APPLE MAGGOT CONTROL STUDIES

Philip Garman

Bulletin 604 • March 1957

THE CONNECTICUT AGRICULTURAL EXPERIMENT STATION
NEW HAVEN

CONTENTS

ACKNOWLEDGMENTS

The author wishes to acknowledge the help obtained from J. F. Townsend in the earlier period of this investigation and following him A. L. DeCaprio. Laboratory tests with flies have been done largely by Mrs. Bessie H. Kennedy. Their conscientious and careful work is duly appreciated. Photographs are by B. W. McFarland.

REFERENCES

DEAN, R. W. Effect of DDT on apple maggot, red mite and curculio. Proc. N. Y. Hort. Soc. 91. 205-209. 1946.

———— Apple maggot control with DDT sprays and dusts. Jour. Econ. Ent. 40. 183-189. 1947.

———— Evaluation of some new insecticides for apple maggot control. Jour. Econ. Ent. 44. 147-153. 1951.

HODSON, A. C. Further studies of lures attractive to the apple maggot. Jour. Econ. Ent. 41. 61-66. 1948.

MCPHAIL, M. Protein lures for fruit flies. Jour. Econ. Ent. 32. 758-761. 1939.

Apple Maggot Control Studies

Philip Garman

Increasing difficulties in the control of apple maggot in Connecticut orchards may be related to the insecticides applied, weather, and possibly changing habits of the insect itself. Resistance to insecticides may be involved. Consequently a review of tests at this laboratory and at the Experimental Farm may have some meaning.

Examination of newer insecticides that followed the introduction of DDT was begun in 1948. Points that required clarification were (1) rapidity of action because of the importance in reducing populations of flies quickly, (2) volatility of the various compounds because of the necessity for protection over a fairly long period of fly emergence from the soil, as well as migration into the orchard from outside, (3) resistance to weathering in order to know if a given insecticide could be expected to protect fruit in rainy periods, and (4) whether some change in field practice could not improve controls with the new products.

Methods

At first, wooden cages with open front and back were utilized for small scale tests. Four-by $3\frac{1}{4}$-inch slides clamped on front and back, one of them sprayed on the inside, proved to be unsatisfactory because they could not be used beyond the first experiment due to contamination on the inside of the cage. Small cardboard containers were next employed in the same way, but the container was discarded after the test. Finally we employed the paper cup as shown in Figures 6 & 7 with inverted petri dish sprayed on the inside. The test was conducted in a constant temperature room under fluorescent light, set for a 12-hour day. Counts of dead and paralyzed flies were made at regular intervals. For the volatility test, petri dishes were sprayed on the inside and exposed in the greenhouse for 1 to 7 weeks before testing. Washing tests were done by spraying two mature privet leaves attached to a stem and washing both surfaces in a rain machine on a revolving platform. After treatment the leaves were inserted through the bottom of the paper cup shown in Figure 6 (see Fig. 7), and the flies allowed to walk over them. The leaves were placed in contact with the glass petri dish covering the cage.

Field experiments were mostly at the Experimental Farm, Mt. Carmel. Results for the most part were from general insect control plots and percentages are averages of samples from 6 to 8 trees.

Examination of Insecticides

Rapidity of Action

Lead arsenate is notably slow in killing maggot flies. Incomplete mortality even after 48 hours is frequently seen. It is, however, frequently important in orchard practice to obtain more rapid kills, hence the introduction of organic insecticides appeared to provide a solution.

The problem remained as to which one of the organics is best and what are their limitations. The following bears on those points. After establishing a general mortality rate for DDT, comparisons of that insecticide with chlordane, methoxychlor, dieldrin, and aldrin were possible. These showed a more rapid mortality after exposure to aldrin, chlordane, and dieldrin than after exposure to DDT (Table 1). Methoxychlor, on the other hand, gave a different slope so that while initial kills were greater than DDT, the action on the whole was inferior.

The work continued in 1948 through 1950 at the end of which time it appeared (for pure chemicals dissolved in xylene) (1) that aldrin, and dieldrin (Figures 1, 2) were about equal in rapidity of kill, (2) DDT and chlordane were about equal to one another, but slightly less effective than those listed under (1), (3) the technical methoxychlor mortality curve crossed over that of DDT where kills were rapid at first, then slowed down (Figure 1), and pp' DDD(TDE) was slower than any other chlorinated hydrocarbon tested up to that time. In one test (Table 2) heptachlor

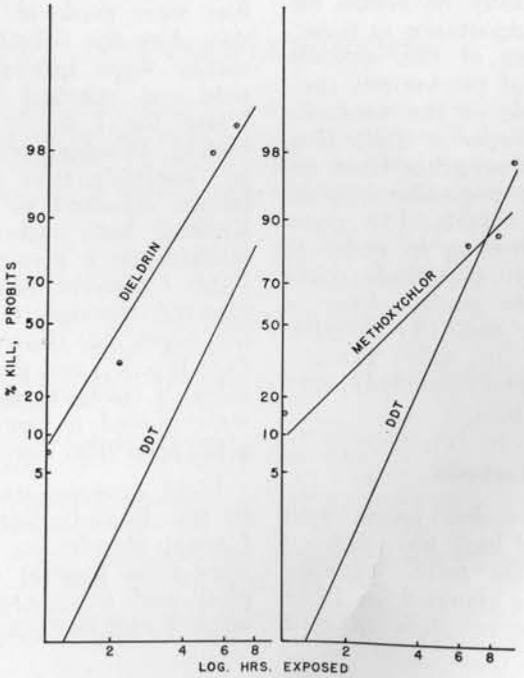

Figure 1. Rapidity of kill by DDT, dieldrin, and methoxychlor.

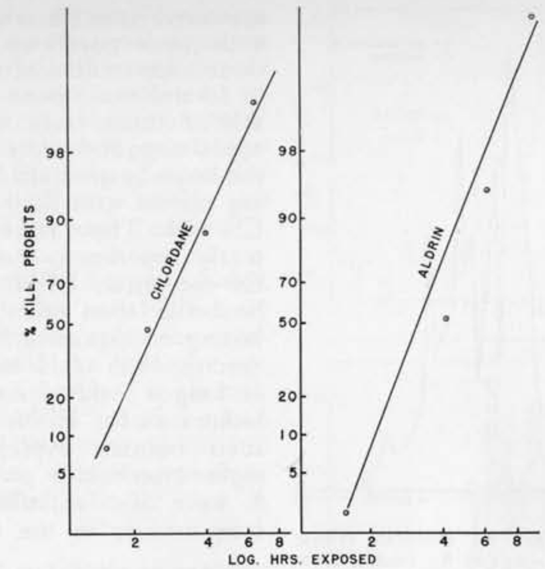

Figure 2. Repidity of kill by chlordane and aldrin.

killed faster than dieldrin, and about equal to chlordane.

After further testing the several chlorinated compounds, it was concluded that (1) aldrin, chlordane, and dieldrin were about equal except for one sample of chlordane several years old which appeared completely ineffective, (2) TDE (DDD) is much slower, but effective at high doses, (Table 3) and (3) 50% methoxychlor and DDT were about equal, and the mortality curve was about the same with purified materials.

As to the phosphates, it was further concluded after several years that parathion, in view of its short period of effectiveness, would require more frequent sprays to control the apple maggot than such insecticides as lead arsenate, chlordane, or DDT. Laboratory tests, however, indicate a longer life than expected for parathion and when combined with DDT as in Black Leaf 253 laboratory results are quite favorable.

At the end of several years' tests, however, we were still unable to decide which of the various newer insecticides would be most efficient in field control of the apple maggot. Something appeared to be missing. Consequently tests were begun to show (1) how volatile each compound or formulation might be and (2) their resistance to rainfall as indicated through use of a laboratory washing device.

Volatility

From the first it became apparent that some of the chlorinated hydrocarbons such as aldrin or perthane (Q 137) had a residual life exposed to air and sunshine in the greenhouse of 1 to 2 weeks only; DDT and TDE 2 weeks, and dieldrin and CS 674, 4 weeks or more. Dieldrin

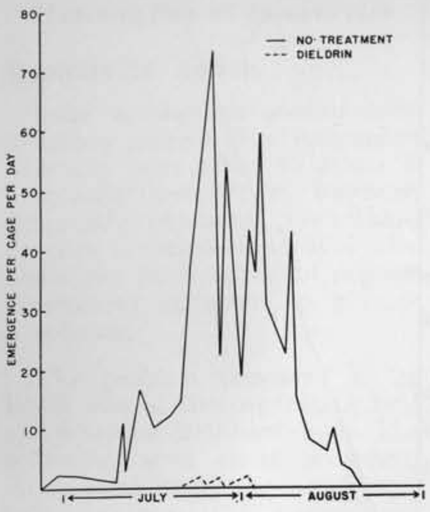

Figure 3. Effect of dieldrin treatment on apple maggot fly emergence.

and CS 674 continued to give satisfactory kills even after 7 weeks' exposure. Among the phosphates, parathion lasted 2 weeks or less at first, but EPN appeared more efficient. Later tests with both parathion and malathion, apparently after a change in formulation, were much better. All of these tests were on the apple maggot fly but tests against the housefly gave similar outstanding results with both dieldrin and CS 674. They remained consistently superior to the phosphates. Of the latter, EPN continued to be better than other phosphates, lasting on exposure 3 to 4 weeks, though 1955 tests indicate about as long a residual action for malathion as for EPN. However, it soon became evident that the eight insecticides given in Table 8 were not volatile enough to lose toxicity in the test period.

Adhesiveness

It now remained to prove which insecticide would withstand rainfall the best. After spraying on privet leaves, washing, and exposing to flies in paper cup cages (Figure 7), it became apparent that nearly all the chlorinated hydrocarbons are affected by rain (Table 9). Some of them, however, washed off much less than others. Formulated methoxychlor washed off very readily and DDT or TDE were reduced in effectiveness as much as 50 per cent by a single 5-minute wash. Dieldrin, CS 674, and EPN were again outstanding as in the volatility tests and the previous selection was thereby confirmed. Malathion showed reduced action and required 96 hours to kill 100 per cent after washing, whereas parathion killed 100 per cent in 24 hours.

Table 1. Apple maggot fly control in cage tests, 2 per cent pure and technical grades of insecticides dissolved in xylene and sprayed on glass slides, December 1948

Treatment	Deposit weight in grams	Per cent mortality after 2 hrs.	4 hrs.	6 hrs.	8 hrs.	24 hrs.
Chlordane (technical)	.0029	36.4	90.9	90.9	100	......
	.0023	30.0	40.0	50.0	70.0	100
	.0011	0.0	27.2	75.0	75.0	100
DDT (recrystallized pp')	.0034	14.2	14.2	28.6	28.6	100
	.0022	12.5	37.5	62.5	87.5	100
	.0016	16.7	50.0	58.3	75.0	100
Dieldrin (crystals)	.0040	0.0	87.5	100	......	......
	.0025	0.0	50.0	100	......	......
	.0019	0.0	57.1	71.4	100.	......
Aldrin (crystals)	.0021	0.0	27.2	81.8	100.	......
	....	5.5	22.2	88.8	100.	......
	.0008	0.0	10.0	80.0	100.	......
Parathion (technical)	.0023	36.3	63.6	81.8	100	......
	.0016	0.0	83.3	100	......	......
	.0013	83.3	83.3	100	......	......
Check, no treatment	....	0.0	0.0	0.0	0.0	33.3

Note: Repeat tests after 24 hours with parathion and dieldrin showed a slower rate of kill for dieldrin but a more rapid rate for parathion. In these the same slides were used as in above table. After one week dieldrin killed faster and more effectively than parathion.

A general summary of rapidity of action, volatility and resistance to rainfall is given in Table 7. Based on superiority in all these categories, dieldrin, Black Leaf 253 (DDT-parathion combination), and EPN appeared to be more effective. This does not mean that chemicals like TEPP or aldrin would not have a place, but merely that these insecticides would either have to be applied more frequently during the height of the season or confined to late season sprays. The slowness of action of lead arsenate is compensated for in some measure by its adhesiveness so that in actual practice it may be equal to some of the faster acting chemicals. Also dieldrin or chlordane, very effective, relatively non-volatile, but adhesive, are limited to early season sprays. Probably CS 674 will also fall in this group because of low tolerances, which leaves

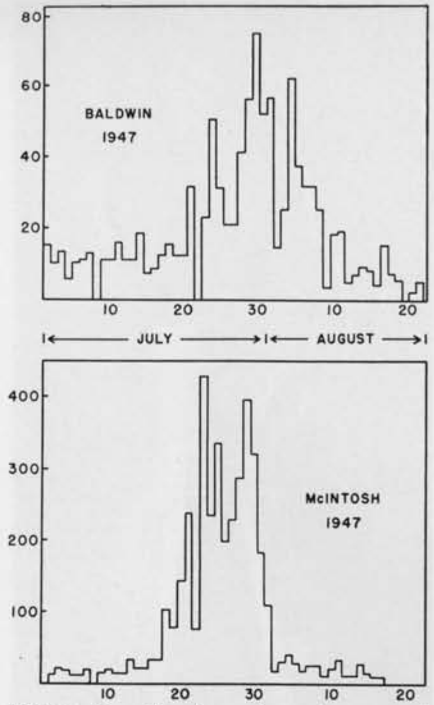

Figure 4. Number of apple maggot flies emerging daily from two varieties in 1947.

Table 2. Apple maggot fly control in cage tests, 5 per cent technical grade of insecticides dissolved in xylene, December, 1948

Treatment	Deposit weight in grams	Per cent mortality after 2 hrs.	4 hrs.	12 hrs.	24 hrs.
Chlordane (technical)	.0026	100	......	......	......
	.0021	70	80	80	100
	.0054	77	88.8	100	......
Dieldrin (technical)	.0021	0.0	11.1	100	......
	.0074	0.0	80.0	100	......
Heptachlor (technical)	.0022	72.7	100	......	......
	.0057	55.5	100	......	......
Check, xylene only		0.0	0.0	0.0	......

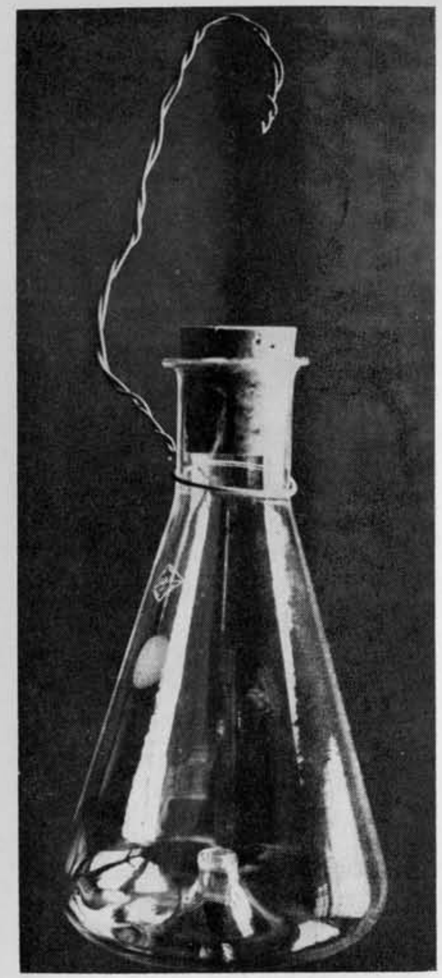

Figure 5. Trap for apple maggot flies; in operation, filled with 10 per cent ammonium acetate half way to the top of central spout.

Black Leaf 253 and lead arsenate.

It would obviously be possible to combine others besides DDT and parathion which would provide similar qualities, together with adequate kill. Field comparisons of DDT and lead arsenate show that DDT must be applied more often except in dry weather, indicating longer adhesion for lead arsenate.

Ground Sprays

Attempts to kill apple maggot flies as they emerge from the ground were begun in 1948. Owing to limited numbers of cages and flies it was impossible to make any rapid progress. In 1948, however, it became at once apparent that we could kill flies before they got out of the ground or during the process. The first year 9.4 and 19.8 grams benzene hexachloride (12% gamma) and chlordane (50%) 2.25 and 4.5 grams per square yard were tried. In this experiment benzene hexachloride at the higher dose reduced the number of flies emerging by 92.2 per cent. The higher dose of chlordane 4.5 grams per square yard (48 lbs./acre, 24 lbs. active) reduced the number 47 to 59 per cent, and was evidently not a sufficiently large dose.

In 1949, DDT and dieldrin were compared at equal doses per square yard. Both were dissolved in oil and emulsified. Dieldrin proved far superior even at lower dosages. In 1951 we compared aldrin and dieldrin wettable powders at 38 to 300 pounds per acre (25% wettable). This would be equivalent to 9.5 and 75 pounds per acre, active ingredient. Single and double applications were made of each insecticide, applied at several rates. From the 75-pound-per-acre treatments the following results were obtained.

	Single Application	Double Application
	Per cent	*reduction*
Aldrin	80.4	89.0
Dieldrin	70.0	85.7

These results make it appear that there is not much difference between aldrin and dieldrin wettable powders put on the soil, in

Table 3. Apple maggot fly control in cage tests, commercial formulations of insecticides sprayed on glass plates, December, 1948

Treatment	Deposit weight in grams	Per cent mortality after 2 hrs.	4 hrs.	8 hours	24 hours
DDT, 50%	.0006	0	0	66	100
	.0007	0	0	0	85
	.0006	14	21	29	50
TDE, 50%	.0018	9	9	36	91
	.0010	30	30	40	90
	.0006	12	12	25	37
Lead arsenate	.0013	8	8	16	16
	.0005	10	10	10	10
	.0003	7	7	20	67
Aldrin, 25%	.0010	9	45	91	100
	.0007	0	9	45	100
	.0005	11	11	18	78
Dieldrin, 25%	.0010	0	40	100	100
	.0008	0	27	81	100
	.0004	11	67	78	100
Parathion, 25%	.0010	10	60	80	100
	.0004	0	9	54	100
	.0005	0	0	11	33

spite of our laboratory results with the flies themselves. Examination of the cage records reveals, however, that aldrin treatments were not effective in preventing fly emergence for much more than 2 weeks after application, thus confirming volatility experiments with the flies. If ground sprays with aldrin are to be depended upon, treatments would therefore have to be made frequently during the summer. Figure 3 shows emergence of flies from cages treated with dieldrin compared with the checks.

During 1952 we compared Dilan powder containing CS 674 and dieldrin emulsion followed by one application of powder. In these tests, Dilan showed up very poorly, but two applications of dieldrin reduced the number of flies emerging by 92 per cent. Applications of dieldrin were made June 2 and July 15. The first application of dieldrin was 1 quart of the emulsion containing ⅜ pounds active ingredient to 25 gallons put on the soil with a power sprayer at the rate of 12 gallons to 200 square feet. The second treatment consisted of 1½ pounds of 21 per cent powder in 15 gallons and 11.7 gallons applied to the 200 square feet. To compare with previous tests, the pounds per acre active ingredient in the case of dieldrin was 39.4 pounds for the emulsion and 52 pounds per acre for the powder.

Continued experiments with ground applications confirmed earlier findings, regarding dieldrin. Tests with endrin in two successive years, however, gave comparable results. In 1955 and 1956 repeat treatments on the same ground treated in 1954 seemed to indicate progressive improvement from year to year. In these tests there was a reduction in fly emergence of 75 per cent in 1954 whereas reduction

Figure 6. Inverted petri dish and paper cup used to test insecticides.

with the same treatments in the same location was 96 per cent in 1955 and 98 per cent from one application in 1956.

Cost. At the above rates of application and current prices of insecticide the cost per acre for dieldrin would be close to $200

Table 4. Apple maggot fly control in cage tests, commercial formulations of insecticides sprayed on glass plates, December 1948

Treatment	Deposit weight in grams	Per cent mortality after 2 hrs.	4 hrs.	8 hrs.	24 hrs.	48 hrs.
Dieldrin, 25%	.0014	0	80	100	......	......
	.0010	0	81	81	100	......
Aldrin, 25%	.0013	21.4	57.1	100	......	......
	.0010	10.0	10.0	10.0	100	......
	.0013	0.0	0.0	42.8	50	71.4
DDT, 50%	.0005	0.0	23.0	67.2	84.6	100
	.0009	12.5	25.0	25.0	(escaped)	
	.0001	12.5	25.0	25.0	75.0	100
Chlordane, 50%	.0007	0.0	18.1	45.7	72.7	100
	.0006	10.0	10.0	10.0	30.0	90.0
	.0008	......	10.0	10.0	60.0	72.7
Lead arsenate	.0012	9.1	9.1	9.1	36.3	54.5
	.0011	0.0	0.0	0.0	28.5	28.5
Parathion, 25%	.0004	0.0	50.0	50.0	100	......
	.0008	7.7	7.7	7.7	30.8	80.0
Check		0.0	0.0	0.0	11.1	11.1

Table 5. Apple maggot fly control in cage tests, commercial formulations of insecticides sprayed on glass plates, January 1949

Treatment	Deposit weight in grams	Per cent mortality after 6 hrs.	24 hrs.	48 hrs.
Aldrin, 25%	.0001	0	0	18.1
	.0004	0	1.0	72.7
Chlordane, 50%	.0005	0	0	30.0
	.0003	0	50.0	75.0
	.0006	22.2	55.5	100
Check, no treatment		0	0	20.0
Comparison by concentration (½ lb. active)				
Aldrin, 25%	2 lbs./100 gals.	0	9.0	72.7
Chlordane, 50%	1 lb./100 gals.	0	0	30.0

for a single application. For aldrin it would be about ¼ less or $150. Both of these figures are too high especially when we consider that the total cost of spraying an acre of average orchard is not over $100 per season. This is, of course, assuming that the whole orchard floor were covered. Actually, it is necessary to treat only under the trees where apples fall, but even assuming only one-half the total area were sprayed the cost of dieldrin at the rate used would still be too high. Our 1949 tests indicated that the active ingredients could be reduced to 10 pounds per acre instead of 40 which would bring the total cost for a single application of dieldrin to $50, and if only half the orchard floor were sprayed

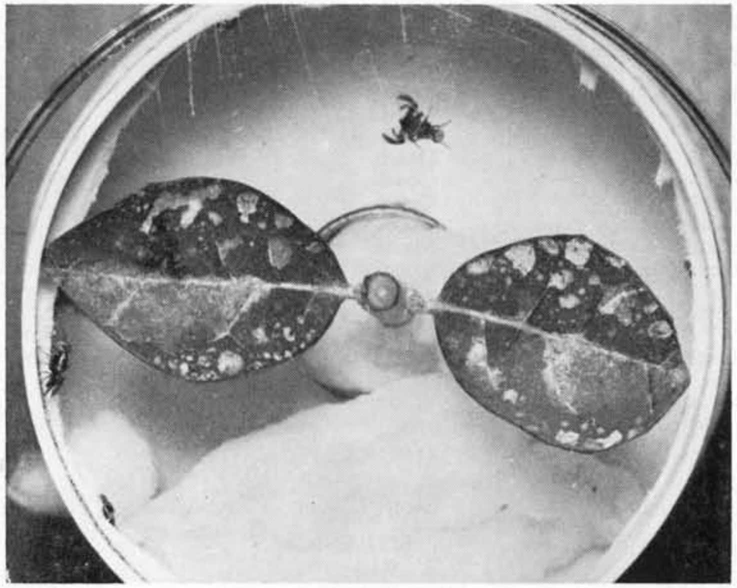

Figure 7. Leaves inserted so as to be in contact with glass petri dish.

Table 6. Comparative effectiveness of various insecticides as measured by apple fly mortality

Treatment	Hours	Treatment	Hours
LD 50		LD 100	
DDT	5	Aldrin	8
Methoxychlor	3	Chlordane	8
Chlordane	3	Dieldrin	8
Dieldrin	2.5	DDT	12
		TDE	12
		Methoxychlor	18

this would be further reduced to $25. There would naturally be some additional saving if any of the mid-season foliage sprays could be omitted. A saving of 5 to 10 bushels could be enough to offset the cost of the insecticide, and improvement of quality by reason of omission of sprays in hot weather would probably mean

Table 7. Comparative performance in the laboratory as to kill, volatility, and adhesion of materials tested for apple maggot fly control

Material	Kill	Volatile	Adhesion
ORGANIC COMPOUNDS			
Phosphates			
R 1303	Good	....	....
Diazinon	Variable	Yes	....
EPN	Good	No	Good
Malathion	Good	No	Washes readily
Parathion	Good	No	Washes in part
TEPP	Good	Yes	....
Black Leaf 253	Good	....	Good
Chlorinated hydrocarbons			
DDT	Good	No	Fair
TDE (DDD)	Good	No	Fair
DDVP	Good	Yes	....
Aldrin	Poor	Yes	....
Dieldrin	Good	No	Good
Endrin	Good	....	....
Isodrin	Good	....	....
Chlordane	Good	....	....
Heptachlor	Good	....	....
Methoxychlor	Good	....	Fair to Good
CS 674 (Bulan)	Good	No	Good
CS 645 (Prolan)	Good	....	....
CS 728 (Dilan)	Good	No	Poor
Perthane (Q 137)	Good to Poor	Yes	Good to Poor
Nitrated compound			
Karathane	Fair to Poor	....	....
INORGANIC COMPOUNDS			
Arsenical			
Lead arsenate	Slow	No	Good
BOTANICALS			
Pyrenone	Slow, Poor	....	Washes readily
Allethrin	Slow, Poor	....	Washes readily
Ryania	Poor	....	Washes readily

Table 8. Volatility as measured by kill of apple maggot flies after exposure to insecticides, laboratory and greenhouse tests

Insecticide	Per cent mortality after 1 wk.	2 wks.	3 wks.	4 wks.	7 wks.
CS 674	100	100	100	100	100
Dieldrin	100	100	100	100	100
EPN	100	100	100	100	0
Parathion	100	100	50*	100	....
Malathion	100	45*	100	100	....
DDT	100	100	100	100	90
Methoxychlor	100	100	100	100	100
TDE (DDD)	....	100	100	100	90

*Changes of formulation were made shortly after this experiment.

a profit on the operation. In the past too, it has been difficult to clean up a maggot infestation in one year following heavy infestations. Utilization of ground sprays enabled at least one grower to get the upper hand after only one year. However, it would

Table 9. Effects of artificial washes in rain machine, equivalent to 6¼ inches of rainfall, on control of apple maggot

Material		Per cent mortality after 24 hrs.	96 hrs.
Dieldrin	unwashed	100	....
	washed	100	....
CS 674	unwashed	100	....
	washed	100	....
DDT	unwashed	100	....
	washed	62.5	100
Methoxychlor	unwashed	100	....
	washed	37.5	37.5
DDD	unwashed	100	....
	washed	0	100
EPN	unwashed	100	....
	washed	89	100
Parathion	unwashed	100	....
	washed	100	....
Malathion	unwashed	100	....
	washed	0	100
BL 258	unwashed	100	....
	washed	0	20
BL 253	unwashed	100	....
	washed	90	100
Diazinon	unwashed	30	30
	washed	10	20

Table 10. Average number of apple maggot flies seen in 5 minutes following application of 2½ per cent aldrin dust to four mature trees

Date	Time	Number of flies per tree Treated	Untreated
Aug. 24*	12:30— 1:30	15	10.5
Aug. 25	12:00— 1:00	0	8.0
Aug. 26	12:00— 1:00	.25	6.7
Aug. 27	9:30—10:30	.25	8.2
Aug. 30	11:30—12:30	1.25	9.2

*This count made just before treatment.

not seem to be practical to use either aldrin or dieldrin at a rate exceeding 10 pounds actual dieldrin or 15 to 20 pounds aldrin per acre.

Foliage sprays or dusts

Control tests with tree sprays have been carried on for a number of years, the objective being improvement of quality through omission of lead arsenate or improvement of maggot control or both. The first trials were to determine whether flies could be removed from the trees by sprays or dusts of DDT or related chemicals. It was found that they could be removed very rapidly. However, it later became apparent that DDT did not furnish the long period of protection needed, so many growers resorted to half lead arsenate-half DDT sprays. The necessity for late protection has furthermore started agitation for later sprays or dusts than formerly employed and the following experiment with aldrin (Table 10) dust bears on this problem. What may be expected in fly removal is clearly apparent here.

On August 24 mature Staymen Winesap trees at the farm of Harold Lewis of Hamden were dusted with 2½ per cent aldrin dust. Counts of the flies on a time basis were made by Mr. DeCaprio before and after treatment. Similar counts were made of untreated trees. Repeat counts were made after 1, 2, 3, and 5 days. Results are given in Table 10.

Table 11. Effectiveness of insecticide combinations on apple maggot control, Baldwin trees in the Burton orchard, 1950

Treatment	Fruit Damaged
	Per cent
Lead arsenate with	
Sulfur	26.5
Thiram	16.9
Thiram and karathane	14.4
Thiram, karathane, and sticker	16.5
Chlordane and TDE (DDD) with	
Sulfur	38.3
Thiram	7.8
Thiram and karathane	25.0
Thiram, karathane, and sticker	5.7

Table 12. Effectiveness on apple maggot control of materials applied on Cortland trees in Westwoods orchard, 1946

Treatment	Fruit Damaged
	Per cent
5 sprays: DDT, 1 lb./100 gals., plus hydroxymethyl flavan for mite control. (June 11 & 25, July 8 & 26, August 6.)	14.17 13.68
5 sprays: DDT, 1 lb./100 gals., plus Genicide (xanthone) for mite control. (Dates as above)	3.83
5 sprays: DDT, 1 lb./100 gals. plus Syndeet for mite control. (Dates as above.)	21.02 14.04
Average of all DDT sprays	14.11
2 sprays: sulfur, lime, and lead arsenate. (June 25 & August 6.)	26.04
3 sprays: lead arsenate, fermate, bentonite, and oil. (April 25, May 14, & June 12.)	8.09

It appears that flies were almost completely eliminated by the treatment but that its effectiveness began to ebb after 5 days. No rains occurred between August 24 and 30.

To get more positive proof of what happens in the way of total insect kill a single tree was sprayed with aldrin on June 21 and all insects collected from a canvas under the tree. These counts produced 38 plum curculios and 29 apple maggot flies and many other insects including some predators and parasites. The treatment brought down three lace wing flies, *Chrysopa oculata*. No moths or Lepidoptera of any sort dropped to the canvas, a fact which has since been shown as important because of the complete failure of aldrin to control the Oriental fruit moth.

The rapid disappearance of aldrin dust from the trees in the Lewis orchard indicated only that it might be useful for very late treatments, perhaps the last part of August.

Table 13. Effect of sticker on methoxychlor-captan-malathion mixture for control of apple maggot, 1955

Treatment	Ratio of picks to drops at harvest*	Clean externally	With maggot injury when cut Plot 1	Plot 2	With conspicuous residue at harvest
	Per cent	*Per cent*	*Per cent*		*Per cent*
1. Standard mix	27.4	90.4	72.3	68.5	5.0
2. Standard mix with sticker (2 less sprays)	46.8	81.1	88.1	60.4	0.4
3. Standard mix with sticker (same number of sprays as 1.)	21.2	93.4	46.0	43.9	30.8

*A measure of maggot control because infested apples drop prematurely.

Table 14. Effectiveness of sprays for control of apple maggot applied June 29 and July 20, Burton orchard, 1951

Spray Combinations	McIntosh
	Per cent damaged
Ferbam and sulfur (no insecticide)	24.6
Lead arsenate with	
Ferbam and sulfur	8.0
Thiram	6.5
Thiram and Crag 341	5.9
Methoxychlor with	
Lead arsenate, ferbam, and sulfur	5.4
DDD, ferbam, and sulfur	6.6
Ferbam and sulfur	5.4
Check, no treatment	82.5

Orchard spray tests

What controls of the apple maggot are we actually getting from completely non-arsenical sprays? Experiments over a period of years again indicate satisfactory control in our Burton orchard plots. Some of the results are given in Tables 11, 14, 15, 17 and 18.

From the 1950 to 1952 Burton orchard experiments at least it would appear that there has been very little difference in maggot control between arsenical and non-arsenical sprays. Chlordane, chlordane-DDD, methoxychlor, and methoxychlor-TDE (DDD) were all reasonably near to the protection afforded by lead arsenate. It still remained to be proved whether we could do the job easier with CS 674, dieldrin, or EPN and whether controls can be improved by later sprays or dusts or if we can do enough good by ground sprays to pay for the extra materials.

The 1953 experiments (Table 15) tested on McIntosh gave better results from organic chemicals than was obtained with arsenate of lead. August and September were relatively dry in that year compared with 1954 and 1955. In 1954 and 1955 control with lead arsenate was almost, if not quite as good, as with the organics. Tables 17 and 18. These results could possibly have been predicted from examination of washing tests. The same differences were apparent in 1954, Table 13, with close to normal rainfall, but in 1955 with above normal rainfall after August 15 lead arsenate was, if anything, superior.

Do adhesives affect maggot control? The experiment (Table 13) seems to show that under conditions prevailing in 1955, maggot-infested fruit could be reduced as much as 25 per cent. The sticker employed in this case was bentonite-skim milk. However, there was a residue differential of 25.8 per cent corresponding closely with the percentage improvement. This may be purely a coincidence, but is interesting nevertheless. Heavy residues, however, must be taken into consideration from a marketing standpoint, which means that other combinations leaving less residue must be considered.

Cause of late fly activity

There are several possible reasons why fly activity has continued later than usual during recent years: first, later emergence of the flies themselves; second, continued favorable weather, absence of early frosts or cold weather and heavy August rains to remove sprays; third, a possibility, not yet proven, lies in resistance of the flies to phosphates, chlorinated hydrocarbons, or lead arsenate; and fourth, destruction of natural enemies, which does not seem to be important for maggot though reduction of diseases from soil disinfection by fungicides may be a possibility.

Taken in order, later emergence frequently occurs for late varieties as shown in Fig. 4. It becomes important here to apply insecticides later to late varieties, or if the varieties are mixed, later sprays of high volatility or low mammalian toxicity on earlier varieties. Trap catches in 1956 followed the emergence curve for Baldwin given in Figure 4.

Dry or wet weather needs consideration in view of results shown in Tables 16 and 17. For example, heavy rains of 1955 removed sprays in late August so that wherever infestations nearby occurred, and flies moved in after spray removal, infestations were heavy. Early frosts are effective in preventing infestations in late varieties. Wherever these occur, infestations are much lighter. Early frosts in 1956 may have been helpful in reducing the infestation in that year.

Resistance of flies to such chemicals as DDT or various phosphates has not been proved, but is nevertheless a possibility.

Destruction of natural enemies such as ants or spiders is certain from ground studies in 1954 and 1955. The reduction of disease organisms within the soil where maggots pupate is another possibility not as yet investigated.

Trap studies

In order to trace, if possible, fly activity in the different plots, a trap (shown in Figure 5) containing 10 per cent ammonium acetate[1] was utilized. Traps placed

[1]Other baits have been devised: see Hodson 1948 and McPhail 1939.

Table 15. Effectiveness of sprays for control of apple maggot applied June 30 and August 5, Burton orchard, 1952

Spray Combinations	McIntosh	Baldwin
	Per cent damaged	
Ferbam and sulfur (no insecticide)	17.4	46.0
Lead arsenate with		
Ferbam and sulfur	7.8	16.3
Captan	0.9	15.2
Dichlone	4.5	13.0
Glyodin	8.5	16.1
Methoxychlor with DDT, ferbam, and sulfur	9.1	12.7
1189 with ferbam and sulfur	6.7	9.5
Methoxychlor with dithane	1.0	15.2

Table 16. Effectiveness of sprays for control of apple maggot, picked fruit, Burton orchard, full spray schedule, 1953

Spray Combinations	McIntosh
	Per cent damaged
Methoxychlor with	
DDD and manzate	2.0
DDD and captan	3.1
Dilan with DDD and ferbam	3.4
Black Leaf 253 with dichlone and ferbam	4.9
Lead arsenate and captan	16.7
Dilan, DDD, and captan	17.4
Check, no treatment	100.0

on the south side of the tree, in the sun, appear to offer data of value in determining (a) when flies are active, or (b) the length of residual action after sprays. It was found by this method in 1955 that the greatest number of flies were caught between July 14 and 17 (spray applied July 18) and between August 2 and 3 (sprayed August 4). It was apparent also that flies returned to traps sooner after such sprays as malathion and methoxychlor than after lead arsenate. In the latter case flies did not reappear in the traps following lead arsenate July sprays for 16 days whereas following Black Leaf 253 (DDT-parathion) they reappeared in 6 days, diazinon in 3 days, malathion in 16 days, and methoxychlor in 16 days. Following August sprays, flies reappeared in methoxychlor trees almost immediately (2 days), malathion 30 days, lead arsenate 41 days. While these figures would be taken with considerable reservation, they tend to show differences in different insecticides which may be important. The fact that flies did not reappear in traps placed in malathion treated trees as soon as other organic insecticides has important bearing on control. Laboratory tests to date for repellancy have been negative.

Traps are also useful in showing the frequency needed to keep trees free of flies. So far, malathion and lead arsenate have given the longest relief but further studies are necessary before we can be sure. The studies do not correspond fully with field experiments reported in Table 17, but it is interesting to see that the greatest fly activity in our orchard came between July 14 and August 4, and also that flies were caught in the traps as late as October 3. This is a different picture from 1954 when none was caught after August 23, or 1956 when none was caught after September 10. It illustrates well the differences from season to season.

Based on our experience, the following interval between sprays in midsummer appears to be advisable, dependent in part on rainfall:

Lead arsenate	14 days
DDT	10 days
Malathion	10 days
Methoxychlor	10 days
TEPP	7 days
Parathion	7 days

Discussion

From the laboratory tests of 1949-55 it seems that the best insecticides for maggot control included EPN, Black Leaf 253, CS 674, and dieldrin. Both CS 674 and dieldrin can be eliminated because of residue tolerances. Lead arsenate could be useful in view of its adhesion though not from speed of action. Of these, EPN, Black Leaf 253, and lead arsenate have been tested at Mt. Carmel and the best performance of lead arsenate has been in years of heavy rainfall. In 1956 EPN was about equal to combinations of methoxychlor-malathion. Late applications, August 16, were beneficial from the standpoint of control. EPN cannot be used on McIntosh or related varieties because of tree injury.

There is some evidence both in laboratory and field tests as given in Table 13 that adhesives improve control, but use of them in late season becomes difficult because of residues. Late sprays of methoxychlor-captan or methoxychlor-malathion left visible residues on McIntosh and Cortlands even after one month, conspicuous residues on Baldwin after two months.

The botanicals or insecticides of plant origin have a low order of effectiveness, as well as poor adhesion so that they must probably be expected, as evident from ryania field tests in 1954 and 1955, to give poor results unless continued perhaps to within a few days of harvest. At the same time they should be applied frequently enough to poison flies migrating in from outside. It would certainly be better to supplement these insecticides somewhere with more efficient toxicants.

Indications from the 1955 season in which rather poor control was obtained from all sprays, are that later sprays may be necessary in such years. If so, what chemicals will give the desired kill and at the same time avoid excess residues? For late sprays the main possibilities are malathion, TEPP, or possibly diazinon. Methoxychlor adhesion in 1956 prevented infestations but left conspicuous residues. Spreaders are indicated. The performance of lead arsenate in 1955 when it was removed by rain shows a need

Table 17. Effectiveness of sprays for control of apple maggot, picked fruit, Burton orchard, full spray schedule, 1954

Spray Combinations	McIntosh	Gravenstein
	Per cent damaged	
Methoxychlor with		
TDE, glyodin, and captan	0.5	15.6
TDE, captan, and malathion	0.5	21.9
Black Leaf 253 and glyodin	2.1	30.8
Diazinon, LO, and 738	2.2	....
Parathion and dithane	4.6	32.3
Lead arsenate, malathion, and captan	7.2	26.9
Ryania and glyodin	8.5	33.6
Check, no treatment	....	57.4

Table 18. Effectiveness of sprays for control of apple maggot, picked fruit and drops, Burton Orchard, full spray schedule, 1955

Spray Combinations	McIntosh	Gravenstein
	Per cent damaged	
Malathion with		
Captan	22.2	26.5
Captan and glyodin	29.8	30.6
Lead arsenate with		
Captan	22.8	26.0
Captan and dieldrin	13.8	21.6
Methoxychlor with captan	25.1	15.5
Ryania with rotenone, captan and glyodin	27.5	16.5
Black Leaf 253 and captan	21.4	....
Check, no treatment	very high	62.9

for later sprays, even with that insecticide.

Fungicides such as Karathane have some killing action for apple maggot flies. Its true value in spray combinations has not yet to be determined, however.

As shown by bait traps in 1955 and 1956 efforts in this field are productive in showing whether late activity is occurring and whether late applications in August or early September are required. The continued late activity of flies in 1955 would indicate that storms such as occurred in that year have little effect on fly activity except to remove insecticides from the trees. Traps also give an index of the needed interval between sprays.

The cost of sprays is a paramount consideration but should probably be tied to effectiveness since loss of even a few bushels per tree would easily cut the difference between two sprays so that no actual saving would occur.

From our experiments to date it would appear that lead arsenate is more effective in wet periods, and the quicker acting insecticides more effective in dry weather. Of the ones tried as foliar sprays, malathion, DDT, and Black Leaf 253 (parathion, DDT) appear to be the more promising. Dieldrin or possibly endrin for ground cover sprays are effective in preventing fly emergence and as stop-gap aids are worth considering, especially when the orchard had a heavy infestation the preceding year. They cannot be expected to prevent migration of flies from nearby unsprayed trees, nor to provide much protection the first year with heavy infestations.