These fumigants are dangerous to humans, and fumigation jobs must be handled with care during the application and ventilated properly when the treatment is completed. Hydrocyanic acid is deadly to humans and especially dangerous because it is nearly odorless. Chloropicrin, even in minute quantities, is distressing and virtually incapacitating to humans because of its penetrating odor and irritating properties.

REPELLENTS are used to keep insects away from something and are not necessarily toxic. Naphthalene and camphor have been used for decades in homes for keeping insects out of stored clothing. Creosote is used to keep termites out of wood.

Of many compounds that have been tested as repellents of mosquitoes, other biting flies, and chiggers, the most effective are dimethyl phthalate, Indalone, and an organic compound known as Rutgers 612. Each of these compounds is effective against only a certain number of species, but a mixture of the three applied to clothing and skin gives fair protection to the user for a short period. Dimethyl phthalate and other repellents act primarily as a killing agent on mites rather than as true repellents. Benzyl benzoate is proving especially effective for giving protection against mites.

INJURY. Insecticides must be used with caution, because they may damage the host as well as the insects or leave a residue that is toxic to man or domestic animals. For instance, lead arsenate sprays that are safe to use on many crops will burn peach and cotton foliage; on these calcium arsenate or a milder compound must be used. Apples sprayed with arsenicals must be washed or cleaned before being eaten, because the arsenical residue on the apple is toxic to humans. Oil sprays cause burning of foliage if applied in too concentrated form, and some insecticidal preparations may cause blistering and dermatitis on animals.

RESIDUAL ACTION. An important characteristic of insecticides is the length of time they remain toxic after being applied. Most stomach poisons remain toxic for long periods and are spoken of as having a high residual action. Nicotine alkaloid and pyrethrum have practically no residual action, losing their potency almost immediately after they are applied, owing to chemical deterioration. Some of the synthetic contact poisons, such as DDT, have a high residual action. The length of residual action governs to a large extent the frequency with which the insecticide must be reapplied.

PLANT CONDITIONING. We have mentioned that certain sprays such as Bordeaux mixture induce a poisoning of plant sap that is toxic to insects. There are other cases of somewhat similar results that are thought to be due to induced physiological change of the plant, such as plant acid-

ity or alkalinity. An example is the reaction of certain arsenicals on cotton. After being treated with acid calcium arsenate, cotton is unusually susceptible to the cotton aphid, which multiplies in great numbers. On the other hand, cotton treated with basic copper arsenate normally suffers no more than ordinary attack by the cotton aphid. The nature of this plant conditioning is not fully understood, but it promises to be an interesting and profitable field for investigation.

APPLICATION. Putting or getting an insecticide where it will do the most good presents problems of many kinds. First, the insecticide must be applied at the correct season and in some cases (as with mosquito larvae) within a period of only a few days. In the second place, weather conditions must be considered, because sprays and dusts cannot be applied during rains or in high winds, and some crops are more susceptible to insecticide burning during periods of high temperature and humidity.

A specialized set of machinery is available for applying sprays, dusts, and aerosols, for dipping cattle, or administering fumigation materials. A careful choice of these must be made for each control project, the area and local condition being taken into consideration, such as topography, height and spacing of the crop, and labor conditions.

CONTROL PROBLEMS

In reviewing the question of insect control there are some pertinent general considerations that must be borne in mind.

COST. We have already mentioned that biological-control programs are carried on and financed by state or Federal agencies. There are other control projects of such great magnitude and such significance nationally that they are planned and financed by these same agencies. For example, about 1929 the Mediterranean fruit fly became established in Florida and was recognized as a pest that might ruin the American citrus fruit industry. Immediately a Government project was initiated to attempt the eradication of the pest. Quarantines were set up, cleanup measures enforced, thousands of tons of suspected fruit destroyed, and exhaustive surveys made. The fly colony apparently was completely extirpated, and the Nation bore the cost. Periodic grasshopper outbreaks threaten to consume all growing crops in entire states; here the Federal Government assists the farmers by supplying materials and machinery to fight a menace national in scope.

But to the householder with moths in the closet, the farmer with his usual array of insect enemies, the mill operator with bugs in his prod-

ucts, in short, to everyone faced with the necessity of controlling insects by his own efforts, cost is a paramount consideration. The control cost must be low enough to allow the control application to be profitable. If, for instance, an insect threatened to reduce the yield of corn 10 bushels per acre, and a control program would avert 80 per cent of this loss, control cost per acre would have to be less than the price of 8 bushels of corn. Otherwise control would not be attempted, because, if it were, either the farmer would break even on the deal and be out the extra work involved, or he would lose money. The same principle holds with all control done by private means.

In devising control methods, therefore, the entomologist must always strive for practical ones from the cost standpoint. With low-priced crops such as field crops, which seldom have a value of more than $300 per acre, the premium is definitely on low-cost control even at a sacrifice of some efficiency in control obtained. In the case of greenhouse crops, the cash value of the product may be $10,000 or more per acre of glass, and the market price may drop disastrously with only a small insect infestation. Here the demand is for perfect control even at a high price.

THE WEAKEST LINK. In order to achieve most in both efficiency and economy, it is necessary to apply control measures at that point in the life history when the insect is most vulnerable or control is most practical. In the life history of many insects there is a point at which the insect may be reached easily by control applications. The cabbageworm, for example, is vulnerable at any time during its larval stage to poisons applied to its host. In the codling moth this vulnerable period is much shorter, being the interval of larval life between hatching and entrance of the young larva into an apple. Here the control is applied. An insecticide with a high residual action, such as lead arsenate or DDT, is applied that will cover the late blossoms or fruit. The young larvae will be caught in their attempt to enter an apple, either by eating a little arsenate as they bite through the apple skin, or by contact with the DDT.

During chinch bug outbreaks, it is impractical, because of expense, to apply an insecticide to all the acreage of grass or grain that harbors the bugs. When, however, the bugs migrate from these crops to corn, it is practical to put a repellent barrier or a strip of insecticidal material along a line that the bugs must cross to reach a new food supply. In this way a small strip of applied insecticide is an effective control of millions of bugs on the march.

COMMUNITY PROJECTS. In the case of some insects it does one person little good to effect control on his premises if the neighbors for some distance around fail to do the same. The ox-warble or cattle grub is easily

controlled by squeezing the full-grown larvae out of the pockets they make beneath the hide of the cow and killing them, even though this method of control does little for the immediate season, since the damage is already done. But, if the neighbors don't do it, warble flies from their cattle will fly over and reinfest those of a person who has attempted control. If done thoroughly over a large section of country, the destruction of this year's warbles will prevent their recurrence next year. The same is true of the control of many species of pest mosquitoes; coordinated control over a large area is usually necessary for relief. In this case, however, the control need is annual.

DISPERSAL OF INFORMATION: EXTENSION. To be successful, insect control must be based on a detailed knowledge of the insects, local conditions, and possible control methods; and any one of these can change in many details from year to year. Most of the control, moreover, must be done by individuals who are not specially trained in the work and who do not have this information readily available. To put the known information into the hands of these people is the field of *extension.* The information must be timely and simply but plainly stated and must reflect up-to-date advances in combating pests.

It is being recognized more and more that extension is a vital phase of insect control. A good control practice not put to use does no good. Extension methods now embrace practically every known way of getting pertinent information to those who need or want it. State and Federal agencies, private research centers, and industrial concerns aid in carrying on the work. Bulletins, circulars, and newsletters are employed more than anything else, supplemented by television and radio talks, magazine and newspaper releases, lectures, and field demonstrations. By these efforts it is hoped ultimately that in the United States everyone with an insect-control problem will be able to find the best known way to handle it.

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