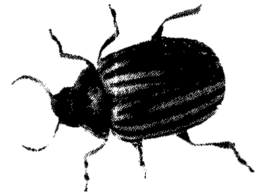
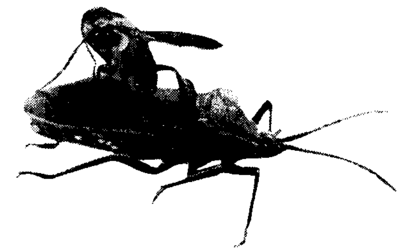
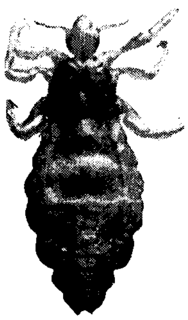
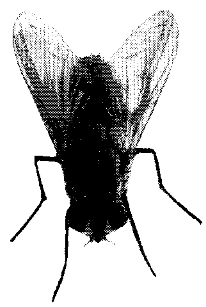




Chemical Progress Against Insects . . .





A STAFF REPORT

Chemicals will remain the weapon of choice for the foreseeable future when insects reach emergency proportions, but the battle will become more precise

Are we gaining an understanding of the insect population? What progress has man made in his attempt to control it? Where do we stand in our efforts to protect our crops from insect destruction?

Various scientists estimate the number of insect species known and described throughout the world between 625,000 and 1,500,000, but this is only an educated guess. Latest figures for Canada and the United States, compiled by USDA, show a population of nearly 82,500 species of insects and 2613 kinds of ticks and mites.

The world's total insect population, counted as individuals, runs into astronomical figures which no one can comprehend. Simple examples point to the enormity: certain agricultural soils have 3 billion springtails (*Collembola*) to the acre; University of Illinois studies indicate 65 million insects, on the average, per acre of forest soil in Illinois; another researcher estimates there are 1.85 million insects in flight in the morning over a square mile, and this number rises to 7 million by evening.

The reproductive capacity and rate of increase of some insects makes the problem of control formidable. A single aphid and her offspring can produce 1.56×10^{24} aphids in one season, if all survive. Among egg laying insects the record probably is held by an East African termite, which has been observed to lay eggs at the rate of 43,000 a day.

Natural causes, of course, are the major influence in keeping down the insect population. Weather probably is the greatest as, in addition to direct effects, weather influences the life cycle of insects and abnormal conditions may shorten the life span significantly. On the other hand, some temporary conditions greatly increase insect populations and their destructive effect.

Diseases, parasites, predators and food supply are very important factors in holding down the growth of insect populations.

Useful Insects

Certainly not all insects are destructive or harmful to man. In fact, the pollinating insects are essential. Many crops could not be reproduced without their aid.

A more limited area in which insects are helpful in the cultivation of crops is in the control of weeds. Probably the most outstanding example in the United States is the beetle *Chrysolina gemellata*, which has made significant inroads against the toxic Klamath—a weed that chokes thousands of acres of western land.

Economically Destructive Insects

While natural factors or biological control are helpful in keeping insects from over-running or dominating our planet, some insects manage consistently, and some sporadically, to exist at such levels as to cause serious economic destruction. Man's problem has been to find means of holding such insect populations below the economically significant level. Where biological control is not able to do this, he must seek what might properly be termed emergency measures. Prehistorically it appears he fought plagues such as grasshoppers with fire or other means. Today, his greatest emergency weapon is chemicals.

During the past 20 years a great deal has been accomplished with synthetic chemical insecticides, but this effort is still hampered by inefficacy, failure to gain widespread use, development of resistance by insects, and other factors, including, in some cases, conflict with biological control.

How much progress then has been made by the use of chemicals in man's battle against insects? What does the balance sheet for chemicals show?

Problems Extensive and Expensive

Several authorities estimate insects directly or indirectly cost Americans $4 billion annually—divided between actual destruction ($3.6 billion) and control measures ($400 million). These estimates may be quite conservative, because of undetected damage. Nobody seems to know precisely where we stand in controlling losses to pests, but all agree that cheaper and more efficient controls are desirable.

For example, 10% of our stored grain is lost to contamination or consumption by insects. U. S. Forest Service reports show timber-killing insects more destructive than fire and disease combined.

Cotton can serve as one example of a crop suffering heavily from insect attacks. Figures compiled by the National Cotton Council, for example in 1953, showed cotton insects destroyed 1,430,000 bales of cotton and 585,000 tons of cottonseed, valued at $261 million. This, however, was

Some of Agriculture's Most Troublesome Insects

	Northeast	Southeast	North Central	South Central	West
Corn Earworm	×	×	×	×	
Mites	×				×
Stored Grain Insects		×	×		
Boll Weevil		×		×	
Codling Moth	×				
Alfalfa Weevil					×
Mexican Bean Beetle		×			
Potato Leafhopper			×		
Army Worm				×	
Apple Maggot	×				
European Chafer			×		
Lygus Bug					×
Cabbage Looper	×				
Cutworm		×		×	
Grasshopper			×	×	×
Aphids	×		×	×	×

SOURCE: Based on Reports to Economic Insect Survey, USDA
Northeast includes: Conn., R. I., N. H., Vt., Mass., Del., N. J., and Me.
Southeast includes: S. C., Md., Va., Ala., N. C.
South Central includes: La., Miss., Okla., Ky., Tenn., Tex., Ark.
North Central includes: Neb., S. D., Minn., Wis., Kan., Ohio, N. D.
West includes: Wash., Utah, Wyo., Ore., Mont., Nev., Idaho, Colo., N. M., Ariz.

an improvement over 1952, when losses to cotton and cottonseed from insects amounted to over $289 million. In fact there has been regular improvement during the past several years.

Man's Control Efforts

In assessing man's control efforts we must give credit to his manipulations of biological factors. For about 100 years the idea of killing insects with predators of their own kind or with parasites or diseases has received considerable attention from agricultural workers. While manipulated biological control is finding some use and is very effective in some cases, it still is looked upon by many as limited in its efficiency and reliability as a crop protection measure.

Man's foremost success in using one insect to control another was with the Australian ladybird beetle (*Vedalia*), imported to control the cottony-cushion scale in California. Albert Koebele made that memorable trip to Australia in 1888, bringing back a mere 28 beetles; other shipments brought the total to 514 by the spring of 1889. Vedalia beetles thrived and have saved the citrus industry millions of dollars. Koebele's trip to Australia cost less than $5000.

Continuing the fight against citrus pests, USDA and University of California field entomologists have led a search throughout the world for parasites and predators. Recently they came up with another lady beetle which feeds on insect pests found in Florida and California: aphids, psyllids, whiteflies, mites, certain scales, and mealybugs. This beneficial insect will also have a spray program worked out to give it the best opportunity to survive and attack pests.

The control of the Japanese beetle with milky disease is rated by some entomologists as second only to the use of the Australian ladybird beetle.

To control the European corn borer, about 11 million parasites have been released since 1930. Of 21 different insect parasite species introduced, only four or five became well enough established to have much value in controlling the corn borer. They have achieved varying degrees of success. In one area in Iowa, borers parasitized rose from one out of 100 in 1944, to one of three in 1947, then decreased to one out of four in 1949, and rose again to two out of three in 1950. These parasites are not giving full control of the borer, but are considered to destroy more each year than do insecticides.

The beet leafhopper, fought by entomologists since 1905, attacks sugar beets especially, but will take to flax, and garden vegetables. Using chiefly DDT, the best leafhopper chemical control program in California costs about $350,000 annually. A parasitic control program started in 1951 has progressed to releasing 600,000 wasps bred from species imported from the Mediterranean area. The question of success in this program will remain unanswered until the end of the 1956 crop season.

Practical biological control appears to be stronger in California than in any other state in the U. S. According to C. P. Clausen, it has been attained to the point where insecticidal applications are not usually required on: cottony-cushion scale, black scale (only in some sections), nigra scale, citrophilus mealybug, long tailed mealybug, alfalfa weevil, and grape skeletonizer. It has been estimated that about 40 species of pest insects have been brought under control in various parts of the world.

The use of virus diseases to control insects is now finding a certain amount of practical application (page 195) and shows promise of increasing.

An entirely different form of biological control has been utilized against screw-worms. Screw-worms, a serious pest in the South, attack the flesh of cattle, sheep, goats, hogs, and game animals. Screw-worm flies winter in Florida and the Southwest and migrate northward to lay eggs on wounded animals. Successful eradication was achieved on the small West Indian island of Curacao in 1955, through release of radiation sterilized male screw-worm flies. Plans now under way in this country call for doing the Curacao job on a vastly larger scale in Florida, but two years will be required to complete arrangements.

Another use of biology to protect crops from insects is to develop insect-resistant crops. Much research is done along these lines. Wheat resistant to the wheat stem saw fly is one example of success.

Another insect control measure valued highly by some is plant quarantine. Quarantines grow ever more difficult as travel accelerates and fast airplane shipment of farm products rises. Even as this difficulty increases, however, quarantine efforts increase at a faster rate.

The Control Outlook

Despite the attention that has been given to the control of crop pests, several traditional enemies remain among the most important. How are they to be brought down?

Screw-worm control in Curacao is probably the only example of true eradication and that has been done by a technique too expensive and difficult to apply over large areas at present.

Biological control in some areas has reduced certain pests below the level considered economically serious by present standards. But for widespread efficacy, this needs concerted action in a long program of development before it is likely to be the answer.

Resistant crop breeding appears hopeful, but it does not appear to be near to widespread practical application.

Quarantine is needed, but is not an absolute. When pests do slip through, as with the pink bollworm, khapra beetle, and spotted alfalfa aphid, all of which are of great concern at present, the cost and effort of combat are severe.

Cropping practices as control measures depend upon careful application consistently throughout an area. This is improving, but with some exceptions it is not likely to be at a highly effective stage in the near future.

Insecticides, then, certainly seem to be the weapon on which we shall lean most heavily during the foreseeable future in the control of economically destructive insects. We do not yet have all pest insects controlled below the economically destructive level. When they surpass that level we have an emergency. Chemicals are the most effective existing weapons for combatting such emergencies. They are also effective in preventing emergencies, as in seed treatment and stored grain treatment.

One of the problems in the use of insecticides is cost. To convince the farmer that he should add to his expense of crop production the cost of material and labor to apply insecticides, has not always been easy, but it has been accomplished gradually. Today the tonnages of insecticides are the most effective testimony to the job done (page 225). But the job is by no means complete and over the thousands of acres of crops not treated, destructive insects are able to breed to revive their attacks on areas previously brought under control by investment in insecticides.

The farmer is a dollars-and-cents man, and impressive figures are available to show the value of insecticide application. For example, recent reports from Illinois estimate that the treatment of 148,835 acres of legumes, grasses, and other crops to control grasshopper infestations yielded a profit of $1,358,108 to the farmers of that state. Treatment of 259,545 acres of clover and alfalfa, in 1954, mostly for clover leaf weevil, pea aphid, and meadow spittlebug, yielded profits totalling $1,997,407. During that same year, a total of more than 170,000 acres was treated for armyworm with profits averaging more than $10 per acre.

The cost problem, then, appears not entirely to be one of actual dollars and cents, but one of education of the farmer, to convince him of the value available. Again, trends in consumption figures speak for the progress, but use possibilities are by no means saturated. Farmer education is a big job now being carried out particularly effectively through the state experiment stations and county agents (AG AND FOOD, September 1955, page 738).

Another aspect of the cost problem is that of trends in manufacturing costs. The editors of AG AND FOOD have recently surveyed industry, government, and university people on major problems confronting the advancement of the chemical battle against insects. One matter of much concern is the increasing cost of getting a new product to the profit stage. An important new addition to that cost factor is the testing and establishment of tolerances required to meet the requirements of the Miller Pesticides Amendment (page 214). But industry recognizes the importance of public health protection and this has become accepted as one of the costs of developing new materials. Also, increasing competition and the rapid rise of new insecticides and obsolescence of existing ones, is an important factor. One of the trends of thinking resulting from increased costs is that more specific products must be found for the more important pests and the company developing the product must maintain careful control of it in order to get back the high investment and gain a profit.

With the responsibilities to public health and the cost of getting new pesticides on the market in conformity with the Miller Amendment, public

In 1920, the method for controlling the European corn borer was to burn infested corn stalks. The corn borer became established in the eastern U.S. about 1915

Insecticides have shown these outstanding accomplishments in crop protection over significant areas . . .

- Widespread control of many insects by DDT
- Control of soil pests particularly in corn, with chlorinated hydrocarbons
- Control of cotton boll weevil with chlorinated hydrocarbons
- Control of grasshoppers with chemical spray program
- Control of mites with dinitrophenols
- Control of corn earworm on sweet corn in the South
- Control of fruit, cotton, and foliage pests with parathion derivative
- Broad sprectrum insect population reduction with malathion with relatively low level organophosphorus toxicity to warm-blooded animals
- Modern fruit spray schedules now make it possible to market more than 90% of the crop as compared with 90% unmarketable crop before use of such sprays. Codling moth is one of the outstanding insects controlled

Yet the insects rated most troublesome are traditional enemies, and many are included among the proved control capabilities. There is still a big job to be done by chemicals against insects.

relations have become a significant factor. All of this could be considerably simplified by finding potent specific insecticides of low toxicity to animals and humans. The search for compounds with such characteristics is one of the objectives ranked highest by many pesticides people, whether government, industry, or university.

Development of Resistance

Almost universally, the development of resistance to insecticides is ranked as the No. 1 problem in the chemical battle against insects. This first was found as resistance to DDT in flies and now is known in several species of insect and applies to several of the chlorinated hydrocarbon insecticides. The organic phosphorus compounds have been found effective in many cases, where resistance to chlorinated hydrocarbons had developed. But now it is observed that some mites develop resistance to the organic phosphorus compounds.

The upset of biological control factors through the use of insecticides must also be considered. An interesting example of this arose in the use of DDT to control codling moth in apple orchards. The DDT killed predators that kept down harmful mite populations with the result that the codling moth was replaced by mites as a serious pest. Other measures then were necessary to control mites.

Directions of the Future

It can be said that the record of chemicals against insects during the past decade is a favorable one. The possibilities of insect pest control are greater than we are using. This is seen in the fact that some of the most highly ranked accomplishments of insecticides pertain to the control of insects that still are rated among the most important in certain areas of the country.

Furthermore, it is likely that chemical control as we know it today, with a number of modifications, is likely to remain the mainstay of control of economic insect crop pests during the foreseeable future.

Some of the problems and influences point the directions of the future. Among opinions collected on the most valuable directions for research during the next five years, search for knowledge about mechanism of insect resistance to insecticides ranks highest. Research will continue vigorously in that area and much progress can be expected in overcoming this retardant to the reduction of crop devastation by insects.

A great deal of advancement is to be expected with the systemic insecticides, perhaps even to the extent of changing somewhat the general lines of thinking with respect to chemical control of insect pests. Pesticides of a type that will offer much less hazard to warm-blooded animals are likely to be the result of some of our strongest efforts. Another line of progress that can be expected to reduce the toxicity problem is the increasing management of pest control by trained specialists—from diagnosis of the problem through application of the control agent.

Another long range approach which may be slower in coming, but which may be big in its implication, is the coordination of the chemical and biological approach to the control of insect pests. Relatively little has been accomplished specifically along these lines. One example has been reported by Ripper in England, where schradan has been found effective gainst certain aphids, but not harmful to the lady beetles that prey upon them.

There is some opinion that in the very long range approach, the whole system of attack may be remodeled. The present technique of mixing costly chemicals into solutions or dusts and spraying them into the air with some guidance, hoping that they will fall where they will be consumed by the right insect, may be subject to some highly scientific revision during the next several years.

With increasing costs of getting a new pest control agent on the market, research will be directed more with the "rifle" than with the "shotgun" approach. The result is likely to be more specific insecticides. Furthermore, with high investment, a company developing a new product is likely to exercise much greater efforts to control the marketing of such products. Prices of these new highly precise materials may be even higher than they are now. As a result, their application will be done with much greater precision. In fact, everything connected with their use is likely to be done with much more scientific care. The day of the professional entomologists, as described by George Decker, in his recent presidential address before the Entomological Society of America, promises to be near at hand by that time. The chemical battle against pests is likely to be managed by specialists throughout—in diagnosis, prescription, sales and application, the scientifically trained expert will be relied upon to do the job with greatest efficiency.