FURTHER COMPLICATIONS OF THE CODLING-MOTH PROBLEM

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The codling moth *Carpocapsa pomonella* (Linn.), the larva of which is the common apple worm, has for years steadily become more difficult to control. Much advancement has been made in the timing of sprays and in the development of machinery for their application. Improvements have been made in the insecticides used and many orchardists have adopted supplementary measures to further reduce codling-moth populations. However, in spite of these improvements, the codling moth has slowly but surely become increasingly hazardous to apple production. There are two apparent explanations why the problem has become more serious in spite of better controls. First, the codling-moth population in any given orchard continues to increase slowly over a period of many years despite control measures instituted against it. Second, evidence has been found that in orchards regularly sprayed, a race of moths possessing at least some degree of resistance to arsenate of lead has made its appearance. The increased resistance is thought to have been brought about by there being some larvae that survive either through their ability to consume small amounts of the insecticide without fatal results, or because of some feeding habit that enables them to enter sprayed fruit without obtaining lethal amounts of poison. These are the individuals that reproduce and they pass on to their offspring these same qualities while those that are susceptible fail to reproduce. Thus, over a period of years a more-resistant strain of moths is developed which is more difficult to control. Experiments designed to test this theory have shown that a higher percentage of larvae from regularly sprayed orchards are able to enter sprayed fruit than those from unsprayed orchards.

Since early in the present century, arsenate of lead has been the standard insecticide used against codling-moths. Practically all other insecticidal materials have been tried and some have shown considerable promise. However, prior to the discovery of DDT (1-trichloro-2,2-bis(*p*-chlorophenyl)-ethane) most workers found that arsenate of lead was better than these other materials. Arsenate of lead, therefore, remained the standard material used in the control of codling moth despite the fact that under conditions of severe infestations its use had not been entirely satisfactory.

When DDT first became available for experimental work against the codling moth, the results obtained in different States varied widely. Some workers reported excellent results, others practically no control. A considerable proportion of this variation appears to have been because much of the DDT used contained a spreader that resulted in such a high "run off" of the DDT that an insufficient amount remained to protect the fruit. However, during the summer of 1945 most workers found DDT to be definitely superior to arsenate of lead and many reported almost complete control. While very few of the results obtained in 1946 have as yet been published, it is the writer's impression, obtained from talks and private correspondence with other workers, and from work conducted at the Oklahoma Agricultural Experiment Station, that they have been very promising. As a result, DDT is now considered by the majority of entomologists to be definitely superior to any other available material that has been thoroughly tested against the codling moth.

Most workers have also found that the use of DDT, despite its better control of codling moth, is likely to result in increased populations of other pests of apples. Such increases are thought to be caused by the DDT being more toxic to the natural enemies of such pests than to the pests themselves. The red-banded leaf roller (*Argyrotaenia velutinana* (Walker)), the woolly apple aphid (*Erisoma lanigerum* (Hausman)), and various species of mites of the genera *Tetranychus* and *Paratetranychus* are examples of pests that workers in various parts of the United States have found likely to increase in importance when DDT is used. In Oklahoma, the wooly apple aphid and the two-spotted spider mite, *Tetranychus bimaculatus* Harvey, are the species that have been most notable in this respect; of the two the mite has been of much greater importance.

Since these mites appear to thrive better in the warmer, drier areas, one would anticipate that this problem would be more severe under Oklahoma conditions than under the conditions existing in many of the apple-growing areas of the United States. Experience at the Oklahoma Agricultural Experiment Station during the past two summers indicates this to be the case, for without exception, every tree sprayed regularly with DDT has become heavily infested with mites and in many instances the infestation has been sufficiently great to cause severe defoliation. It therefore appears that before DDT can come into general usage in Oklahoma orchards it will be necessary to find ways and means of controlling the mites brought on by its use, for if the mites are uncontrolled, their damage through destruction of leaves may be more severe than the injury to the fruit caused by the codling moth.

Because of these new complications, experiments were begun in 1946 to obtain additional information concerning the efficacy of DDT to control the codling moth and to test methods and materials for solving the increased mite problem brought on by the use of DDT. This paper is a preliminary report on the results of these experiments.

PLOT ARRANGEMENT AND TREATMENTS

In the Experiment Station orchard at Perkins, Oklahoma, four plots were laid out in such a manner that each plot contained the same varieties of apples with one or two trees of each variety in each plot. There were from 15 to 17 trees in each plot. Starting with the first cover spray, these plots were sprayed according to the regular spray schedule with DDT at the rate of 2 pounds of a 50-percent water-wettable powder to each 100 gallons of spray. A total of seven sprays was applied. In one of these plots 1.25 pounds of dinitro-o-cyclohexylphenol, commonly called *DN-111* and recommended by numerous workers as an acaricide, were added to each 100 gallons of spray. In other plots no acaricide was used until heavy mite populations were present. Individual trees were then sprayed with varying strengths of the following materials, each of which has been recommended as effective against mites: Azobenzene, hexachlorocyclohexane, hydroxypentamethylflavan, "di(*p*-phenyl) methyl carbinol", and dicyclohexylamine salt of dinitro-*o*-cyclohexylphenol.

In addition to these plots, 11 other two-tree plots were selected. One tree in each plot was of the variety Jonathan and the other a Winesap. One of these plots was sprayed twice with DDT, the others twice with a mixture of DDT and one of the acaricides. These applications were made in late June and early July before mite populations became high.

METHODS USED IN DETERMINING MITE INFESTATION

Counts of the number of mites on 25-leaf samples from each tree were made preceding the application of each material, two days after spraying and at ten-day intervals thereafter. Similar counts were made from check trees. In making these counts, 25 leaves were collected from each of the count trees. The first ten were selected from water sprouts and limbs near the center of the tree. Fifteen additional leaves were selected at random from the periphery. A turntable, operated from the battery of a car, was constructed for use in counting the mites. A paper disc 9 cm in diameter was attached to the center of the turntable by means of a small thumb tack. Immediately above the paper disk was a funnel made of cellulose acetate, the lower opening of which was of the same diameter as the disk. Four sectors were marked off on this disc. The arc of each contained 10 degrees and the sides converged at a point near the center of the circle, resulting in one-ninth of the total area being marked off. Immediately before brushing the mites from the leaves, a light coating of varnish was applid to the disk by means of a brush to cause the mites to adhere wherever they fell. The switch was then turned on, causing the turntable to revolve at a uniform rate and the mites brushed by hand from the leaves, onto the whirling disk, by using a one-inch camel's-hair brush. The disks were examined under a stereoscopic microscope and the mites within the marked-off areas counted. This number was multiplied by nine to determine the total population of each 25-leaf sample and one twenty-fifth of this number was considered the average mite population per leaf.

EFFECT ON MITE POPULATIONS

Typically there was a tremendous drop in the mite populations in the 48-hour period following the application of each of the acaricides. But in many cases within a week's time the population was again high, frequently even higher than when the application was made. During this same period, there were also large fluctuations in the mite populations on the check trees. As a result, analyses of the data failed to show significant differences in the treatments immediately following their application. The rapid build-up of the populations following the treatments was brought about by the hatching of eggs, usually very numerous at the time the treatments were applied. In some cases, where large decreases in mite

TABLE I

Control of spider mites Tetranychus bimaculatus *Harvey obtained by spraying with various acaricides, Perkins, Oklahoma, 1946*

Material	Amount per 100 gallons	Percentage of effective control[a] 10th day after spraying	20th day after spraying	30th day after spraying
Azobenzene	0.5 lb.	0	0	0
	1 lb.	0	0	0
	2 lbs.	0	0	0
Hexachloro-cyclohexane	0.5 lb.	0	0	0
	1 lb.	31	2.6	0
	2 lbs.	32	0	0
Hydroxy-pentamethyl flavan	0.5 lb.	0	0	0
	1 lb.	0	0	0
	2 lbs.	10	0	0
Dinitro-o-cyclohexylphenol	1.24 lbs.	93	87	67
"Di(p-phenyl) methyl carbinol"	0.5 lb.	97	96	85
	1 lb.	94	95	98

[a]Effective control figured according to Abbott's formula.

populations occurred on the check trees it was because the leaves became dried out owing to excessive mite feeding so that they were no longer able to support mite populations. Under these conditions, high percentages of the leaves frequently were shed. However, where *DN-111* and "di(*p*-phenyl) methyl carbinol" were used the populations remained low. Table I summarizes the results of these tests 10 to 30 days following their application.

Excepting the plot sprayed with *DN-111*, these sprays were not applied until the mite population had become heavy which resulted in a great many eggs being present on the leaves in most cases. It appears that the *DN-111* and "di(*p*-phenyl) methyl carbinol" were either toxic to the eggs or left a residue that was lethal to the young mites hatching from them. The eggs were not killed by the other materials and insufficient residues were left to affect materially the recently hatched mites.

DN-111 HARMLESS TO FOLIAGE AT HIGH TEMPERATURES

Another interesting point brought out in these experiments is that *DN-111* apparently may be used during periods of high temperatures under the conditions existing in the Experiment Station orchard last summer. Some workers in other parts of the country have reported that injury to the leaves has occurred when *DN-111* is applied in hot weather. The manufacturers recommend that it be used only when the temperature is under 90°F and when the temperature is not expected to rise to 90° during the next 24-hour period. In 1946 the temperature rose to 90°F or higher on each day throughout the period the mite populations were severe. Observations made during 1945 had indicated that this material could be used under our conditions at higher temperatures and therefore in 1946 the sprays were applied regardless of the temperatures. One application was made at a temperature of 100°F. In no case was appreciable injury observed.

EFFECT OF TREATMENTS ON CODLING-MOTH INFESTATION

During the season of 1946 there was an exceedingly light crop of apples in the Experiment Station orchard. Many of the experimental trees bore no crops and many of the others exceedingly light crops. As a result, sufficient fruits were not available in many of the plots to yield significant information concerning the effects of the various treatments upon codling-moth control. The data, however, gave strong indications that the DDT when used with but one to two applications of the various acaricides was superior to arsenate of lead. An average of 31 percent of the apples were infested after being sprayed throughout the season with DDT plus 1 or 2 sprays to control red spider, as compared with 53 percent after treatment with arsenate of lead. However, in the plot in which *DN-111* was added to each spray of DDT, the codling-moth infestation averaged 69 percent. Although further work must be completed before one may definitely conclude that this difference in codling-moth infestation was due to the treatments applied, there are indications that *DN-111* added to DDT sprays may further complicate this problem by reducing the ability of the DDT to prevent codling-moth infestation. It is hoped that the work planned for the coming season will provide more complete information.

SUMMARY

DDT is a very promising substitute for arsenate of lead in the control of codling moth on apples.

Use of DDT greatly increases mite populations with resulting damage due to defoliation unless the mites are controlled by other materials.

"Di(*p*-phenyl) methyl carbinol" and *DN-111* are promising materials to control mites.

DN-111 may be used at temperatures up to 100°F under conditions similar to those existing in Oklahoma in 1946 without serious injury to apple foliage.

DN-111 may adversely affect the ability of DDT to control codling moth.

Further information is needed concerning the effects of these materials on codling-moth and mite populations.