

The Use of Insecticides and Their Toxicity to Plants

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The use of insecticides for insect control is not new, but goes back some 90 years to the accidental discovery of the value of paris green in the control of the Colorado potato beetle. Other early materials included lead and calcium arsenates, fluorine compounds and the plant products of hellebore, nicotine, pyrethrum, rotenone and ryania. For many years these materials gave good results against certain pests, but were quickly superceded when the phenomenal results with the new synthetic organic compounds became known. This era of the so-called "miracle" insecticides started about 10 years ago with the release of DDT for general use. At first DDT was considered to be the answer to practically all pest problems, but additional research and its use under field conditions soon indicated some of its shortcomings, such as its inability to control some pests, its phytotoxicity to certain plants, and the development of resistance to it by some pest species.

Figures on the manufacture of insecticides clearly show the abrupt change around 1950 from the older materials to the new synthetic organic compounds. A comparison of the Census Bureau figures on insecticides manufactured in 1939 with those of 1954 shows a drop of the two arsenates, calcium and lead, from 100 million pounds to 19 million pounds annually. DDT for military purposes reached 12 million pounds during World War II and for all purposes in 1954 to 97 million pounds. Other chlorinated hydrocarbon compounds and the organic phosphates followed, so that by 1955, 60 were registered for crop use and 30 had been approved under provisions of the Miller Act. In addition to the release of new chemicals the total amount of insecticides used showed a large increase during this 10 year period.

The problems of insect control can be divided into two categories: Those of an acute or emergency nature and those that are chronic. Emergency problems are those of high population levels which need immediate attention. Often the pest increases suddenly over a wide area and causes an outbreak. Under this heading could be considered the European corn borer, grasshoppers, the tomato hornworms, the armyworm, the chinch bug, cutworms, and many others. Such pests may be present every year but with a combination of favorable climatic and environmental conditions they increase rapidly. Immediate action is often necessary to save the crop and to prevent further spread. All too often such outbreaks are well established before information reaches entomologists who have to make the control recommendations.

A chronic insect problem is one that is present much of the time but is seldom serious enough to attract attention. The insects may feed and reduce yields 5 to 25 percent without being noticed by farmers. Perhaps an outstanding example of such a pest is the potato leafhopper. Partial control was obtained with copper compounds, but the change to the more effective DDT increased yields by 50 percent or more. Wilson

(4) found that this same pest on alfalfa was responsible for much of the yellowing attributed to plant food deficiencies. Methoxychlor not only gave increased yields but also permitted the plants to thrive better the following year. Everly (2) reports that insecticides used against such a minor pest as the clover root borer resulted in better stands and increased yields.

At present our country has large surpluses of many foodstuffs, but by 1970 the picture may be entirely different, for by then our population will have increased by one-fourth. Agricultural land cannot be increased and so to produce more food on the same number of acres it will be necessary to follow all technicological advances. Many people have called this the age of chemical farming, as we have been placing greater dependence on chemical fertilizers, soil disinfectants, insecticides, fungicides and weed killers. Insect control will have an important part in producing more and better food for all peoples.

The new insecticides have been effective against a wide range of pests and have many advantages over the older materials. Perhaps the outstanding advantage is a better kill at a cheaper cost. An excellent example is a comparison of the control of the potato leafhopper with bordeaux mixture or copper-line dust with that of DDT. The copper compounds gave some protection but by midsummer the foliage would turn brown. With DDT the leafhoppers were eliminated, the plants stayed green and yields increased. Growers soon found that six to eight applications were sufficient to protect the plants and still not keep the foliage green late in the summer.

Ease of application is another advantage, for they are available in several type of formulations: wettable powder, dusts, granules, emulsifiable concentrates and oil solutions. Application equipment has also been improved or changed materially. In recent years, in Indiana at least, there has been a gradual change over to sprayers, especially the low pressure type. Since this type is used for weeds and is comparatively cheap, many farms are now equipped to spray for weeds, insects and plant diseases. The emulsions are ideal to use in such sprayers, as they do not clog the screens or nozzle tips. Orchard and row-crop sprayers and dusters have also undergone improvements. Advances have been made in aerial application equipment and now large acreages can be treated in a few hours with a spray, a dust or with granules. Research is still under way with granular materials, but they show promise for aerial applications, for spreaders and for mixing the insecticide in a fertilizer.

Long residual action is a characteristic of some new insecticides. They give protection against insect attack for longer periods and reduce the number of applications necessary. On cabbage, the author observed that some materials had to be re-applied in 10 to 14 days, while strobane and endrin gave protection for 30 days or longer. This long residual property is of value where insect migrations continue over a period of time, or where reinfestation is possible. Good examples are chinch bugs, cockroaches, ants and flies. They are also of value against soil insects such as termites, wireworms, white grubs and corn rootworms.

An insecticide with a short residual life is desirable in some circumstances such as treating edible crops during or near the time of harvest. Such materials have the advantage of killing the pest immediately and still not leave a dangerous quantity of residue on a crop to be eaten by man or livestock. Several of the organic phosphate compounds fit into this group, for some leave little or no residue after 24 to 72 hours. Another interesting characteristic of some phosphates is systemic action. They are taken up in the sap of the plant and kill certain types of insects. Their effective life is from one to 21 days.

The new insecticides have given better control, but their use has created new problems associated with their higher toxicity and their longer effective life. These problems include the dangers to humans and to livestock, the killing of beneficial insects, possible toxic concentrations in soils, off-flavor to edible products, toxicity to plants, and the development of resistance or tolerance to insecticides. The federal Food, Drug and Cosmetic Act of 1937 and the Miller Amendment of 1954 were passed to give the public protection from possible dangers from all insecticides. Effective this year, all insecticides just have their use approved by a federal agency and their residues on edible products must come within the tolerances established by the Food and Drug authorities.

The widespread use of chemical control has destroyed many beneficial insects, including parasitic and predaceous forms that often are of value in keeping pest species at low levels. This upsetting of the normal balance of nature has resulted in destructive populations of insects which in the past received little attention. A good example is the use of DDT for the control of the codling moth. DDT was so much better than lead arsenate that it became the standard insecticide on apples. In a year or two, however, the red-banded leaf-roller became a serious problem in orchards and so a second material had to be added to take care of the leaf-roller. Still another problem developed in these same orchards, a serious mite problem which required a third material.

Residues of the more toxic chemicals in and on crops used for human or livestock consumption are giving concern to health officials. Some of the newer compounds are poisonous in small quantities and persist for days or even weeks. In addition, some materials are highly dangerous to the applicator at the time of application. Efforts are being made by manufacturers, research workers and federal officials to provide greater safety to the public. With the establishment of tolerances under the Miller Act and with additional research, many of the dangers should be eliminated. However, it is of utmost importance that entomologists reconsider control recommendations in the light of these new regulations.

Concern has been expressed about the build-up of chemicals in the soil following repeated applications of insecticides. This has happened in the past where the soil in an orchard has so much arsenical accumulations that other crops could not grow. With the new chemicals, tests to date indicate that crops can tolerate enormous quantities in the soil before plant growth is affected. This, of course, would vary with the insecticide, the crop and the soil type. Bauer and Dahm (1) found that dosages of aldrin in the soil up to 64 pounds per acre caused no del-

eterious effect on growth of a variety of plants. Indiana potato growers apply as much as 15 pounds of DDT per acre per year and as much as 45 pounds over a 10-year period and to date no harmful effects have been noted.

Another problem is off flavor in fruits and vegetables resulting from foliage or soil applications. There is evidence to indicate that some chlorinated hydrocarbon and some phosphate compounds may affect quality. The principal offender, however, has been benzene hexachloride, which has affected fruits, vegetables, eggs and the flesh of chickens and livestock. This chemical is persistent in the soil, for one report indicates that potatoes grown after seven years were still unsaleable.

Still another problem is the development of resistance or tolerance by certain insects to both the chlorinated hydrocarbons and the phosphate compounds. This topic is to be discussed by another speaker on this symposium.

Phytotoxicity has been reported on a wide variety of plants. The injury may be caused by the chemical itself or by the solvent used in preparing the different formulations. Of the chemicals, many of the hydrocarbon compounds injure plants of the family Cucurbitaceae. This is especially true of toxaphene and strobane, while the regular form of DDT causes some injury to certain varieties of squash and cucumbers. Several members of this group and some of the phosphate compounds may injure tomatoes. BHC and its purified gamma isomer known as lindane may destroy germination of certain seeds or may cause distortion of the seedling. The author (3) found that injury to corn seed is directly correlated with the amount of actual gamma used and that lindane at the standard dosage does not seriously affect germination and early plant growth. The injury from BHC is similar to that of weed killers and appears to be to the growth points of the seedling rather than to the seed itself.

A wide variety of solvents are used in the formulation of insecticides. Oils are frequently used and injury from them is associated with the amount of unsulfonated hydrocarbons left in the oil. Because of its high volatility xylene is often mentioned as a good solvent, but under some conditions it too has caused injury. Certain alcohols and ketones are also used for solvents. Injury from solvents may be a distortion similar to that of a hormone or weed-killer and may be a yellowing and burning of the leaves. Other factors involved in injury are the percentage of solvent necessary to dissolve the insecticide and the ability of the emulsifier to blend the dissolved insecticide with water. A few years ago an Indiana potato grower had serious distortion to foliage following one application of DDT. Upon investigation, the manufacturer admitted that the standard solvent had not been used.

Control of insect pests today relies heavily on chemicals. The use of insecticides has been so satisfactory that for the immediate future even greater dependence will be placed on this method of checking insect losses. Cultural practices and biological control are still of value and have a definite place in recommendations, but will be subordinate to chemicals. Further study is, of course, needed to discover the possi-

bilities and shortcomings of available materials and to develop safer and cheaper methods of obtaining maximum protection against insect pests.

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