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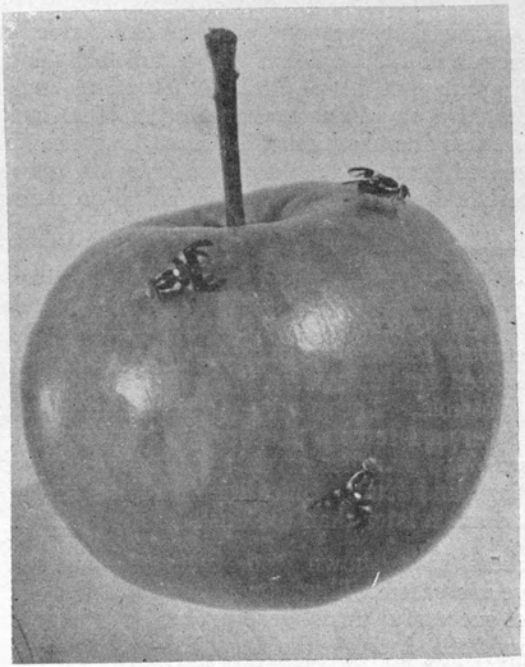

Adult flies of the apple maggot, one of Connecticut's most important fruit insects.

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APPLE maggot flies (*Rhagoletis pomonella* Walsh) occasionally remain in Connecticut apple orchards until picking time, necessitating extension of the control season. The continuation of the regular arsenate of lead sprays is undesirable much after the first of August, since they may leave poisonous residues on the fruit. Rotenone dusts, on the other hand, may be safely applied much later, because they are relatively harmless to human beings.

Experiments with various rotenone preparations derived from derris and cubé root were begun in 1936, when it was found that the dusts were quite effective in killing maggot flies. Field observations made shortly after application indicated a rapid destruction of the flies, but a rather short period of effectiveness due to action of light on the rotenone. Experiments were then started to extend the lasting qualities of the rotenone by the addition of materials designed to prevent chemical breakdown.

Jones, Campbell, et al. (1) proved that lampblack mixed with rotenone lengthened its period of effectiveness. By screening out ultraviolet light, this material cuts down the action of sunlight on the insecticide. The poison may eventually be destroyed before the fruit is harvested. However, an objectionable sooty residue remains from the lampblack. Iron salts are also known to screen out ultraviolet light, so we tried clays and slates as high in iron as possible. These were effective over a longer period than lampblack and other non-ferrous carriers. Moreover, the pink or reddish dusts made from clays or other carriers containing iron oxide are inconspicuous on foliage and fruit. Since their residues are not objectionable, they may be used much later than the dusts containing lampblack.

Various workers have shown, too, that rotenone combinations with pyrophyllite give increased killing power over combinations with ordinary clays. Our first successful dusts were prepared with pyrophyllite and oil, the latter being added to increase the deposit and effectiveness (3). During 1942 we tried a mixture prepared with red clay containing iron oxide, to which oil was added. However, red clays apparently absorb the oil much more completely than does the pyrophyllite, and the drift of the dust away from the trees is consequently greater. As might be expected, this fact, as well as the probably decreased efficiency of rotenone in clays, as demonstrated by Wilson (3) and Turner (2), prevented any marked improvement in maggot control.

Because the war has interrupted supplies, further work is being suspended until rotenone-bearing insecticides are more readily available. However, our more important experiments to date are described herein as a progress report on the usefulness of rotenone dusts for maggot control in Connecticut orchards.

Laboratory Experiments

Laboratory experiments were started in 1936. The methods used consisted of dusting or spraying green apples about 1½ inches in diameter and hanging them in the top of small glass-front cages. In some of the tests, a count of dead and live flies was made daily, in others less regularly. A second method consisted of dusting lantern slides with insecticide in a settling tower and placing them in a small cage with glass front and back. The slides were placed at the rear of the cage which was turned to face the light. In flying to the light the flies came in contact with the insecticide and could be observed through the glass front. In these tests counts were made more than once a day because the action was rapid. All toxicity experiments were conducted in a room held at 75° to 76° F. and approximately 60 per cent relative humidity.

Table 1 gives some of the tests with apples, as described. It was apparent that .75 per cent rotenone dust gave the best kill, but that a number of other materials, including lead arsenate, calcium arsenate, basic zinc arsenate, cryolite and phenothiazine, prevent oviposition by the flies in the apples.

TABLE 1. LABORATORY EXPERIMENTS IN CONTROL OF APPLE MAGGOT FLIES, 1936–37

Material	Spray or dust	Number of tests	Number of females used	Per cent mortality in 20 days	Egg punctures per female
Derris root (4% rotenone)	Spray[1]	3	104	90.9[2]	.68
.75% rotenone (commercial dust)	Dust	3	134	100.0[3]	.18
Lead arsenate	Spray[1]	4	82	84.1	3.3
Calcium arsenate	Spray	2	40	60.0	4.8
Basic zinc arsenate	Spray	2	45	71.1	3.7
Phenothiazine	Spray	2	59	57.6	7.9
Check	No spray	3	56	19.6	40.7

[1] Dilution except for dust—3 gms. poison, 3 gms. wheat flour in 800 cc.
[2] Mortality 100 per cent in 14 days in two tests.
[3] Mortality 100 per cent in 14 days in all tests.

During 1940 we experimented extensively with a special "stabilized" rotenone, making use of the lantern slide technique. Our results indicated that there was no significant difference in the kills obtained with stabilized and unstabilized rotenone exposed to ultraviolet light for the same length of time. This work has been reported previously.[1] At the same time, experiments were begun with iron hydroxide and clays containing iron for preventing the destruction of rotenone by ultraviolet. Results are shown in Tables 2 to 4. In these tests, dusted slides were exposed under an S_4 Mazda sun lamp at 12 inches for various lengths of time and then were placed in the cages.

[1] Station Bulletin **445**. pp. 341-342, 1941.

TABLE 2. COMPARISON OF THREE DUST FORMULAE FOR KILLING APPLE MAGGOT FLIES
Light Exposure 20 Hours, S_4 Sun Lamp

Formulae	Per cent mortality, 48 hours
No. 1 .5% rotenone[1], 90% pyrophyllite	0.
	0.7
	0.
	Average 0.2
No. 7 .5% rotenone, 90% ferric hydroxide	41
	78
	73
	100
	Average 73.0
No. 12 .5% rotenone, 80% pyrophyllite, 10% lampblack	46
	30
	41
	44
	Average 40.2

[1] Source, 10 per cent ground derris root containing 5 per cent rotenone.

Following the experiment which indicated the value of ferric hydroxide for preventing breakdown of rotenone, we made a comparison of pyrophyllite, and clays and slate dusts containing 6 to 8 per cent iron oxide. Different exposures to ultraviolet showed a distinct improvement for the red clay over a white dust (Table 3). A more extended experiment, using the formulae given in the same table, exposed for 8, 16 and 24 hours, gave similar results.

TABLE 3. COMPARISON OF PYROPHYLLITE (WHITE) AND HALL CLAY (RED) AS CARRIERS FOR ROTENONE, SUMMER 1940
Per Cent Mortality in 48 Hours

Formulae	Light exposure			
	4 hours	8 hours	16 hours	24 hours
No. 1 .5% rotenone, 90% pyrophyllite	92.5	86.9	20.1	10.1
No. 15 .5% rotenone, 90% Hall clay	96.1	92.2	61.5	62.8

To determine further the amount of destruction by the S_4 sun lamp, different concentrations of rotenone were tried in pyrophyllite and Hall clay (red). Fly mortality after the dust had been exposed to light for 24 hours was approximately the same for the .5 per cent rotenone with pyrophyllite and the .25 per cent with Hall clay; and also for the 2.0 per cent rotenone with pyrophyllite and the 1.0 per cent with Hall clay. In other words, red clays were about twice as effective as pyrophyllite in preventing breakdown under the sun lamp.

Chemical analyses, by Dr. H. J. Fisher of this Station, gave 38.6 per cent reduction in rotenone for Hall clay and 57.3 per cent for pyrophyllite

after 24 hours' exposure to the sun lamp. This represents a difference of 28.7 per cent in favor of the red clay.

Continuing this work in 1942 with red clays and red slates, we confirmed previous results. The superiority of dusts containing iron for preventing breakdown by ultraviolet light was even more apparent than in preceding tests. See Table 4.

TABLE 4. COMPARISON OF TALC AND RED CLAY AND SLATE FOR PREVENTING BREAKDOWN OF ROTENONE BY ULTRAVIOLET LIGHT

All Mixtures .5 Per Cent Rotenone[1]

Material	Weight on slide, in grams	Per cent mortality in 48 hours	Sun lamp exposure hours
Red clay[2]	.0054	100	24
Red clay	.0108	100	24
Red clay	.0120	100	24
Red slate	.0073	100	24
Red slate	.0118	100	24
Red slate	.0147	100	24
Talc (white)	.0095	16	24
Talc (white)	.0156	0	24
Talc (white)	.0198	22	24
Red clay[2]	.0060	100	0
Red slate	.0070	100	0
Talc	.0080	100	0
Talc	.0098	100	0
Check—no dust	——	16	—

[1] Material dusted on 3¼ x 4 inch slide, placed under the ultraviolet lamp and then used as a window in a small cage.
[2] Obtained from the Southeastern Clay Company.

Field Experiments

Methods

In these experiments a power duster was used, and dusting was done in the morning between 6 and 9 o'clock. During the later experiments attempts were made to apply the dust following storms. This was made possible by frequent consultation of weather maps and reports. Trees were dusted from both sides, and the ground underneath was also covered. Intervals of 10 days to two weeks between applications were employed for the most part. The Burton orchard was sampled from the trees, but the drops were collected and samples obtained from the collected fruits. In the Townsend orchard samples were taken from all fruit after it was harvested. This was done as carefully and systematically as possible. All samples of fruit were cut open.

Results

In the Shepard orchard during 1937 commercial rotenone dusts, with and without sulfur, gave rather poor control of the maggot, though under circumstances where any control was difficult. The trees were very large

and there was a source of reinfestation not far away. These circumstances, together with the employment of a dust with clay filler, were probably responsible for the poor showing in control.

During 1938 experiments were started with the same insecticide at the Burton orchard in Mount Carmel where we had found a row of Gravensteins heavily infested the previous year. The season was very wet and, although the control from use of rotenone dust did not come up to expectations, there was evidently some reduction in injury. This work was continued in 1939 (see Table 5 for results and formula) making use of the oil-pyrophyllite-rotenone mixture, with the result that the picked fruit was practically clean (3.3 per cent infested) and the drops fairly so (21.4 per cent). Only four applications were made in 1939.

TABLE 5. APPLE MAGGOT CONTROL, BURTON ORCHARD, MOUNT CARMEL
Variety, Gravenstein

Treatment	Year	Kind of fruit	Per cent injured by maggot
.5% rotenone-oil dust	1938	Drops	37
4 applications	1938	Picked	16
.5% rotenone-oil dust	1939	Drops	21
4 applications	1939	Picked	3
.5% rotenone-oil dust	1940	Drops	26
5 applications	1940	Picked	7
No treatment for maggot	1941	Drops	46
	1941	Picked	44
One lead arsenate maggot spray	1942	Drops	36
	1942	Picked	6

All dusts were rotenone-oil-pyrophyllite except those in 1938. 4 per cent white lubricating oil (80 visc.) was used. Derris or cubé were used as sources of rotenone.

TABLE 6. APPLE MAGGOT CONTROL WITH .5 PER CENT ROTENONE-OIL DUST, TOWNSEND ORCHARD, WESTWOODS, 1938-42

Tree	Variety	Per cent injured by maggot			
		1939	1940[1]	1941	1942
B2	Cortland	94.0	86.6	40.0	41.6
B5	Cortland	97.0	61.0	31.0	12.0
B9	Cortland	97.0	70.0	26.5	12.0
B13	Cortland	99.0	70.0	28.8	12.0
B17	Cortland	99.0	74.0	26.6	16.0
L	Stayman Winesap	—	99.5[2]	8.8	3.2
Nearby farm	McIntosh	—	—	97.8	—

[1] Dusting begun in this year.
[2] No maggot treatment.
Note: Five dusts in 1940 approximately one week apart, .5% rotenone.
Four dusts in 1941 approximately two weeks apart, .5% rotenone.
Five dusts in 1942 10 days to two weeks apart, .5% rotenone.

In 1940 we used the same materials but made five applications instead of four. The drop fruits showed 26 per cent infestation by maggot, and

the picked, 7 per cent. Nineteen forty was a bad year for maggot. The following year, 1941, no maggot sprays or dusts were applied to the row, and 46 per cent of the drops and 44 per cent of the picked fruit was infested.

It is evident from this experiment that rotenone-oil-pyrophyllite dusts reduced the maggot infestation considerably. However, a return of the flies followed shortly after the applications, and it was necessary to give several treatments to secure the desired results.

In 1939 we started work in a heavily infested orchard in Westwoods. Here a row of Cortlands, within 100 yards of infested trees, was selected, and a count was made of the fruit infestation at harvest. The apples from different trees varied from 94 to 99 per cent maggoty. They were dusted in 1940, the treatment including a row of Baldwins and other varieties on either side. Oil-pyrophyllite dust, carrying .5 per cent rotenone, was used. The reduction in infestation, while not great, was definite and the fruit averaged 25 per cent less maggoty than in 1939. The treatment was continued in 1941, and reduction in the infestation over 1939 averaged 66.6 per cent. The following year, 1942, the entire orchard was dusted. This year the infestation was 78.5 per cent less than in 1939. During 1940 and 1941 check counts were made of other varieties in the same orchard or in a nearby unsprayed orchard. These counts, given in Table 6, indicated that a high level of infestations continued in untreated fruit during 1940 and 1941.

From these, as well as the Burton orchard experiments, it is evident that rotenone dusts have a definite value for controlling the apple maggot. In the course of the experiments it was found that such treatments could be continued to within a week of harvest without giving objectionable residues. However, in view of the fact that rotenone dusts, even on a pre-war basis, are expensive, it would appear for the present that treatments should be limited to orchards where flies remain on the apples until quite late—or after the season when it is safe to apply lead arsenate.

During the course of the experiments it was found that maggot dusts, as employed from 1938-42, have little or no effect in preventing outbreaks of the European red mite, but July applications apparently have some value in killing apple leafhopper adults. Our 1942 experiments included some tests with rotenone-DN dusts combined. Results were not satisfactory and additional studies of these combinations are needed.

Conclusions

Rotenone dusts at .5 per cent combined with oil-pyrophyllite carrier have reduced injury from the apple maggot in two experimental orchards during the years 1938 to 1942. Previously, cage tests indicated that rotenone dusts are very effective killing agents for the maggot flies and destroy them much more rapidly than lead arsenate. Rotenone dusts used in the field lose their toxicity in four or five days, judging by the reappearance of maggot flies following applications.

Laboratory experiments indicate that clays and slates containing iron slow down the destruction of rotenone by ultraviolet light. Rotenone dusts mixed with carriers containing iron are practical because the residues left on the fruit are inconspicuous.

Field tests indicate that the rotenone mixtures used have little value for control of the European red mite but have apparently reduced trouble from the white apple leafhopper.

Because of the expense involved, rotenone dusts for maggot control for the present should probably be used only when it is too late in the season to apply arsenate of lead safely.

Literature Cited

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