eradication could be effected within a few years, but the migratory habits of the fly were not known at that time. It was soon found that there was no way of preventing flies from moving into Texas citrus groves from northeastern Mexico and that eradication was impossible. Research efforts were then directed toward developing ways and means of treating Texas fruit which would permit it to be shipped safely to other fruit areas.

One method of sterilization consists of lowering the inside temperature of the fruit to 32°–33° F. and holding it there for 18 days, or keeping the temperature at 33°–34° for 22 days. Either will kill any larvae in the fruit.

The second method is more economical and more widely used in Texas. Known as the vapor-heat process, it involves raising the inside temperature of the fruit. Larvae can be killed much more quickly with high temperatures than with low temperatures. In order to treat large quantities of fruit properly, specially designed rooms are necessary; the rooms also can be used during the regular packing-house procedure for the coloring of fruit. Treatment consists of forcing a large volume of air, saturated water vapor, and water in the form of a fine mist through the load of fruit, at a temperature of not less than 110°. After the inside temperature of the fruit has been raised to that point, it is maintained there for the duration of the holding period. The process is then reversed and a large quantity of dry air is forced through the load of fruit in order to reduce the temperature as rapidly as possible and permit the fruit to be packed for shipping.

P. A. HOIDALE *began his career in the Department of Agriculture with the Bureau of Plant Industry in April 1915. In 1917 he transferred to the Federal Horticultural Board in the control of the pink bollworm. When the Mexican fruit fly was first found in the Rio Grande Valley, he was placed in charge of the control project.*

Spider Mites, Insects, and DDT

Howard Baker

As recently as 1944, apple growers throughout the United States feared that the codling moth would put them out of business. Other insects and mites were of comparatively little concern. Today the situation is reversed. The codling moth has been reduced to a pest of minor importance and a number of other insects and mites have become problems. DDT is primarily responsible for this reversal: It brought the codling moth under control, but factors associated with its use have been responsible for some measure of the resurgence of other pests.

Others had had similar experiences. Cotton growers saw the cotton aphid increase following applications of calcium arsenate to control the boll weevil. Pecan growers have seen the black pecan aphid increase following application of bordeaux mixture to control pecan scab. Citrus growers found more scale insects and mites after the use of sprays to control diseases or to correct nutritional deficiencies.

Never before, however, have so many pests with such a wide range of habits and characteristics increased to injurious levels following application of any one material as has occurred following the use of DDT in apple spray programs.

Losses due to the codling moth reached alarming proportions during the 1930's and early 1940's. Fortunate indeed was the grower who could hold them down to 10 or 20 percent of his crop. Much larger losses were not unusual. Despite the use of stronger spray mixtures and more frequent and heavier applications, control became more and more difficult. The harder the orchardists fought the codling

moth, the harder it was to control and the greater the injury it caused. The codling moth was so all-important that other pests received but scant attention. That was the situation when DDT was introduced to a discouraged industry.

First tested by a few growers on a large scale in 1945, DDT became generally available to the industry in 1946. It promptly proved its worth in checking the codling moth and soon displaced lead arsenate or other materials in most apple-insect spray programs. Timely, thorough applications of 1 or 2 pounds of a 50 percent DDT wettable powder per 100 gallons of spray in an average of three to six cover sprays, depending on the region, brought the codling moth under control. Growers who had become accustomed to losses of 15 percent or more of their crop are now dissatisfied with losses of more than 1 or 2 percent. Many have losses of less than 1 percent.

DDT also controls other insect pests on apples. It is effective against most leaf-feeding insects that attack apples and pears, such as tent caterpillars, fall webworms, Japanese beetles, casebearers, leafhoppers, and, to some extent, aphids. Some pests it does not control, at least not when used in ordinary, practical amounts. Some other pests seem to be even more serious following the use of DDT than when it is not used. Various species of orchard spider mites, the red-banded leaf roller, and some scale insects, pests formerly serious only occasionally or in restricted areas, have threatened to cause or have caused serious injury more often than formerly and on a more general scale. Additional insects, for instance the woolly apple aphid, plum curculio, and yellow-necked caterpillar, have also increased in numbers in some places.

Why is this?

Several reasons have been advanced. Research might uncover others. The effect of DDT on the natural enemies of injurious species and the tendency to omit materials, such as lead arsenate and mineral-oil emulsions, from standard DDT spray programs are the two reasons most commonly advanced to explain the situation.

Many orchard pests are normally greatly reduced in numbers and held in check by natural enemies, particularly parasitic and predacious insects and predacious mites and spiders, that feed on and destroy them. DDT is highly toxic to many of these natural enemies. It kills them off at a much higher rate than it does some of the injurious species on which they prey. That is one reason why such pests as orchard spider mites, red-banded leaf roller, and woolly apple aphid are apt to develop in injurious numbers when DDT is used in the spray program. Not all outbreaks of these and other species are associated with the use of DDT—other factors are involved, factors that we do not fully know or understand yet.

DDT is less effective against some insects than materials it has displaced in apple spray schedules—materials such as lead arsenate and mineral-oil emulsions, or their substitutes, that had a wider range of usefulness than to control only the codling moth. This has led to increases in importance of some of the insects that were controlled through their use. It accounts somewhat for the increase in injury caused by such insects as the plum curculio, red-banded leaf roller, and San Jose and Forbes scales.

DDT AND THE changes in the comparative importance of the insects and mites infesting apples that have occurred following its use have profoundly affected apple spray schedules and the trend of research to develop the simplest possible spray program. Attention used to be focused on finding and developing a material that would control the codling moth better than lead arsenate. Now it is directed toward working out a complete spray program that will take care of all pests that may be present. This means finding and developing materials that can be used with DDT or substituted for it to control such pests as mites, leaf rollers, curculios, aphids, and scales, as well as

the codling moth. A great deal of progress has been made.

VARIOUS SPECIES OF MITES, formerly serious pests only occasionally or in restricted areas, came into the limelight along with DDT and have since caused, or threatened to cause, serious injury each season in all important orchard areas. The most important are the European red mite, two-spotted spider mite, and Pacific mite. The clover or brown mite has increased in Colorado and other western fruit-producing areas, and several new or little-known species of *Tetranychus* and other spider mites have become more important. For example, at least 11 species of mites in 1952 were known to infest orchards in the Yakima Valley of Washington; three of them were recognized in that area for the first time in 1950.

Orchard spider mites may be divided roughly into two groups for control purposes—those that overwinter in the egg stage on the trees and those that overwinter as adults in trash, under bark scales, and in other protected places, mostly on the ground. The European red mite and clover mite are in the first group. Most of the others, if not all, are in the second group.

Dormant sprays are quite effective against the overwintering eggs of mites. They delay or obviate the need for summer sprays to control the species that overwinter in this stage, depending on the timeliness and thoroughness of their application and whether weather conditions during the growing season are favorable for mite activity and development. Mineral-oil emulsions diluted to provide 3 or occasionally 4 percent oil in the dilute spray are most commonly employed in dormant sprays applied to control mites. Lime-sulfur is occasionally used; it has some value but is less effective than oil and is not generally recommended unless needed for some other purpose. Some dinitro insecticides also have shown promise for use in dormant sprays against mite eggs, but they are more likely to injure the trees than oil if used carelessly and not strictly according to directions.

Another material that has given good, early-season control of the species of mites overwintering in the egg stage is parathion. One pound of a 25 percent wettable powder per 100 gallons of spray in the calyx application has given as good control of these species as a 3 percent dormant oil. Parathion cannot be used safely on all varieties so early in the season; it may cause serious injury to McIntosh and related apples and increase russeting of other varieties, such as Golden Delicious and Jonathan.

Dormant sprays are of little value against the two-spotted spider mite, Pacific mite, and other species wintering as adults. With some of these species, this is partly because they feed on other hosts before moving into the apple trees.

Recent research has aimed to develop safer, more effective materials for use in summer applications. Such materials have been badly needed to combat the mite species against which dormant sprays are ineffective as well as to control midseason or later outbreaks of the species against which dormant sprays are used. Summer-oil emulsions, 1 to 1.5 percent, and various forms of sulfur were formerly commonly employed for the purpose but sometimes caused injury and were not always as effective as desired.

The first promising substitute that came into wide use against mites was the dicyclohexylamine salt of dinitro-*o*-cyclohexylphenol (DN-111). Its tendency to cause injury when high temperatures prevail and its failure to be fully effective against the European red mite at safe strengths limit its usefulness.

Many materials have been tested in summer sprays against mites. A few have proved their worth in enough tests to justify recommending them. The most promising ones include parathion, tetraethyl pyrophosphate (TEPP), 2-(*p-tert-butylphenoxy*)-1-

methylethyl 2-chloroethyl sulfite (Aramite), O-ethyl O-*p*-nitrophenyl benzenethiophosphonate (EPN), and 1,1-bis(*p*-chlorophenyl)ethanol (DMC).

Some growers prefer to include these materials in one or more of the regular cover sprays applied to control the codling moth in order to prevent the development of mite infestations. Other growers prefer to withhold their use, unless needed for other purposes, until mites show up in sufficient numbers to require control. In the latter case, two applications about 7 to 10 days apart may be required. Both systems have many advocates and both have advantages and disadvantages. Only further research will prove which is superior.

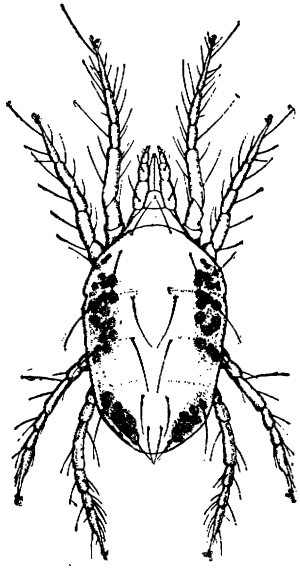
Just when marked progress was being made in developing effective treatments for mite control the problem of resistance attracted attention. Early in 1951 recommended quantities of parathion did not control the European red mite in Washington. Later in the season other species of mites, including some not previously suspected of being present, were not controlled satisfactorily and other promising new materials were not as effective as they had been earlier. Still later reports indicated that mites were becoming harder to control in other areas—West Virginia and New Jersey. Possibly the orchard mites were developing resistance to insecticides. That is not altogether surprising, because a resistant strain of the two-spotted spider mite has been reported by greenhouse workers. It is apparent that the problem of orchard mites is far from solved: We have to reexamine spray schedules; find insecticides that do not lead to increases in mite populations to replace materials whose use seems to favor such increases; determine the factors that affect the development of mites; and put forth further efforts to find materials that will hold in check all species of mites.

THE RED-BANDED LEAF ROLLER is perhaps second only to mites among the pests that have increased in importance in apple orchards following the use of DDT. It has long been widely distributed on many hosts, but is ordinarily heavily parasitized. Rare indeed was the orchardist who knowingly had to contend with it until a few years ago. Now it is a problem pest throughout the Midwest and East, where in 1947 and 1948 particularly it caused severe damage in many orchards. A study of the problem showed that including lead arsenate in the first two or three cover sprays usually takes care of this leaf roller for the season. Later studies revealed the value of TDE, parathion, and EPN in controlling it. TDE is particularly effective and valuable to combat infestations during the summer whenever outbreaks threaten. Now the red-banded leaf roller is a pest growers need no longer fear but one they must plan to take care of.

THE WOOLLY APPLE APHID, a pest widely distributed throughout all apple-growing areas in the United States, has been held in check by the parasite *Aphelinus mali*. This aphid is the insect that lives in the little cottonlike masses that are often seen around pruning wounds and other scars on the trees and in the axils of leaves on new growth, particularly on water sprouts. It may also occur on the roots of the trees. A particularly important pest in the Pacific Northwest because of its connection with spread of the perennial canker disease, it is only in that area that it has increased to serious proportions following the use of DDT. Presumably because of the effect of DDT on the *Aphelinus* parasite, the woolly apple aphid is once again a pest to be reckoned with in that area.

Formerly controlled with nicotine sulfate when the parasite did not take care of it, it can now be checked by including materials such as benzene hexachloride, parathion, or TEPP in an early cover spray, or controlled later with either of the latter two materials. Benzene hexachloride may impart an off-flavor to the fruit if used after the early part of the season.

THE PLUM CURCULIO, an important fruit pest east of the Rocky Mountains, is most commonly associated with stone fruits, particularly peaches and plums. On apples it seldom caused serious injury when the regular spray program included lead arsenate to control the codling moth. Ordinary dosages of DDT do not control it effectively. Its jump in importance to apple growers dates from the time they changed their spray programs from lead arsenate to DDT. The best answer has been to include lead arsenate in the early-season part of the spray program, especially in the calyx and first-cover spray. For heavy infestations a special application between the calyx and first-cover spray is often desirable. Other materials show promise, but none seems to be superior to lead arsenate for use against plum curculio on apples.



Pacific mite.

APPLE GROWERS have known the San Jose scale for many years, but few were familiar with Forbes scale, which is like it in appearance and habits. Many growers in the Midwest now are concerned with both species. Long held under control by the use of dormant- and summer-oil emulsions, the scales are growing in importance as the use of oil in the regular spray program steadily declines.

Dormant-oil emulsions at ordinary strengths, usually 3 percent oil in the dilute spray, are highly effective against the San Jose scale but do not seem to be so effective against Forbes scale. It appears that former wide use of oil in summer cover sprays may have had more effect in scale control than was generally recognized.

Our experimental work has shown that dormant sprays may not be necessary to control either one of the scales if a material such as parathion is included in the regular spray schedule. The minimum effective dosage of parathion has not been determined, but one-fourth pound or more of 25 percent parathion per 100 gallons in six applications or one-half pound in three applications have given complete protection in tests in Indiana. A single summer application of one-half pound of 25 percent parathion per 100 gallons has given partial control of Forbes scale on apples.

I HAVE DISCUSSED only the pests that have created serious problems for years and in important producing areas following the use of DDT. Others, such as the yellow-necked caterpillar in West Virginia, Virginia, and Maryland and mealybugs elsewhere, have appeared for a season or two in limited sections, presumably (but not necessarily) because of a direct or indirect effect of the use of DDT. In general, effective treatments have been developed promptly or adjustments made in the spray program to control such outbreaks, and they have not proved too serious. Other ordinarily minor pests no doubt will appear in outbreak proportions from time to time and require temporary or continuing adjustments to take care of them. But the apple grower must be ever on the alert and his spray program must be a flexible one.

The reader should not conclude that increases in importance of previously minor pests following the use of DDT have been confined to apples or that DDT is the only one of the newer insecticides whose use has led to such developments. For example, the use of DDT has been associated with increases of mites on peaches, grapes, pecans, shade trees, and cotton; mealybugs on grapes; aphids on cotton; the red-banded leaf roller on peaches and grapes; and cottony-cushion scale on citrus. On the other hand, the use of materials such as methoxychlor has been followed by more mites on apples and peaches and aphids on cotton. The use of parathion has been followed by increases of the soft scale on citrus. But all in all DDT on apple trees has been more to blame than the others for outbreaks of pests that used to be of little importance. Despite the problems its use has created, DDT has been a great benefit to apple growers; advantages resulting from its use far outweigh its disadvantages.

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Japanese beetle.

The Japanese Beetle

Charles H. Hadley
Walter E. Fleming

Harry B. Weiss, who since became director of the New Jersey Division of Plant Industry, found a few shiny, metallic green beetles in a nursery near Riverton, N. J., in 1916. He did not recognize them at first, nor did anyone else, but they were finally identified as Japanese beetles, *Popillia japonica.* That was the first record of their occurrence in the United States. Entomological literature contained little information about them other than that they were common on the main islands of Japan and were not considered a serious pest. We knew little about their habits in Japan and nothing to indicate whether they would become serious in the United States. We did know that related beetles had caused considerable trouble in the Old World and in the other Pacific islands that they had invaded.

Apparently the beetle had come to the United States with plants before restrictions were established by the Plant Pest Act of 1912.

The adult Japanese beetle is plump, shiny brown and green with 12 white spots, and about one-half inch long. It is seen only in the summer and may feed on 275 kinds of plants.

Its white grub stage is in the ground, where it feeds on the roots of plants. The beetle does damage estimated at 10 million dollars a year to farm and orchard crops, residential and public ornamental plantings, lawns, and golf courses.

Men in the Department of Agriculture began an investigation in 1917 to get information about its development and habits in its new home. By the end of that year it was obvious that the beetle had found ideal conditions for