itself. And they can reduce the diversity of the ecosystem and thus invite future problems.

All these charges against chemical pesticides are true, in a sense, and all have been stated before. They've been stated so often that they're fast losing their power to inflame men's passions. Clearly the trend has been away from the emotional and occasionally simple-minded denunciations of "chemicals" toward advocacy of a "new" concept, usually referred to as integrated pest management.

The subject is currently getting a lot of attention. The Council on Environmental Quality recently issued a well-publicized report on the topic. The U.S. Department of Agriculture, aided by the far-reaching network of state extension services and agricultural schools and in conjunction with the National Science Foundation and the Environmental Protection Agency, is spearheading 19 large-scale regional programs to develop integrated control techniques for six major crop systems.

Also, a federally funded International Biological Program has been established to develop better systems of pest management on a national and worldwide basis. The program, involving 19 cooperating U.S. universities, is coordinated by the University of California's Center for Biological Control, with Dr. Carl W. Huffaker as project head.

Dr. Huffaker describes integrated pest management as "the system of pest management that will bring the greatest benefits, at the most reasonable cost, on a long-term basis, to the farmer and to society." The goal is to bring to bear the best of all available control techniques against pest problems, rather than to place what has been called "blind reliance" on chemical pesticides.

In the full sense of the term, integrated pest management encompasses all pest control measures, including the use of fungicides and herbicides. However, since broad-spectrum chemical insecticides have received the bulk of the blame for ecological damage, and since the main thrust of the current research effort is to find alternatives to the use of those insecticides, this C&EN special report will, in the main, confine itself to that one aspect of an admittedly larger problem.

Integrated pest management is not a panacea for all our pest problems. It is not really new, although the concept has certainly been neglected since the advent of chemical pesticides. Nor is it a "back-to-nature" philosophy (although it indeed favors natural controls whenever they will work) that rejects chemicals out of hand.

In fact, says Dr. Ray F. Smith, assistant director of the International Biological Program, "Pesticides remain, in spite of their adverse publicity, our most powerful tools in the management of pests. The pesticides, as developed in the past 25 years, are highly effective and economical and can be marshaled quickly to have immediate impact on a pest population—even over a large area." When pest populations approach economic damage levels, there is little else to do but use pesticides. Thus, he says, despite their admitted disadvantages and limitations, "Pesticides must and will continue to be used in a major way."

Still, a major aim of research on integrated control is to find practical alternatives to the use of broad-spectrum chemical pesticides. If all goes well, according to the officials who developed the proposal that led to the International Biological Program, "It will be possible to reduce the use of the more undesirable pesticides by 40 to 50% within five years, and perhaps by 70 to 80% within 10 years."

There are many alternatives to using broad-spectrum chemical pesticides. One of them—doing nothing at all—is patently impractical. Another—using narrow-spectrum chemical pesticides—is practical, but also obvious. The practicality of some of the other suggested options has yet to be confirmed. It's improbable that any single approach will provide the final solution any more than DDT did. Anyway, integrated pest management, by definition, implies a multiplicity of approaches.

The better ideas include things as simple as getting farmers to adopt or go back to agricultural practices that hamper, rather than promote, the multiplication of pests; as sophisticated as raising microbes to infect pests with deadly diseases; as devious as preventing insects from reproducing, by messing up their sex lives with radiation, hormones, and aphrodisiacs; and as sensible as promoting the welfare of other creatures that help keep the pests under control.



Cotton boll weevil is one major target of new insect control methods

Hobbes clearly proves that every creature
Lives in a state of war by nature.
So, naturalists observe, a flea
Hath smaller fleas that on him prey;
And these have smaller still to bite 'em;
And so proceed ad infinitum.
Jonathan Swift, 1733

In nature's balance, the insects and other arthropods that are, from man's standpoint, "pests" are kept in check because there are other, "beneficial" organisms that eat, parasitize, or infect great numbers of the "pests." But when man tampers with the balance of nature—by tilling the soil, by transporting plant varieties from one region to another, by developing one-crop agricultural systems, or by applying chemical pesticides—he can unintentionally tip the balance in favor of the pests.

For example, in the early 1930's, in Nova Scotia, there were devastating outbreaks of several apple pests, notably oyster-shell scale and the European red mite. Dr. A. D. Pickett and coworkers at the Canadian Department of Agriculture's research station at Kentville, N.S., found that the normal predators and parasites of these pests had been almost exterminated as a side effect of the use of then-new sulfur fungicides. Switching to other fungi-

1940's and 1950's, mite populations exploded wherever broad-spectrum chemical pesticides were used, according to Dr. A. W. MacPhee, present head of the Kentville station's entomology section. Such experiences led the Nova Scotia scientists to develop some of the earliest programs for integrated pest control—emphasizing judicious use of selective chemicals, placing maximum reliance on natural control mechanisms, and reserving broad-spectrum products for "emergency" situations.

In addition to preserving natural predators and parasites, pest control programs aim at introducing useful new ones. According to USDA, attempts have been made to import predators and parasites of about 80 pests into the U.S.



Larval parasite (Apanteles rubecula) *lays eggs in cabbage worm*

Of 520 species thus imported, about 115 have become established, and about 20 of these now provide significant control of some of the worst plant pests.

Man also intervenes to boost natural levels of both indigenous and imported predators and parasites. Commercial insectaries rear a number of useful species by the billions for timely release in fields and orchards. One of the most successful of these has been the Trichogramma wasp. This tiny—too small to be harmful to humans—parasitic wasp lays its own eggs in many kinds of moth and butterfly eggs. It is becoming increasingly important in the control of Heliothis moths, various species of which are major pests of cotton, corn, tobacco, and tomatoes.

Also important is the green lacewing, sometimes referred to as "the broad-spectrum predator" because it attacks so many kinds of pests, including aphids, mites, whiteflies, mealy bugs, and leafhoppers. The green lacewing larva is known as the "aphid lion" because of its voracious appetite for those insects. Among the other commercially produced insects are the Vedalia ladybug and the golden chalcid wasp, both used to control citrus scale. Also, various mite-eating mites are reared and released to feed on plant-eating mites that afflict apples, pears, and citrus fruits.

Scientists are also waging biological warfare on insect and arthropod pests at the microscopic level. Dr. Lee A. Bulla, a microbiologist at USDA's Agricultural Research Service laboratories in Peoria, Ill., points out that "A variety of bacteria, viruses, fungi, and protozoa are pathogenic to insects and have tremendous potential for use as control agents." Research has been going on for decades; however, there are only two commercially available bacterial insecticides. And although more than 300 viruses are known insect pathogens, all are still in the research or experimental stages. Practical use of fungi and protozoa lies still farther in the future.

The first bacterial insecticide to be produced commercially (beginning in the 1940's) was a preparation containing spores of *Bacillus popilliae*, which causes milky spore disease in Japanese beetles and a few other beetle species. It has been used since then, with modest success. However, it takes time for the spores to become widely established, and the pesky Japanese import, with few other indigenous enemies, continues to extend its domain in the U.S.

The other commercially available bacterial insecticides are all preparations containing spores of *Bacillus thuringiensis* (BT) and also the crystalline endotoxin produced by the bacteria. It is effective against more than a hundred species of caterpillars, many of which—such as the cabbage looper, the alfalfa caterpillar, and the tomato worm—are serious pests.

When BT is ingested, it kills in ways. First, the toxin paralyzes caterpillar's gut, inhibiting fe Then the bacteria penetrate th wall, causing septicemia. Effecti seems to require a pH of 9 or hig the gut content, a characteristic sessed only by the susceptible lep tera. Thus, BT is apparently comp harmless to man, to beneficial in and, for that matter, to everythin the high-pH caterpillars. This is cided ecological advantage, and practical one, because BT prepara are exempt from tolerance require for recommended uses.

Early BT formulations varied w in potency and, as a result, wer their way to acquiring a bad r Fortunately, that situation was edied in the late 1960's when Dr. ard Dulmage of ARS's Brownsv Tex., laboratories isolated a new pendable, highly potent BT var now generally known as the strain. The new strain even appea be effective against the cotton worm, which was not very vulnerab the earlier BT products. Experime use against the gypsy moth caterp has also been encouraging; and the vironmental Protection Agency approved BT formulations for ground and aerial applications (C&E April 9, page 11).

All commercial BT products—Ab Laboratories' Dipel, Internati Minerals & Chemical Corp.'s Thurici and Nutrilite, Inc.'s Biotrol XK (tributed by Thompson-Hayward Ch ical Co.)—are now based on the pot HD-1 strain, and BT's popularity increasing rapidly.

"If research on other bacteria done with the intensity devoted to *thuringiensis*," Dr. Bulla observes, reservoir of control agents could be veloped to cope with many differe kinds of insect problems." In fact, li such research is going on; the near-te outlook for new bacterial insecticid is not encouraging.

Viruses, in contrast, are receiving great deal of attention from the ag cultural research community. Viral secticides are even more selective th the bacterials. However, the very fact their high specificity makes many of viruses unlikely candidates for co mercialization. Unlike BT, which can grown in bulk using straightforw fermentation techniques, viruses obligate parasites that can only gro in the tissues of their hosts. So produc tion of viral insecticides requires, firs the production of large numbers o disease-free host insects—a difficult, tedious, and expensive process. Conse quently, development costs for a viru insecticide are at least as high as, an probably higher than, the costs of brin ing a broad-spectrum chemical to mar ket. Yet the market will, in most cases, be a very limited one. Industry is un

the prospect of a decent return on investment is too remote.

There is, however, one exception: the nuclear polyhedrosis virus specific to Heliothis moth larvae. That virus is now being produced in limited commercial quantities by IMC (as Viron/H) and by Nutrilite (as Biotrol VHZ) and sold, under temporary labels, for experimental use against the cotton bollworm. If all goes well, its application may be extended to other Heliothis species. IMC comments that the host worms are among the most destructive of insect pests and that an agent specific to Heliothis larvae has a multimillion-acre market potential.

Nutrilite vice president E. B. Westall tells C&EN that his firm is also producing "relatively large quantities" of a viral insecticide for use by the U.S. Forest Service against the tussock moth. Mr. Westall emphasizes, however, that the product is not at present a "label item."

Viruses have already proved themselves useful—sometimes by accident of nature, sometimes by design of scientists—in suppressing several other forest pests, including the European spruce sawfly and the European pine sawfly (both of which wreaked havoc with North American timber until they were reunited with the viruses that kept them in check in their native Europe). Several other viral insecticides are under serious investigation. It appears probable that many other viruses will come to play important roles in integrated control programs, but that the viruses may have to be produced by governmental, academic, or other publicly financed agencies rather than by industry. Fortunately, a little virus can go a long way. The organisms are highly infectious and, once introduced, can spread rapidly, destroying large populations of insects and eventually becoming established in the ecosystem. In many cases, mass production of viruses may turn out to be unnecessary.

Two other groups of potential pest control agents that have received much scientific and popular attention in recent years are the insect hormones—which can upset normal metabolic processes—and the insect pheromones—which can disrupt, inhibit, or pervert normal insect behavior. Although these compounds are, technically, chemical agents, their modes of action, their selectivity, and their theoretically high potency set them sufficiently apart from "conventional" chemical pesticides to warrant special consideration for integrated control programs.

Among the hormones, the ones that have shown the most promise as pesticides are the so-called juvenile hormones (JH), or growth regulators. JH is normally present in insect larvae. At a certain stage of development, the larvae stop producing JH and undergo metamorphosis. But if the larvae continue to be exposed to JH (from external sources), they either fail to metamorphose, or change into bizarre intermediate forms that can't reproduce.



Hormones upset normal insect development

Certain chemicals can keep insects from maturing completely, thus making it impossible for them to reproduce. The pupa (left) of a yellow mealworm, for instance, is sprayed with a synthetic hormone. Instead of undergoing normal metamorphosis to produce a full adult (center), it develops an adult head and thorax, but because of the hormone, not an adult abdomen (right).

The history of the discovery, isolation, and structure determination of juvenile hormones goes back at least 40 years (C&EN, Nov. 29, 1971, page 33). However, the natural hormones are produced in exceedingly minute quantities; practical use in control programs has had to await the recent—and continuing—development of synthetic hormones, of synthetic analogs of the natural hormones, and of "hormone mimics" (substances that are chemically unrelated to the natural hormones but have similar physiological effects).

Scientists both in the U.S. and abroad are working feverishly to develop and refine these compounds; however there are still many problems with potency, with stability, and with difficulty of synthesis that have combined to hinder commercialization and widespread use. And, like other pesticides, they must go through the extensive and expensive safety testing needed to satisfy EPA registration requirements.

Nevertheless, two U.S. firms, Zoecon and Stauffer, are actively developing hormonelike compounds. Stauffer says that its juvenile hormone mimics could make a major contribution to pest management programs, but that much R&D remains to be done before it can recommend them for practical use.

On the record, at least, Zoecon is considerably more sanguine. In January the Syntex subsidiary filed with EPA the first application for registration of an insect growth regulator for control of mosquito emergence from breeding sites. The company also submitted a petition for temporary negligible residue tolerance, noting that some of the first applications would be for mosquito control in flood-irrigated pastures and rice fields. If granted, the experimental permit and temporary exemption will allow only test marketing. Zoecon points out, however, that they will also allow greatly expanded field-scale trials and that they are the first steps toward full registration and full-scale commercial marketing.

The Palo Alto, Calif., firm is also testing, in the laboratory and in the field, a number of other growth regulators against such insects as aphids, scales, mealy bugs, and the navel orangeworm. The mosquito control product is only the first, Zoecon says, of a new class of insect control substances that, because of their nonpersistency and relatively low toxicity, will have a major impact on pesticide markets.

And well they may. But even if some formidable technical and economic barriers can be surmounted, hormones probably don't represent the be-all, end-all in pest control. For one thing, they are effective only at certain stages of insect development; timing of application can be even more critical than for other pesticides.

Also, the "hormones" keep the insect in the larval form, and thus prevent reproduction. But in the case of many

insect pests, the adults—reproductive capabilities aside—are harmless, while the larvae cause the major damage to plants. There is certainly no short-term advantage in holding insects in the larval stage longer than usual. Thus, although growth regulators will almost surely come to be useful in overall pest management programs, other agents will still be needed for the immediate prevention of severe crop losses.

Finally, contrary to some popular speculation, it appears likely that insects will eventually become resistant to growth regulators, just as they have to other chemical pesticides.

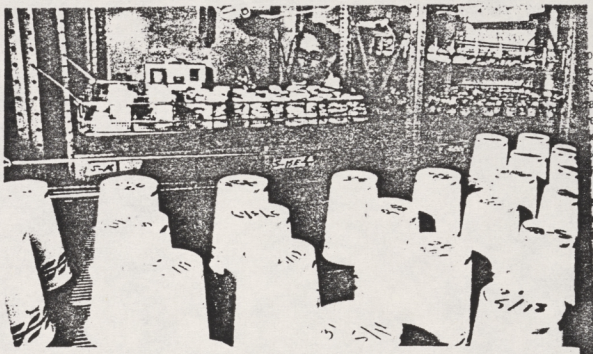
Insect sex pheromones have triggered the imagination of the popular press even more than have the growth-regulating hormones. The public has been regaled with juicy accounts of how a fraction of a picogram of pheromone can turn billions of average male insects into raving sex maniacs that will mindlessly crawl or fly to convenient traps or lethal devices—thereby failing their duty to preserve the species and ultimately bringing about the extinction of that species. Or, conversely, to present the males with such a surfeit of pheromone that they are first whipped to a frenzy of libido, then overshelmed, and, finally, "turned off" completely.

As a matter of fact, there's quite a bit of truth in those admittedly exaggerated stories; synthetic pheromones appear to have a respectable future in pest control. As usual, the concept is not new. It's long been known that you can catch more flies with honey, that metaldehyde both attracts and poisons slugs, that a fragrant perfume can attract human males, and that a bitch in heat will draw every loose male dog within a 2-mile radius.

But in the case of pest control, says USDA chemist Morton Beroza, "A more elegant approach is to isolate and identify the chemicals that the insects themselves manufacture and use to ensure their propagation." Dr. Beroza and his associates—as well as many other workers at many other institutions—have for several years been pursuing the development of synthetic pheromones, pheromone synergists, and chemically unrelated compounds (somewhat analogous to the hormone mimics) that nevertheless act as sex attractants.

Pheromones have been isolated and identified for a goodly number of insect species, and synthetic sex attractants have been prepared for such economically important insects as the codling moth (a major pest of apples and pears), the boll weevil, the gypsy moth, the pink bollworm, the redbanded leaf roller, and the cabbage looper. Extensive field testing is under way for these and other attractants. The attractants can be employed in two basic ways—to trap the insects, or to disrupt their normal behavior.

In the first application, tiny amounts of the potent chemicals are used to lure insects to traps set out in orchards, fields, or forests. The traps serve two separate purposes, which, however, sometimes overlap. First, they can show—by the number of insects they catch—whether the infestation is rising to a dangerous level and thus indicate when other control measures (chemical spray, release of sterile males, or whatever) need to be taken. They also monitor the effectiveness of such control measures. In addition, when the insect population is low, the traps often attract and immobilize enough of the males to reduce the normal incidence of mating and thus help keep the population at a tolerable level. However, when great numbers of insects (in proportion to the number of traps) are on hand, the odds are good that a given male will be attracted to a virgin female rather than to a trap, and that there will be no significant effect on reproduction or on population levels.



Agriculture Department technician checks health of pink bollworm colonies. Bollworms are produced for sterilization and release against natural infestations

In disruptive applications, the idea is to fill the air with so much of the chemical that the male insect can't distinguish a female from his general surroundings, and so doesn't mate. Simple in theory, the method is fraught with difficulties in practice. For one thing, the broadcast release of attractant requires tremendous quantities (at least in relation to the tiny amounts needed for the point-source traps) of currently scarce and very expensive chemicals. And there are many other problems to be solved—for example, optimum means of dispensing, stability, possible interactions with plant life, and so on. However, several disruption studies are going on, and some apparently successful programs have been carried out on small acreages.

Sex attractants are farther along the road to commercialization than are the growth regulators. Zoecon markets a line of sticky traps baited with the firm's synthetic lures, and these are now fairly widely used in integrated control programs for detection, survey, and monitoring purposes. Zoecon asserts that the traps have already helped bring about more judicious use of conventional chemical insecticides. Although Zoecon also produces materials for use in suppression studies, such applications are still in the experimental stage. Commercialization must wait until the attractants can be produced in sufficient quantities at competitive prices, and until the products run the gauntlet of the registration procedure (protocols for which are only now being established). Nevertheless, Zoecon says, synthetic sex attractants have excellent prospects as active insect control agents.

Another sex-based method of insect control is the sterile-male release technique, pioneered by USDA's Edward F. Knipling. In this approach, billions of male insects are reared, then sterilized—in the reproductive sense—usually by radiation, although alkylating agents and other chemosterilants are also sometimes used. The sterile males are released in insect-infested areas, there to compete with normal males for the attention of the females. However, the eggs "fertilized" by the sterile males don't develop. If the ratio of sterile to normal males is high enough, the population of that particular insect falls off drastically, sometimes to the vanishing point.

In a 1955 program, sterile-male releases eradicated the screwworm from the Caribbean island of Curaçao, and later programs virtually eliminated that serious cattle pest in Florida. The technique is also being used in the southwestern U.S., where there have been major successes but also major setbacks. Early results were highly encouraging. But the screwworm flies keep re-entering the U.S. from Mexico. There were severe outbreaks in the southwestern U.S. in 1972, the result of a combination of factors including unfavorable weather conditions and the relaxation of surveillance and other preventive measures. The program continues, however, and should be much

more effective once it is expanded to include all of Mexico.

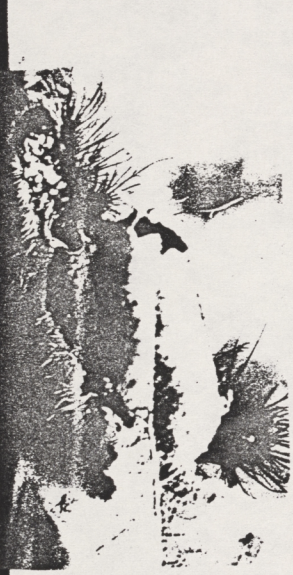
Sterile-male releases have also eradicated several pests in isolated areas: the Oriental fruit fly on Guam, the melon fly on Rota (an island in the Marianas), and the Mediterranean fruit fly on the isle of Capri.

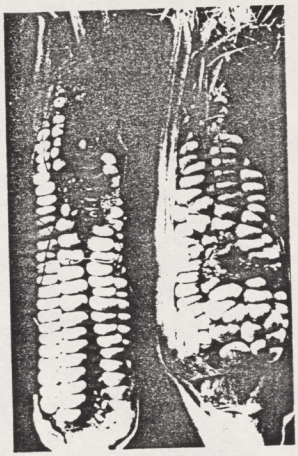
Several other programs have been less successful, primarily because the sterile males were released in areas where pest levels were already so high that even billions of sterile males couldn't compete against the much greater numbers of their normal counterparts. In situations of that sort, sterile males can still be an important component of integrated programs. For example, they can be released to "finish off" insect infestations that have previously been reduced to manageable levels by chemicals or by other biological control agents.

Except in the control of isolated populations, sterile-male releases are usually effective only when carried out in concerted programs over fairly large areas. Therefore, although commercial production and retail marketing of sterile male insects can't be ruled out, government agencies will probably continue to provide the major impetus to their use.

Direct sterilization is not the only avenue to genetic control of insect populations. In a review of the subject [*Science*, 178, 1164 (1972)] Dr. Roger H. Smith and Dr. R. C. von Borstel cited several other routes. For example, it should be possible to induce inherited partial sterility, ultimately causing the decline and disappearance of a species. Or to contrive "conditionally lethal" mutations that would permit an insect to survive in one environment but not in another. Also, the geneticists note, selection systems can be devised that could, in the course of generations, transmute an insect species' normal preference for a crop diet into an appetite for weeds—thus turning a "pest" into a "beneficial insect." On the other hand, they caution, careless genetic meddling could create instead an even worse pest, or a new one.

A hint of what may someday be accomplished by genetic transformation of insects can be inferred from what has already been accomplished with plants. Over the years, by careful selection and hybridization, plant geneticists have not only dramatically increased crop









Losses due to insect damage run into the millions of dollars annually. Above left, a voracious gypsy moth eats away at a leaf; center, a corn earworm at work; right, a southern army worm chews on a bean plant leaf; lower right, cotton leaf worms

sistant to many diseases.

Imparting insect resistance to plants is apparently more difficult, and relatively less progress has been made in that direction. However, the rewards for even limited success can be great. For example, although USDA pegs the total cost of research to develop plant varieties resistant to the Hessian fly, the wheat-stem sawfly, the European corn borer, and the alfalfa aphid at about $9.3 million, it estimates the annual savings—in terms of reduced losses from those pests—to be in excess of $300 million.

Once imparted, resistance seems to hold up fairly well. But the work is never really finished. New insect biotypes appear that are able to attack previously resistant plant varieties. Sometimes introduction of a new variety turns a previously innocuous insect into a serious pest. The geneticists are seldom more than one jump ahead of the highly adaptable insects. Still, inbred resistance is, in almost all respects, the ideal way to combat insect pests. Genetics is an explosively expanding science, and genetic control techniques are almost certain to assume increasing importance in long-term pest management programs.

Before the advent of chemical pesticides, farmers relied on a variety of practices to prevent or minimize pest damage—picking off the bugs by hand and squashing them; timing planting and harvesting so that the growing period coincided as little as possible with periods when pests were at large; removing crop residues and alternate host plants; crop rotation; quarantines; and sometimes, as a last resort, the farmers survived by eating the locusts that had eaten the grain.

But as modern agriculture developed, some of these habits fell into disuse. Also, there were some new practices—monoculture, introduction of high-yield plant varieties, changed patterns of fertilization and irrigation—that actually improved the pests' chances for survival and proliferation.

For a time, it looked as if chemicals alone might be enough to hold the line. But as more and more insects become resistant to chemicals, and as more and more chemical pesticides are restricted in use, those mundane physical methods of pest control—or modern modifications thereof—are regaining much of their former importance.

Given the present U.S. society, it is highly unlikely that assigning people to catch and kill bugs will ever again become a major means of dealing with pests. But there is a modern modification of the old-fashioned bugcatcher—the field scout, the very cornerstone of integrated pest management. The field scout's job, appropriately, is to scout the fields and, when pest levels start to rise, to report the facts to his boss, who then presumably takes proper action. Who is the field scout's boss? Well, integrated pest management implies that there must be managers. And increasingly, that manager may be an entomologist in private practice.

For instance, John W. Nickelsen of Shafter, Calif., describes himself as an applied insect ecologist. Mr. Nickelsen has a staff of three full-time professionals, augmented in the growing season by 17 field scouts. Together, they survey 43,000 acres planted to such diverse crops as cotton, potatoes, grapes, citrus fruit, alfalfa, sugar beets, grain, melons, and tomatoes. Services include checking the fields to keep tabs on types and levels of infestations. When pests threaten to approach the economic danger level, Mr. Nickelsen advises the grower what to do: whether, when, and what to spray, and what other steps should be taken. It is usually up to the farmer to arrange for the actual work, although Mr. Nickelsen notes that his own staff sometimes performs such duties as setting out traps and releasing predators and parasites obtained from insectaries.

Mr. Nickelsen isn't opposed to



Aerial spraying will still be key part of integrated pest control

chemical pesticides, recommends their use when they're needed, and agrees that nothing is likely to replace them completely. But, he says, the trend is to rely more on natural and biological controls, and "knowing when *not* to spray is just as important as knowing when *to* spray." Unlike the chemical companies' field men, Mr. Nickelsen adds, his welfare doesn't depend on selling chemicals—and farmers are willing to pay for his unbiased advice because, in the long run, it saves them money.

Mr. Nickelsen has been in the integrated pest management business for more than 20 years. Business has always been good, he says, but lately it's getting better, what with all the publicity. As the demand grows, more and more entomologists are setting up similar consultation services. However, most of the work in integrated pest management is still being carried on under the auspices of USDA and other agricultural agencies.

The potential manpower requirement in both the private and public sectors of the economy, for integrated pest management of the 350 million acres of U.S. cropland (never mind the millions of acres of forests) comes to about 11,000 professional crop protection specialists and 170,000 field scouts, according to USDA. It will be a long time, if ever, before that potential comes close to attainment. But even now lack of qualified personnel is one of the factors delaying wider adoption of integrated pest management. (CEQ lists several other factors; they can be fairly well summarized, in an oversimplified fashion, as inertia.)

The availability of specialists is it

Association promotes pest management practices

It's almost axiomatic that any group of professionals will sooner or later get together and form a professional association (or associations). The struggling young profession of integrated pest management is certainly no exception. One such organization is known as the Association of Applied Insect Ecologists (AAIE).

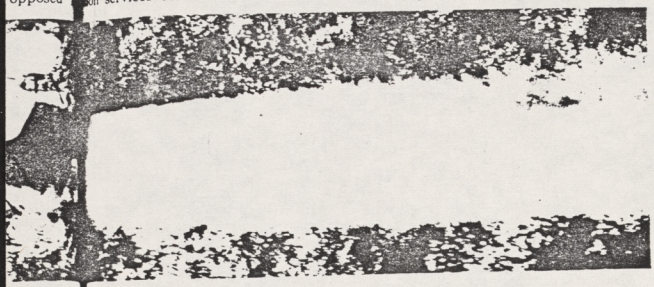
Founded in 1967, with headquarters in Santa Clara, Calif., AAIE currently has more than 100 members, mostly in California and the Southwest. Executive secretary Maclay Burt notes that "about a dozen pest management firms comprise the strength and leadership of the association," and that the balance of the membership includes the firms' associates, academic personnel, and government officials.

Until recently, AAIE was funded entirely by its individual members (yearly dues, $25). But growth demands on the association now require supplemental financing, Mr. Burt says, and AAIE is currently seeking to enroll "affiliates"—primarily agri-business firms—that will ante up $300 per year.

"One of the greatest handicaps to the growth of integrated pest management is the lack of economic knowledge about the benefit to growers and the actual cost of operating integrated control programs," Mr. Burt asserts. Accordingly, AAIE has made two project proposals requesting funds for studies to determine the economic benefits. AAIE also works with colleges and universities in setting up curriculums and training programs for potential pest managers.

Like other professional associations, AAIE is also naturally interested in promoting the welfare of its members. One of the association's goals for 1973 is "to develop programs to achieve true professional status and recognition for AAIE members."

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part limited by the number of institutions that offer appropriate training programs. Although the majority are educated primarily as entomologists, the crop protection specialist must be a multidisciplinary man with considerable knowledge of chemistry, botany, and agriculture. Curriculums designed to provide such training are under development at several major universities. In addition, several state extension services conduct courses for field scouts, who can be trained in three or four days.

Although integrated pest management is suffering some severe growing pains, it *is* growing. With the Federal government pushing it hard, it will continue growing, probably at an accelerated rate.

What effects will the growth of integrated pest management have on the billion-pound-a-year pesticide market? How will it change the industry? How can the chemical industry contribute (and a profit) to the development of integrated controls?

On the assumption that nobody would be studying those questions any harder than the pesticide makers, C&EN has used them to 11 chemical companies with substantial vested interests in pesticides: American Cyanamid, Chemagro, Chevron (Ortho), Ciba-Geigy, Dow, FMC (Niagara), Pennwalt, Stauffer, Thompson-Hayward, Union Carbide, and Velsicol.

The 11 companies are unanimously in favor of integrated pest management, although one comments wryly that "To be against IPM is akin to being opposed to motherhood and apple pie." Another firm points out that these programs have more appeal at the national level than with the individual farmer. For instance, a specific pest might cause only a 10% national loss in yield, but this could mean that some fields would be very severely damaged. Many growers are reluctant to risk such economic loss."

Ciba-Geigy contends, however, that integrated pest management "is a reality today in a number of agricultural areas, such as deciduous fruit, cotton, and tobacco. It will become widely established in many other agricultural markets when our knowledge of the biology and behavior of pests becomes greater, and as new cropping practices are adopted."

And Chemagro relates, a little sadly, "The integrated pest control approach is not new to us. As early as 1967 we developed an integrated control program for cotton that took into account carefully timed applications of minimum effective dosages of a variety of pesticide chemicals, as a total cotton insect control program. Products and dosage rates were selected to least affect parasites and predators of the cotton bollworm.

"Although this program was introduced into the field at considerable expense, it was almost unanimously ignored by the experts responsible for developing cotton insect control programs. Our attempt was nearly a total failure." Today, of course, the reception would be entirely different, Chemagro adds.

None of the firms will admit the prospect of being hurt by the rise of integrated pest management, but all agree that there will be changes and, inevitably, higher prices. Stauffer, for example, says, "Pest management programs will have little or no effect on our business. Chemical pesticides are included in all pest management programs. New chemicals will be needed as programs become more sophisticated. To ensure that these new products are acceptable, it is expected that research and development costs will increase."

Dow concedes that, "It is possible that pesticide use may be reduced in some crops and under some conditions." But there is nothing in sight at present "that gives any real grounds for believing that there can be a large drop in pesticide usage if we are to continue to eat." Dow also notes the coming increased sophistication in pesticides and believes "that the industry will move slowly but surely to a 'prescribe and dispense' system."

American Cyanamid, Ortho, and Dow all point out that the eventual success of integrated controls will require changes not only by farmers and pesticide producers but also by consumers and lawmakers.

Dow puts it this way: "We must also consider factors of economics and acceptability of results. This is where things become difficult. For example, we have a product, a miticide, that is quite useful in integrated control programs in apple and pear orchards. It doesn't bother the predacious mites and, at fairly low rates, it does a good enough job of controlling the harmful mites, while leaving a small population for the predators to feed on.

"In this particular case, damage is not done to the fruit when populations are small; therefore the product and the technique are acceptable. But this is not the case when you are trying to control an insect that causes actual damage to the fruit itself. In that circumstance, the pest population must be as nearly wiped out as possible in order to meet the economic facts of life in the food industry. Damaged fruit is just not acceptable to today's housewife." It is very difficult to determine what is an acceptable level of pest infestation, Dow says. "Here is where the philosophy of EPA bumps head on into the economics of food production and the food standards set by the Food and Drug Administration."

All 11 firms believe that their main contributions to integrated pest management will be in the form of improved chemical pesticides. They also mention that many of their more selective pesticides already fit nicely into integrated control programs, and they re-emphasize the continuing necessity for judicious use of broad-spectrum chemicals.

However, Pennwalt adds that its microencapsulation program will also make significant contributions to integrated control. The company is now marketing, under an experimental label, a product consisting of methyl parathion-containing microcapsules dispersed in water, in a flowable formulation for release by ordinary ground or air equipment. Pennwalt says the encapsulated product is effective for a longer time in the field, yet safer to handle, than ordinary emulsifiable concentrates.

Pennwalt has also encapsulated the gypsy moth sex attractant. The encapsulated material persists long enough in the field to show promise for use in control by "male confusion" (disruption) techniques, but the unencapsulated attractant does not, according to Pennwalt.

Still on the subject of industry contributions, T. J. White, manager of American Cyanamid's pesticides department, takes issue with John Nickelsen's comment on chemical company field men: "Our field men are highly competent to advise the farmer on timing and materials for optimum pest control." Noting the projected requirements for crop protection specialists, Mr. White adds that, "It would seem wiser to upgrade already available field men on private payrolls, through licensing, certification, etc., than to build a vast new bureaucracy."