

THE TOXICITY OF COMBINATIONS OF NICOTINE,
UNDER MICHIGAN CONDITIONS, TO THE TREE AND
TO THE CODLING MOTH, Carpocapsa pomonella,
Linn.

THESIS

Submitted to the faculty of Michigan State
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degree of Doctor of Philosophy.

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1936

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INTRODUCTION

"The codling moth destroys annually more than the State Agricultural College has cost, from first to last, and will, unless checked, destroy enough in 10 years to pay for our State Capitol." - Sec'y Thompson in Proc. Mich. Pom. Soc., 1874, p. 152.

The Development of Codling Moth Sprays in Michigan. The codling moth, Carpocapsa pomonella, attained the status of a major factor in apple production in Michigan about 1871, (1)* and since then efforts toward its control have never ceased. In 1880 liquid insecticides were used to protect the fruit by A. J. Cook (6), who applied two sprays of London purple on May 25 and June 20, and achieved complete control. Paris green, aceto-arsenite of copper, used since 1876 for control of canker worm (4) was also suggested by him, in view of its use the previous season by J. S. Woodard at Lockport, New York, with excellent results.

Spraying was in general use by 1890 (5) and is still considered the only effective protection against codling moth damage. The schedule was enlarged about 1903 (33) to include summer applications against the second generation of codling moth. At the same time Pettit (33) mentioned the use of lead arsenate (17) for codling moth control, and cautioned growers against its adhesive properties, but the material by 1910 (15) was in general use.

The Limitations of Arsenical Insecticides. Lead arsenate has maintained its position as a satisfactory codling moth insecticide, but the adhesive properties responsible for

* Numbers in parenthesis refer to literature cited.

this finally created the problem which Pettit (loc. cit.) may have anticipated, namely the removal of harmful residues before consumption of the fruit. The toxicity of arsenical residues was considered in the Federal food and drugs act of 1906 (8), and a limit designated, but no serious problem existed until about 1926. By this time codling moth control in arid districts required repeated applications, and resulted in harvested fruit with many times the limit of arsenical residue, together with lead residues considered deleterious to public health. Federal tolerances necessitated the removal of these residues, or the substitution of insecticides which would leave no harmful residues at harvest. The increased cost of control with lead arsenate due to residue removal permitted more general recommendation of nicotine sulfate combinations for codling moth control, previously considered too expensive (26), and instigated a critical study of this material.

LITERATURE REVIEW

Nicotine * is an alkaloid insecticide which was first marketed in 1885 as Gold Leaf Tobacco Extract (16). It was used as a contact spray, often in combination with arsenicals, to control orchard pests, other than the codling moth.

Nicotine, as a sulfate containing 40% of nicotine, was first tested for codling moth control by De Sellem (7) in

* Nicotine, $C_{10}H_{14}N_2$, is the poisonous constituent of the tobacco plant, in which it exists in combination with malic and citric acids. It is a colorless, oily liquid soluble in water - - -. It rapidly oxidizes in contact with the air--. Organic Chemistry, Bernthsen and Sudborough, P. 590. 1930.

Washington in 1915 and 1916. It was subsequently tested in several states, including Michigan (30), where it was applied alone, or in combination with soap or lead arsenate with results which were somewhat erratic (27) though indicative of possible control.

The Nicotine-Oil Combination. Nicotine sulfate was first used in combination with oil (distillate emulsion) by Foster and Jones (21) for the control of pear thrips in California. Experiments in codling moth control in 1927 and 1928 were reviewed by Herbert and Leonard (26) and included tests of nicotine sulfate alone or in combination with casein spreaders or summer oil emulsions. De Sellem (26) obtained results with oil and nicotine which surpassed those of the arsenate of lead tests in 1927. In 1928 workers in Washington, Oregon and Idaho tested oil, nicotine and a combination of the two, and found inferior control with either used alone, but control comparable to the lead arsenate treatment when combined (26, 29).

Newcomer and Yothers in 1928 and 1929 (32) found nicotine sulfate an effective ovicide at a concentration of 1-800, and obtained good results in field experiments with a combination of nicotine sulfate 1-1600 and $\frac{3}{4}\%$ emulsified oil. They appreciated the necessity for retarding the volatilization of the nicotine to retain its toxicity long enough to act as an effective ovicide and larvicide for codling moth. They also tested sodium bisulfate, aluminum sulfate, glycerine and corn syrup with nicotine sulfate, none of which was as successful as the oil-nicotine combination. Newcomer and Yothers (loc.

cit. p. 24) analyzed the sprayed foliage for percentage of nicotine to study the duration of its activity, and studies on the use of oil-nicotine in the northwest by Leonard (18) during the same season included this work, although published first. The method of analyzing the sprayed foliage for persisting nicotine has since been a valuable index, and will be referred to subsequently.

Since 1930, when it was first tested by the Michigan State College Agricultural Experiment Station, the combination of oil and nicotine sulfate has ordinarily been accepted as a satisfactory substitute for lead arsenate in codling moth control, with the limitation that it must be applied more often (14) to counteract the volatilization. This condition has stimulated research for a combination which would retain toxicity long enough to permit correlating the renewal with the growth of the apple, as in the case of lead arsenate. To effect this, the volatilization must be extended 4 to 6 days longer than the oil and nicotine combination permits.

Nicotine Tannate. Nicotine tannate was prepared by J. M. Ginsburg in an attempt to develop nicotine as a stomach poison (24). This material was used to control codling moth in 1929 by Headlee, Ginsburg and Filmer in New Jersey (24), also by Newcomer and Yothers(32) in the Pacific Northwest. These experiments and later tests in New Jersey by Filmer (18) and Driggers and Pepper (10), and in Michigan by Hutson (20) indicate a toxicity and resultant codling moth control approximating the nicotine sulfate-

summer oil combination. No effective retention of toxicity for more than 10 days is shown by the analyses of applications (32, 18) and the occasional injury to the fruit and considerable discomfort to the men using the material (20) has reacted against its general adoption. Fixed Nicotine Compounds. Driggers and Pepper (10), in testing nicotine tannate in New Jersey, found a significant reduction in codling moth injury in the plot which received bentonite sulfur as a fungicide, and also obtained better results with nicotine sulfate and bentonite sulfur, or bentonite and soap, than with lead arsenate (11). They attribute to bentonite the property of "fixing" nicotine and point out the remarkably adhesive properties of bentonite-sulfur (11), and the marked increase in retention of nicotine, as shown by their analyses, was apparently due to these factors. Nearly twice as much nicotine was retained on the block receiving nicotine tannate and bentonite sulfur as on that sprayed with nicotine tannate alone. The toxicity to codling moth was also prolonged, as indicated by their laboratory tests.

EXPERIMENTAL THEORY AND OBJECTIVES

Michigan conditions justify the development of a codling moth insecticide which obviates the necessity of residue removal at harvest. The harvest period extends from mid-summer to late fall, and large quantities of fruit are moved by truck during this time, either to market or terminal storage facilities. The inclusion of residue re-

removal is not compatible with the marketing practice of many growers. Many prefer to use an arsenical substitute in their spraying program than to attempt residue removal from early varieties, or to invest in removal equipment for fall varieties.

It is well known that environmental changes affect insecticides as well as insects, and the established practice is to determine the local reactions of new insecticidal measures before their general recommendation.

These factors, therefore, were responsible for a program of studying, in Michigan, the various nicotine combinations elsewhere shown toxic to the codling moth and of developing a treatment suitable to our conditions. Materials were available for studying the effect of retention of nicotine in insoluble and non-volatile forms on codling moth control, in comparison to the soluble and volatile nicotine sulfate-summer oil combination. All experiments were to be compared with the control achieved by the lead arsenate schedule recommended for that area.

Another effect which must always be considered in testing insecticides is that of repeated applications of the material to the tree. This is further complicated by profound varietal differences. The various constituents of an insecticide must be relatively harmless to the fruit and foliage, not only individually, but in combination. It was, therefore, intended to compare any manifestations of fruit or foliage injury resulting from the experimental schedules.

EXPERIMENTAL PROCEDURE

Extremely variable weather conditions in 1934 and 1935, as well as changes in materials and schedules resulting from experience during 1934, necessitate the presentation of each year's experiments separately. Data from many points in the country were considered before the program for 1935 was assembled, and influenced the modification of materials apparently satisfactory here in 1934.

EXPERIMENTS IN 1934

The following experiments were designed to determine the relative value of nicotine sulfate in combination with bentonite, bentonite-sulfur, and summer oil in controlling a heavy codling moth infestation in a well managed commercial orchard. All tests were compared with the lead arsenate schedule as recommended by the Michigan State College Agricultural Experiment Station for this area. In addition to the insecticidal efficiency, data were desired on the relative toxicity of the schedules to the fruit and foliage.

Experimental Conditions. The orchard in which these experiments were conducted is located ten miles from Benton Harbor, in Berrien County, and is owned by C. C. Kniebes. In this area there are normally two full broods of codling moth, and the mean yearly rainfall is 32.31 inches. The location is exceptionally well suited for apple production. A large proportion of this area is devoted to summer apple production, and the majority of this fruit is marketed in Chicago, often delivered by truck. Removal of residues is not readily adapted to these varieties, nor to the marketing practices.

Efforts to keep arsenical and lead residues within established tolerances by curtailing applications, particularly on summer varieties, had permitted the development of a codling moth population of epidemic proportions in many orchards by the season of 1933.

The experimental plots were located in a block of twenty-three year old trees, and included McIntosh, Jonathan, Wealthy, Yellow Transparent and a few trees of Grimes Golden varieties. The orchard is planted in a strong, heavy soil, and the trees have been maintained in excellent vigor for many years.

An index to the population of codling moths present was afforded by examination of the corrugated paper bands, treated to kill larvae pupating in them, which had been placed on the trees in 1933, after the loose bark under which pupation normally occurs had been removed. One hundred bands, taken at random from trees which had borne a crop in 1933, were found to contain an average of 150 larvae per band. A further index of the population is afforded by the catch of moths in pots containing an attractant which were hung in several trees in 1934. The number of moths recorded from these pots during the peak flight on June 1st and 2nd averaged slightly over 50 for each of nine pots on each day.

Experimental Methods and Materials. The equipment available for application of the experimental schedules consisted of a horse-drawn John Bean Company sprayer, capable of delivering about twelve gallons per minute with a pressure of 225 to 300 pounds.

The method of application deferred somewhat to the limitations of the equipment, but entirely satisfactory coverage of the trees was obtained by the use of two single nozzle spray guns. One operator sprayed from the ground, assuming responsibility for coverage on the lower half of the trees, and the entire inside portion. The other meanwhile completed the upper portion, working from the top of the sprayer. This method was considered the best way of covering some of the largest trees, spreading as much as 36 feet, and pruned wide and flat at the top. The rate of application was increased as the foliage developed, with a maximum application of about 35 gallons per tree on the largest varieties, and an average of 20 gallons throughout the season. The six experimental schedules used are outlined in Table I.

TABLE I

CODLING MOTH PROJECT

KNIEBES ORCHARD, BERRIEN COUNTY

MICHIGAN

1934

Schedule of Cover Sprays

1. 1st Brood: Kolofog, 6#; B. L. 40, $\frac{3}{4}$ pt.; S.A.S., 2#.
2nd Brood: B. L. 155, 5#; 14 day interval.
2. 1st Brood: Flotation sulfur, 5#; B. L. 155, 5#.
2nd Brood: B. L. 40, $\frac{1}{2}$ pt.; Orthol-K, $\frac{1}{2}$ gal., or
B. L. 155, 3#. 7 day interval.
3. 1st Brood: B. L. 155 BX, 3#; Orthol-K, 1 gal. in peak.
2nd Brood: B. L. 155 BX, 3#; Orthol-K, $\frac{1}{2}$ gal.
10 day interval.
4. 1st Brood: B. L. 155 BX, 5#; Orthol-K, $\frac{3}{4}$ gal. in peak.
2nd Brood: B. L. 155 BX, 5#; 14 day interval.
5. 1st Brood: Lead arsenate, 3#; Lime, 4#.
2nd Brood: Same
10-14 day interval.
6. 1st Brood: Lead arsenate, 3#; Lime, 4#; B. L. 40, 1 pt.
7 day interval.

In testing various insecticide combinations for codling moth control, it is customary to maintain a uniform treatment of all trees throughout the pre-blossom period, and usually the calyx spray is common to all, as in this instance, lead arsenate and lime sulphur being indicated for all plots. In the first cover spray, ten days later, lead arsenate was used throughout but the fungicide, except on schedule 4, was changed to flotation sulfur.

The materials tested in the schedules for first brood control should be described. A test of bentonite sulfur, nicotine sulfate, and sulfo-ammonium soap was included, this being one of the most successful in New Jersey experiments. (10, 11). The bentonite sulfur used is manufactured by the Niagara Sprayer and Chemical Company, under the name of "Kolofof." According to Doane (9), "It is a colloidal sulfur obtained by fusing the colloidal material bentonite with ground elemental sulfur. . ." The nicotine sulfate used in all cases was "Black Leaf 40," manufactured by the Tobacco By-Products and Chemical Corporation. The schedule was designed to test bentonite nicotine sulfate (B. L. 155) with flotation sulfur (schedule 2), for a fungicide is often necessary through most of the season, because of inefficient scab control in the pre-blossom sprays.

B. L. 155 BX represents a minor variation from the bentonite-nicotine sulfate combination used in B. L. 155, presumably increasing its efficiency.

The summer oil used in all schedules was Orthol-K medium, but the supply broke down on July 21, and Ansbacher medium was substituted until a fresh supply of Orthol-K could be obtained

on August 6.

The materials used subsequent to the first cover spray, together with the actual date of application, are included in Table II.

TABLE II

SPRAY SCHEDULE - KNIEBES ORCHARD - BERRIEN COUNTY, MICHIGAN
1934

Date	Plot 1	Plot 2	Plot 3
Calyx	2 Gals. Lime Sul.	2 Gals. Lime Sul.	2 Gals. Lime Sul.
15-18 May	3# Lead Arsenate	3# Lead Arsenate	3# Lead Arsenate
10 day	5# Flotation Sul.	5# Flotation Sul.	5# Flotation Sul.
31 May	3# Lead Arsenate	3# Lead Arsenate	3# Lead Arsenate
21 day	6# Kolofog; $\frac{3}{4}$ pt.	5# B. L. 155	3# B. L. 155 BX
5 June	B. L. 40; 2# S.A.S.	5# Flotation Sul.	
28 day	6# Kolofog; $\frac{3}{4}$ pt.	5# B. L. 155	3# B. L. 155 BX
12 June	B. L. 40; 2# S.A.S.	5# Flotation Sul.	1 Gal. summer oil
35 day	6# Kolofog; $\frac{3}{4}$ pt.	5# B. L. 155	
19 June	B. L. 40; 2# S.A.S.	5# Flotation Sul.	
45 day	6# Kolofog; $\frac{3}{4}$ pt.	5# B. L. 155	3# B. L. 155 BX
28 June	B. L. 40; 2# S.A.S.	5# Flotation Sul.	
<u>SECOND BROOD</u>			
7 July	5# B. L. 155 BX	$\frac{1}{2}$ pt. B. L. 40	3# B. L. 155 BX
		$\frac{1}{2}$ Gal. summer oil	$\frac{1}{2}$ Gal. summer oil
14 July		$\frac{1}{2}$ pt. B. L. 40	
		$\frac{1}{2}$ Gal. summer oil	
17 July			3# B. L. 155 BX
			$\frac{1}{2}$ Gal. summer oil
21 July	*1 pt. B. L. 40		
	1 Gal. summer oil		
23 July	**	$\frac{1}{2}$ pt. B. L. 40	
		$\frac{1}{2}$ Gal. summer oil	
24 July	All Yellow Transparent	$\frac{3}{4}$ pt. B. L. 40; $\frac{3}{4}$ Gal. oil	
27 July			3# B. L. 155 BX
			$\frac{1}{2}$ Gal. summer oil
31 July	***	3# B. L. 155	
6 Aug.	** 5# B. L. 155	3# B. L. 155	3# B. L. 155 BX
	*		$\frac{1}{2}$ Gal. summer oil
13 Aug.		3# B. L. 155	
16 Aug.			3# B. L. 155 BX
			$\frac{1}{2}$ Gal. summer oil
20 Aug.	5# B. L. 155	3# B. L. 155	
27 Aug.		3# B. L. 155	3# B. L. 155 BX
			$\frac{1}{2}$ Gal. summer oil
* Ansbacher oil substituted for Orthol-K; burning on previously uninjured Grimes.			
** Delayed from 21st because of high temperatures.			
*** B. L. 155 substituted for oil-nicotine to prevent further injury to leaves burned by sulfur spray.			
** Orthol-K, fresh supply, substituted for the Ansbacher.			
*			

TABLE II

(Cont'd)

Date	Plot 4	Plot 5	Plot 6
Calyx 15-18 May	2 Gals. Lime Sul. 3# Lead Arsenate	2 Gals. Lime Sul. 3# Lead Arsenate	2 Gals. Lime Sul. 3# Lead Arsenate
10 day 31 May	2 Gals. Lime Sul. 3# Lead Arsenate	5# Flotation Sul. 3# Lead Arsenate	5# Flotation Sul. 3# Lead Arsenate
21 day 5 June	5# B. L. 155 BX		
8 June			3# Lead Arsenate 4# Lime; 1 pt. B.L. 40
28 day 12 June	5# B. L. 155 BX $\frac{3}{4}$ Gal. summer oil	3# Lead Arsenate 4# Lime	
15 June			3# Lead Arsenate 4# Lime; 1 pt. B.L. 40
35 day 19 June	5# B. L. 155 BX		
22 June			3# Lead Arsenate 4# Lime; 1 pt. B.L. 40
25 June		3# Lead Arsenate 4# Lime	
45 day 28 June	5# B. L. 155 BX		
29 June			3# Lead Arsenate 4# Lime; 1 pt. B.L. 40
<u>SECOND BROOD</u>			
3 July		3# Lead Arsenate 4# Lime	
7 July	5# B. L. 155 BX		
16 July		3# Lead Arsenate 4# Lime	
23 July	5# B. L. 155 BX		
24 July	All Yellow Transparent $\frac{3}{4}$ pt. B. L. 40, $\frac{3}{4}$ Gal. oil		
28 July		3# Lead Arsenate 4# Lime	
6 Aug.	5# B. L. 155 BX		
9 Aug.		3# Lead Arsenate 4# Lime	
20 Aug.	5# B. L. 155 BX		
23 Aug.		3# Lead Arsenate 4# Lime	

The schedules were applied to plots containing nine trees each. Each treatment was replicated three times, making a total of 27 trees in three locations from which to take results. The replications were arranged in a modification of the Latin square of R. A. Fisher (19), described by Hartzell (23) as the best method to overcome heterogeneity in field tests. The available area did not permit six nine-tree plots, without jeopardizing the randomization. Furthermore, it was desirable to confine lead arsenate schedules to the fall varieties, or summer varieties which would stand washing to remove spray residues. The arrangement of plots in relation to the varieties and to each other is indicated on Figure I.

Figure 1

Location of Plots and Count Trees
Kniebes' Orchard, Berrien Co., Mich.

m m m 5 m <u>m</u> m m m j	m m m 3 m m m <u>j</u> j j	m <u>m</u> m 6 m m m j j j	m <u>m</u> m 4 m m m j j j	<u>m</u> m m 5 m m m j j j
j j j 6 j j <u>j</u> w w <u>w</u>	j <u>j</u> j 4 j j j w w <u>w</u>	j <u>j</u> j 5 w <u>w</u> w w w w	j <u>j</u> j 2 w w w <u>w</u> w w	j <u>j</u> j 1 <u>w</u> w w w w w
w w <u>w</u> 3 t t t <u>t</u> t t	<u>w</u> w w 1 t <u>t</u> t t t t	<u>w</u> w w 6 w w w <u>t</u> t t	<u>w</u> w w 4 w w w t <u>t</u> t	w w w 2 <u>w</u> w w t t <u>t</u>
t t t 1 <u>t</u> t t <u>g</u> g g	t t t 3 <u>t</u> t t <u>g</u> g g	<u>t</u> t t 2 t t t <u>g</u> g g	m - McIntosh j - Jonathan w - Wealthy t - Yellow Trans- parent g - Grimes <u>x</u> - Count Tree O - Plot Number	

Environmental Conditions. Environmental characteristics affect insecticides as well as insects, and under extreme conditions the effectiveness of the schedule may be impaired by severe injury to the tree, or by excessive precipitation may be rendered ineffective. Seasonal conditions vary, making it necessary to consider the conditions under which the program was completed.

In these experiments schedules were closely followed, both as to timing and concentration of ingredients. A certain amount of injury to the foliage is expected when a spray is applied in hot weather, and in an experimental program these effects must be studied in the critical range as often as possible, to determine the reaction under extreme conditions. Yet it must be remembered that if such a temperature is reached only once in 50 years, no spray can be fairly expected to react normally, and a test then would be unfair, if a matter of twenty-four hours will bring normal temperatures.

The data on daily temperature and rainfall are presented in Table III. These data were collected by the nearest U.S. Weather Bureau station, approximately three miles away. Temperature records vary little from those prevailing at the orchard, but precipitation occurred several times at the Weather Bureau station that did not reach the orchard. These occasions are noted in Table III.

TABLE III

Temperature and Precipitation Records

Coloma, Michigan, 1934

Date	May		Pre- cip.	June		Pre- cip.	July		Pre- cip.	Aug.		Pre- cip.
	Temp. Max. Min.			Temp. Max. Min.			Temp. Max. Min.			Temp. Max. Min.		
1	75	50		104	70		85	65		97	59	
2	72	52		97	56		95	63		95	72	*.18
3	83	50		99	54		82	67	.12	85	62	
4	87	65		91	62		90	60		95	61	
5	80	61		94	70		87	60	*T	90	67	
6	85	53		81	61		86	62	*.07	84	65	*.18
7	76	55		81	55		85	52		95	66	*.02
8	80	50		94	52		88	63		100	66	
9	89	50	1.15	88	64		95	65		99	72	
10	85	62	T	85	62		97	72		95	72	
11	63	38		85	63		92	65	*.08	89	63	
12	63	31		76	46	.2	97	64		98	62	
13	64	48	.23	73	49		86	68		85	76	
14	62	42		83	53		90	62		89	53	
15	60	44		91	66		90	68		76	63	*.72
16	75	40		84	61		87	60		80	65	.08
17	86	53		93	62		92	60		86	63	
18	87	54		83	60	.1	97	65		95	65	
19	90	72		84	55		99	75		84	64	1.08
20	89	65		92	68		101	72		71	52	
21	92	70		88	65		106	71		80	50	
22	83	45	.72	75	53	*.22	101	77		78	64	
23	73	41		93	52		107	70		79	54	
24	69	47	.27	89	62	*.17	106	75		65	55	.42
25	69	35		84	62		103	76		73	51	
26	68	41		91	70		96	67		81	52	
27	73	45		90	67		85	63	*.06	80	54	
28	80	51		100	66		84	58		78	55	
29	82	53		96	74	*.08	74	58		70	42	
30	88	52		85	64		90	60		77	47	
31	97	62					94	53		78	57	
Mean	77.9	50.9		88.3	60.5		91.1	65.0		84.7	60.3	
Total			2.37			1.67			.54			2.68
Ave. (10 Yrs)			3.65			2.93			2.50			2.37
Deficiency (at orchard)			-1.28			-2.63			-2.38			-.79
* Indicates no precipitation at orchard.												

Results.

The Effect on Foliage. The extreme deficiency in moisture did not have any serious effect on the fruit, for the soil was admirably suited to withstand drought. Weathering of spray material was also reduced to a minimum, for spray coverages were renewed immediately following any precipitation. The injury to foliage was less than might have been expected during the extremely hot periods, probably because of the low relative humidity which usually prevailed. The primary injury which occurred was related to abnormally high temperatures which prevailed very early in the season, when foliage was tender, or to poor drying conditions during periods of high temperature under the heavy foliage of some varieties. Secondary injury followed where toxic materials were permitted to enter lesions from the primary toxicant, and in many cases caused the abscission of these leaves.

A study of the foliage injury resulting from these schedules was conducted. On June 27th the average number of leaves per spur from 300 spurs per plot was determined for each treatment. Wealthy and Jonathan varieties were selected as being most susceptible to injury of the varieties present (13). This gave a figure to be used as a base count. Counts were made on July 24th, September 11th, and October 12th, by the same method and on the same trees. From these data the percentage of leaf fall per plot was computed as an index of the relative injury to the leaves which most affect the bearing qualities of the trees. Non-bearing spurs were used, because no new leaves were produced on these after the base count. The results of these counts are included in Table IV.

TABLE IV

LEAF COUNTS - WEALTHY AND JONATHAN

KNIEBES ORCHARD, BERRIEN COUNTY, MICH.

1934

Plot No.	<u>June 27</u>	<u>July 24</u>		<u>Sept. 11</u>		<u>Oct. 12</u>	
	Leaves per twig	Leaves per twig	% loss	Leaves per twig	% loss	Leaves per twig	% loss
1	8.11	7.52	7.3	6.00	26.0	6.01	26.0
2	8.29	7.69	7.2	6.15	25.8	6.07	26.8
3	7.93	7.73	2.5	6.52	17.8	6.47	18.4
4	7.75	7.79	2.1	6.32	18.5	5.74	26.0
5	8.09	7.88	2.6	6.24	22.9	5.37	33.6
6	8.03	7.51	6.5	5.96	25.8	5.70	29.0
*1	8.59	8.10	5.7	6.20	27.8	5.95	30.7
2	8.26	7.13	13.7	6.20	25.0	5.90	28.6
3	7.88	7.28	7.6	6.53	17.1	6.26	20.6
4	7.90	7.71	2.4	6.52	17.5	6.20	21.5
5	8.28	7.89	4.7	5.92	28.5	4.68	43.5
6*	8.31	7.73	7.0	5.38	35.3	4.07	51.0
Plots 1-6 Wealthy				Plots*1-6* Jonathan			

Both plots receiving sulfur during the first brood show a considerable leaf fall by July 24th, more by September 11, then only normal loss. This was due to the application of sulfur during the hot weather in June, particularly on June 28th, when the last application was made. This type of injury was most serious on those trees receiving flotation sulfur, as indicated by the result of the July 24th count on Jonathans. The injury on trees of the same variety receiving Kolofog surpassed that from flotation sulfur by September 11th, because of injury resulting from an application of one per cent summer oil (with nicotine) four weeks after the last application of Kolofog on July 21st. This injury was typical of oil on sulfur, and indicated that the weathering of the bentonite-sulfur had been inhibited by the drought. The injury was further complicated on both Plots 1 and 2, receiving summer oil, by the fact that the penetration of oil through the leaf tissues injured by sulfur alone, caused them to fall. However, the primary injury by oil following bentonite-sulfur was decisively illustrated by a few Grimes trees, previously uninjured by sulfur sprays, which were severely burned immediately following the oil application four weeks later. The flotation sulfur application of June 28th had weathered sufficiently by July 7th to permit the application of one-half per cent oil (with nicotine) without injury except the oil penetration through old lesions. Spectacular leaf injury from sulfur and oil occurred on the new leaves of the new shoot growth, but is not indicated in Table IV.

Plots 3 and 4, receiving B. L. 155 BX (with oil in Plot 3, second brood) show the least leaf fall, and no injury was observed during the spraying. The data indicate a heavier leaf fall on Jonathans in Plot 3 by July 24th, probably due to the application of oil on the 16th, but no later injury is indicated.

Plots 5 and 6 may be considered together, since the agent causing leaf fall was lead arsenate in both cases. Even though lime was added in both plots as a corrective against injury, the leaf fall, which is especially characteristic of arsenical injury, surpassed that of any other schedule. This was particularly true during September, when the percentage of fallen leaves increased from 30 to nearly 50. It is interesting to note that the leaf fall continued from Plot 6 through the season, even though the applications ceased on June 29th.

In summarizing, it may be said that little or no injury resulted from applications of bentonite-nicotine, with or without summer oil. Applications of sulfur under existing weather conditions caused significant injury to the foliage, aggravated by any oil, because of penetration. In the case of bentonite-sulfur (Kolofog), residual sulfur caused primary oil-on-sulfur injury. Applications of lead arsenate caused foliage injury, with dropping, which increased as the season advanced, apparently related to the amount applied in a given period, rather than any weather factor. This was enhanced, doubtless, by the lack of rainfall.

The Effect on Fruit. Spray injury to the fruit was confined to that caused by sulfur applications during the hot weather. Beginning with the hot period during which the "10-day" application was made, a type of injury called "sunscald" was produced, not only in this orchard but in the whole region, whenever sulfur application preceded a hot period. In these experiments the "10-day" (after petal fall) application included 5# of flotation sulfur, except Plot 4, which received 2 gallons of liquid lime sulfur. The temperature during this application, on the 31st of May, was 97°Fahrenheit at the observation point three miles away. Some burning occurred on the foliage of McIntosh, Yellow Transparent, and other varieties. Fruit injury occurred on Yellow Transparent, Wealthy, and on Jonathan.

Later injury developed on Yellow Transparent and Wealthy from applications during June, particularly the one made on June 28th, when the humidity was slightly higher than when previous applications were made at comparable temperatures.

The injury to Wealthy included a stem end injury, causing many to drop before maturity, and injury to the exposed surface which caused the apples to crack. Lack of time prevented a count of fruit injury at harvest, but it was more apparent than significant.

The harvest of Yellow Transparents, however, occurred shortly after the injury became apparent, and before it was masked by growth of the fruit. The pickers were instructed to remove all these apples with the first pick-

ing. A certain proportion of injury was evident on all plots, due to the sulfur injury of May 31st, not exceeding .6% in any case. Additional injury due to the later sprays, as indicated above, increased this as much as 2% on the plot receiving flotation sulfur.

Codling Moth Control

The data on relative control were obtained from trees selected for their uniformity of bearing. In most cases two trees were selected in each replication, and, as two varieties were included in each replication, one tree of each variety was chosen. The exact distribution of count trees is indicated in Figure I.

All apples from each count tree were examined, and the number of clean or uninjured apples recorded. The apples showing codling moth injury were separated into two classes, those having injuries caused by unsuccessful attempts of entering larvae, usually called shallow entries or "stings," and those injuries made by larvae successfully escaping the spray film, usually called deep entries or "worms."

The apples removed during the thinning process were examined, but the injury was found to be negligible, and it was considered that the trees started on a uniform basis after they were thinned.

After thinning was complete, all dropped fruit from the count trees was examined and scored for injury at regular intervals, the totals being included with those of the picked fruit.

These data are presented in Table V. Schedule or

plot numbers correspond with Table II. Data presented in this table include results from four varieties, but omissions of some treatments on early varieties make direct comparison of all schedules impossible. As stated previously, the lead arsenate schedules are mostly confined to the later ripening varieties, because of difficulty of residue removal from summer apples.

TABLE V
 CODLING MOTH INJURY
 PER CENT ENTRIES
 KNIEBES ORCHARD, BERRIEN CO.
 1934

Plot No.	Type of Entry	HARVEST DATE			
		Yellow T. 17-31 July	Wealthy 22 Aug-5 Sept.	McIntosh 5 Sept.	Jonathan 12 Oct.
1.	Deep	1.68	4.47		16.25
	Shallow	1.70	3.53		14.83
2.	Deep	.42	5.06		10.82
	Shallow	1.38	4.92		12.27
3.	Deep	1.30	5.89	38.30	8.55
	Shallow	1.13	4.17	16.65	7.62
4.	Deep	2.18	9.64	45.83	8.85
	Shallow	1.82	5.19	12.50	10.67
5.	Deep		3.43	43.03	4.09
	Shallow		3.76	24.07	19.87
6.	Deep	1.32	5.76	36.18	24.80
	Shallow	2.62	6.88	13.47	21.53
Total examined		45,031	28,220	13,334	18,398

Extreme variation in the degree of control obtained on different varieties is outstanding. Three factors are responsible for this. Data presented here were collected over a period of three months, that is, counts were made on varieties harvested as the second brood codling moth was emerging, and continued at intervals until this brood was entering hibernation. During this time the codling moth population increased many fold, and the increased injury on successively ripening varieties reflects this. The factor of varietal susceptibility enters into the results obtained on McIntosh, known to be prone to heavy codling moth injury. In this case the effect was further aggravated by the fact that these extremely large trees, after three years of capacity crops of 30 to 35 bushels apiece, had set only one-third to one-half a crop. In anticipation of this they had not been pruned, and the dense growth interfered with effective spraying. The count trees, however, could not be said to have failed to bear an average crop, though some of the other trees did.

There being no striking contradictions in the control obtained, the variations in control serve to indicate the relative control under several conditions, and thus offset the disadvantage of being unable to collect the data from all varieties for direct comparison.

Relative Control, Yellow Transparent. The harvest of Yellow Transparent occurred during the emergence of the second brood moths, and almost no second brood injury is

included in data on this variety. Therefore, the first brood schedules may be evaluated by these data. Yellow Transparents are susceptible to codling moth injury, but the control obtained does not reflect this. The differences between plots are too small to be significant, but it must be admitted that the control was excellent. This was probably due to the fact that a seven day interval between sprays during the period of first brood emergence from June 5th to 19th was too short to demonstrate variations in materials applied. The retention of toxicity was more than seven days, though variations might have occurred under normal conditions of rainfall (28).

There was no variation in size which could be correlated with the spray treatment, but variations in finish were apparent. The plot receiving Kolofog showed considerable residue and a rough finish, and the plot sprayed with flotation sulfur and B. L. 155 showed, to a lesser degree, the same effect. The lead arsenate and B. L. 40 (nicotine sulfate) treatment had the best finish, though the finish on the B. L. 155 plot, having had two summer oil sprays with the B. L. 155, was nearly as good. Very little residue was apparent on the plot receiving five pounds of B. L. 155 BX.

The results obtained in the harvest of the Yellow Transparents thus tend to indicate that the start of the second generation of codling moth found the plots nearly equal in control, and that later variations are due more to the second brood spray schedules than to the first.

Relative Control, Wealthy. The next variety to be harvested was the Wealthy, bearing a heavy crop on relatively small trees. It is apparent that variation between the plots was developing, although the control had not suffered particularly. Plot No. 1, with B. L. 155 following Kolofog and B. L. 40, gave considerably better control than B. L. 155 BX straight through (Plot 4) both on a 14 day schedule. Plot 1 also gave slightly better control than Plots 2 and 3, which received a lighter application (Table II) at more frequent intervals. The standard lead arsenate schedule gave the best control. The size of the fruit again was normal for the season in all plots, but the finish of the fruit from the plots which had received sulfur sprays was inferior because of residue and injury resulting from a combination of sulfur and heat, not necessarily at the time of the application of sulfur. The plot receiving the B. L. 155 BX and summer oil had the best finish when packed. The lead arsenate plot had a heavy residue, with a trace of spotting in the color, due to the accumulation of the spray residue in drops. When picked the fruit was in excellent condition, but after washing it did not compare favorably with the other plots because of slight bruises.

Relative Control, McIntosh. The McIntosh trees were very large and had produced three heavy crops in succession, thus developing the heaviest population of codling moths in the orchard. They were not pruned in anticipation of a light set in 1934, and a light set occurred, making spraying difficult. Precautions were taken to obtain the best possible coverage when spraying this variety, but the control was poor.

Yields were sufficient to give significant figures, and the opportunity to study the materials under the most difficult conditions gave interesting results. The nicotine combinations gave decisively better control than the lead arsenate schedule, particularly Plot 3. This was apparent for several weeks before harvest. The lead arsenate plot showed a significant increase in the percentage of shallow entries as compared with the bentonite-nicotine combinations. This was apparently due to reduction in the codling moth population before the larvae attempted to enter the apples, for the total injuries, deep and shallow entries combined, may be considered the best index of the population or potential. Such a significant reduction in the number of total entries can only be due to effective ovicidal action in Plots 3 and 4, reducing the potential population.

Relative Control, Jonathan. The Jonathans, harvested five weeks later, were located beside the McIntosh, and observations indicated that they shared the heavier moth population incident to the conditions described. They were not pruned, in anticipation of a light set of fruit, but the count trees produced a normal crop. The data show a greater percentage of injury for this variety and resemble the results from the McIntosh in the relative control obtained by the different schedules. Again the lead arsenate schedule was surpassed in percentage of clean apples by Plots 3 and 4, receiving 5 pounds of B. L. 155 BX (plus summer oil in No. 3). Plot 2 gave slightly more clean apples than the lead schedule, receiving a frequent application of three

pounds of B. L. 155. Plot No. 1 dropped from second place to fifth, receiving B. L. 155 at 14-day intervals. Plot 6, receiving no second brood applications, gave very poor control.

Analysis of the proportion of shallow and deep entries in each treatment show that the lead arsenate schedule permitted the development of more shallow entries but less deep entries than any of the bentonite-nicotine combinations. Five times as many shallow entries as deep entries were scored against the lead arsenate schedule, while in the bentonite-nicotine schedules the proportion was nearly equal. The shallow entries in the plot treated with lead arsenate were for the most part very small, a condition partly resulting from the excellent coverage maintained in the absence of rains. The reduction in percentage of shallow entries in the case of the bentonite-nicotine combinations might well be correlated with a reduction in the moth population in these plots rather than a reduction of larval population, for the higher percentage of deep entries indicates poorer larval control than in the lead arsenate plots.

Discussion of Relative Control

Considering first the lead arsenate schedule, it is evident that while less deep entries usually resulted from this treatment than any other, the percentage of shallow entries materially reduced the percentage of clean apples, placing this schedule third in Jonathan and fourth in McIntosh.

Plot No. 1 gave good control while Kolofog and B. L. 40 were used, the control decreasing from 3.38% total injury to

31.08% as the season advanced, with the use of B. L. 155 at 14-day intervals, shallow and deep entries at all times being nearly equal.

Plot No. 2 gave very good control, 1.80% total injury with a weekly application of B. L. 155 during the first brood, and almost as good during the early part of the second brood, when one-half per cent oil-nicotine was used, followed by three pounds B. L. 155 at 7-day intervals, but the latter part of the season showed a considerable decrease in control, (23.09% injury on Jonathan), indicating that the concentration should have been slightly greater.

Plot No. 3 gave the best sustained control, receiving only three pounds B. L. 155 BX, with one per cent summer oil in the peak, for the first brood, and three pounds B. L. 155 BX with one-half per cent oil in the second brood. The early control was excellent, only 2.43% total injury on Yellow Transparents, and the control during the later part of the season was proportionately even better, only 16.17% total injury. The advantage may have been in the addition of the oil, although that concentration ($\frac{1}{2}\%$) is considered insufficient for control as an ovicide. Again, it may be due to the 10-day interval used in this schedule during the second brood, the oil helping to retain the coverage, and perhaps thus affecting the insecticidal efficiency of the B. L. 155 BX.

Plot No. 4 gave the poorest control on Wealthys, yet maintained nearly as good control on Jonathans, holding its position in relation to Plot No. 3. This plot receiv-

ed B. L. 155 BX at 14-day intervals for the second brood, giving five per cent less clean Jonathans than Wealthys, while Plot No. 1 received the same schedule of B. L. 155 and gave twenty-three per cent less clean Jonathans than Wealthys. This indicates an additional insecticidal efficiency for the B. L. 155 BX, and may explain the showing of Plot No. 3.

Plot No. 6 shows a control during the first brood and extending into the second brood which might be expected from such a heavy schedule during a dry season, but on varieties which ripened late the control was poor. This may be attributed to the growth of the apple and the weathering of the materials with a consequent reduction of coverage.

For convenience in comparing the season relation of the various treatments, charts have been prepared which compare the percentage of clean apples in each variety for each treatment with the lead arsenate schedule. These are presented in Figure II.

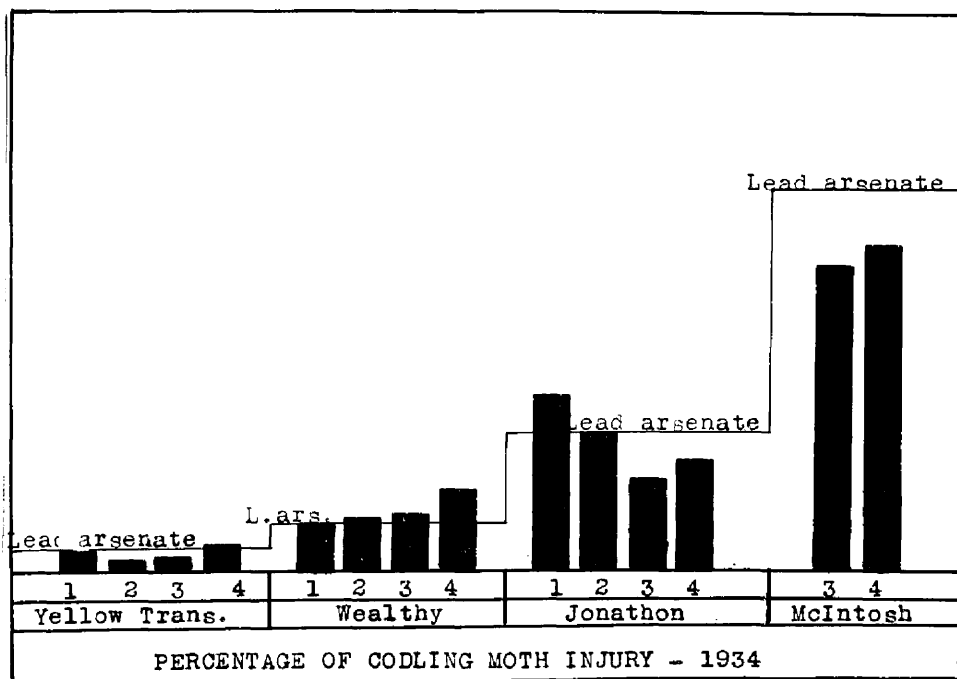


Figure II

SUMMARY

The results may be summarized as follows:

1. All schedules gave excellent control of the first brood of codling moth, thus effectively protecting summer varieties of apples.
2. Schedules including sulfur during the first brood caused injury to fruit and foliage.
3. Oil (with nicotine) applications caused injury when following sulfur.
4. Bentonite combinations gave control of codling moth, the B. L. 155 BX combinations slightly surpassing B. L. 155.
5. B. L. 155 BX combinations sustained control throughout the season, although not as efficient at first.
6. Arsenate of lead schedules gave the best control of deep entries.
7. Schedules confined to the first brood do not give sufficient control on fall varieties.
8. Despite the alarming appearance of trees injured by sulfur sprays, arsenate of lead caused more leaf fall.

EXPERIMENTS IN 1935

Changes in Procedure. In 1935 all materials were applied on a 10-day schedule of cover sprays, and, with one exception, no changes in materials were made during the season. This permitted exact comparison of materials alone, omitting variables of schedules and changes in materials during the season such as occurred in 1934. Furthermore by obtaining complete control of the orchard, by lease, opportunity to study possible injury was afforded without jeopardizing satisfactory relations with the owner. This, of course, permitted inclusion of new and relatively untried materials.

Varietal differences, responsible for large variations on data obtained in 1934, were controlled by acquiring a very uniform block of trees, large enough to permit replication of plots and of such a regular bearing habit that all trees could be used as count trees. Varietal differences were tested in another block, from which data were obtained to compare, without obscuring, the data on relative control of the different schedules obtained on the uniform block.

Other advantages afforded by the 1935 program were effective, reliable equipment, opportunity for unlimited study of crop during harvest, proximity to laboratory and other Experiment Station facilities, etc., all of which contribute to an effective research program.

Changes in materials were occasioned by the inability of processed bentonite-nicotine sulfate compounds to withstand normal rainfall in eastern states in 1934. Driggers and Pepper

(12) found that under New Jersey conditions the retention of nicotine by factory processed bentonite and nicotine sulfate compounds was much less than when the same ingredients were mixed at the time of application. The physical properties of the bentonite were apparently affected, and the control was poorest in the case of the B. L. 155 that was used with success in the Michigan experiments in 1934. Therefore, the "155" series in 1935 are modifications of those used in 1934, some of the formulae having been changed to increase adhesive or retentive properties.

In addition, the Nico-Zin series was introduced, a soluble and non-volatile material to be used alone or with oil.

The use of oils in combination with nicotine insecticides was necessitated by the development of a new type of "soluble oil" by Knight and Cleveland (28) and Cleveland (3). This material was tested by them in 1933 and 1934 and indicated certain advantages which necessitated its inclusion in the 1935 tests.

The experiments in 1935 were confined to schedules comparing soluble and non-volatile nicotine combinations, (Nico-Zin series), soluble and volatile nicotine combinations, (oil-nicotine series,) and insoluble and non-volatile nicotine combinations, (B. L. 155 series), with the standard arsenate of lead schedule as recommended by the Experiment Station of Michigan State College, both in control of the codling moth and in effect on the fruit and foliage of the tree. Each series included tests of combinations of the nicotine insecticide with one or more

summer oils in varying proportions. The schedule of cover sprays, Table VII, indicates the materials used and the amounts of each.

Experimental Conditions. The orchard included about eight acres, which were divided into two types. The old orchard, Figure III, with 160 trees about 30 years old, included Baldwin, Spy and Ben Davis varieties, with a few Wealthys and scattered trees of other varieties of no importance. The orchard was planted too close, and had been overpruned at some time, causing many watersprouts. Subsequent neglect had permitted San Jose scale to build up, and the trees contained much dead wood. However, there were few trees gone, facilitating the arrangement of plots, and the condition of the trees afforded an opportunity to test materials under unfavorable spraying conditions. The dead limbs were removed, the watersprouts were thinned out, and the trees were cut back to permit the sprayer to pass between the rows, but no attempt was made to prune for easier spraying.

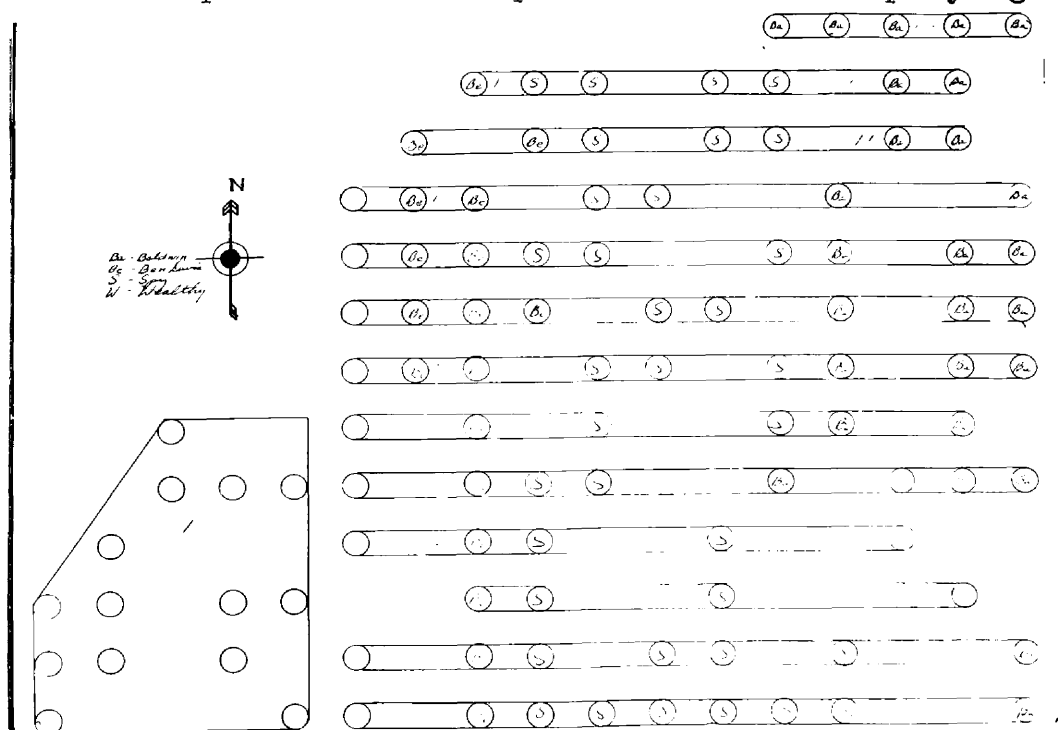


Figure III.

Figure III illustrates the manner in which 13 plots were located in this area, each including a row of twelve trees across the main varieties, Baldwin, Spy and Ben Davis. Only the trees which bore a crop worthy of consideration as a count tree were indicated on the map, so the omissions do not always indicate the lack of a tree.

The young orchard, Figure IV, adjoined the old orchard on the west side and contained 112 McIntosh trees, about fourteen years old, planted at forty-foot intervals. In addition, one row west of the McIntosh included a few Yellow Transparent and Jonathan trees.

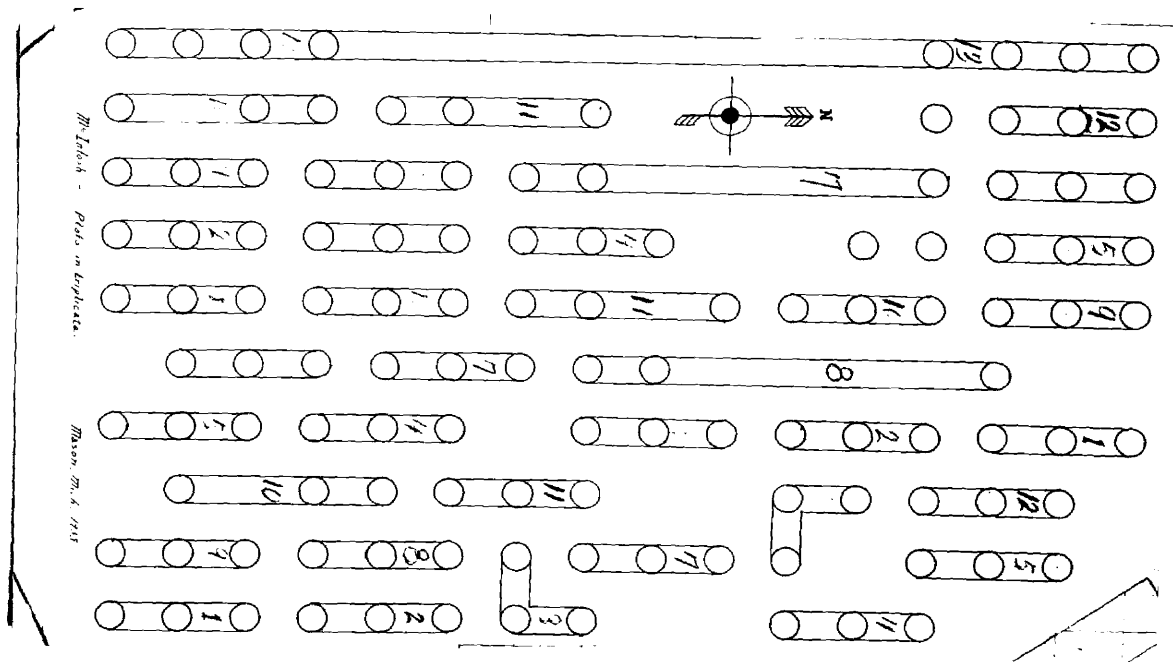


Figure IV.

The McIntosh block was exceptionally uniform in size and vigor, and had been so cultivated that the trees were not suffering from lack of nutrition, though their growth was less than that of many young orchards. Their uniformity permitted the use of a replicated plot arrangement as shown in Figure IV, namely three replications of three tree plots. There were trees enough to accomodate 12 schedules in this manner, all trees being considered as count trees. Omissions in Figure IV represent missing trees. Plot No. 13 consisted of the Yellow Transparent row mentioned previously. No pruning was required, and spraying conditions were optimum, so far as the trees were concerned.

Ammonium sulfate was applied at the rate 5# per tree in the old orchard and at the rate of $2\frac{1}{2}$ # per tree in the young orchard, in the delayed dormant period. This resulted in vigorous growth of the young trees and a sufficient growth of the old trees without production of watersprouts in either case. This rather light application of fertilizer was indicated to guard against stimulation of growth to such a point that spray injury studies would be impossible.

Applications were made with a Bean Sprayer, developing 350-425 lbs. pressure. An eight nozzle broom gun was usually used in the young trees, spraying from the tank, while a Bean single nozzle gun was used in the old block, except when weather conditions permitted using the broom only for the application on one side, and the single nozzle gun for the other. In the old block the single gun was also used for spraying the under side of the trees from the ground. Each application

was complete, and only twice were the applications interrupted by rain.

Spray applications during the pre-blossom, calyx, and first cover period were uniform for the whole orchard, and were modified to conform with weather conditions and other requirements as indicated in Table VI.

TABLE VI

SPRAY SCHEDULE - MASON, MICHIGAN

1935

Date	Trees	Material	Rainfall since previous spray
Apr. 20, 22	McIntosh	Bordo 4-4-50, Kleenup 3%, B. L. 40, 1 pt.	0.00
22	All old trees except Spies	Bordo 4-4-50, Kleenup 3%, B. L. 40, 1 pt.	
27	Spies	Bordo 4-4-50, Kleenup 3%, B. L. 40, 1 pt.	
FIRST APPLICATION			
Apr. 30	All but Spies-Lime sulfur 2½ Gals. W. side) All but Spies-Lead arsenate 3 pounds. E. side)		.71
SECOND APPLICATION			
May 4	Both sides all trees	Lime sulfur 2½ Gals. Lead arsenate 3 pounds.	1.24
THIRD APPLICATION			
May 6, 7	Both sides all trees	Lime sulfur 2½ Gals. Lead arsenate 3 pounds.	.31
FOURTH APPLICATION			
May 10	West side) all trees)	Lime sulfur 2½ Gals. Lead arsenate 3 pounds.	.21
11	East side) all trees)		
FIFTH APPLICATION			
May 14	E. side) all trees) NW & NE side McI's)	Lime sulfur 2½ Gals. Lead arsenate 3 pounds.	.32
	N & S sides) all trees) S. side McI's)	Lime sulfur 2½ Gals. Lead arsenate 3 pounds.	
SIXTH APPLICATION			

TABLE VI
 SPRAY SCHEDULE - MASON, MICHIGAN
 1935

Continued

Date	Trees	Material	Rainfall since previous spray
May 27	S & W side McI's	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	
28	E & N side McI's	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	.38
29	W side McI's	Light application: Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	
29	All but Spies in old block	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	
31	Spies	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	1.37
CALYX			
June 7	N & S side old trees	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	1.09
8	E side of McI's	Lime sulfur $2\frac{1}{2}$ Gals. Lead arsenate 3 pounds.	
FIRST COVER			

The first application, of three per cent dormant oil, Bordeaux 4-4-50 and B. L. 40, 1:800, was applied in the delayed dormant period for control of scale, scab, and aphids. Five subsequent pre-blossom sprays were required for control of scab and chewing insects, consisting of lime sulfur, $2\frac{1}{2}$ gallons, lead arsenate, three pounds. During the pre-blossom period, persistent rains required additional fungicidal protection, as shown by the amount of rainfall between applications. (See Table VI, column 4.) The calyx applications were made May 27-31, and the first cover on June 7-8, with the same materials as used in the pre-blossom sprays. This completed the schedule for control of scab and curculio, and no primary scab infection developed.

Experimental Materials and Methods. The application made on June 16-17, was the first of the series of experimental schedules, and subsequently all plots were sprayed with the materials outlined in Table VII, at ten-day intervals, as indicated in Table VIII. The only exception was Plot 8, the base check or standard of comparison, lead arsenate and lime, which was sprayed at 14-day intervals, as recommended by the Department of Entomology. The last application was made on the 26th of August, and completed the eighth of the series of nicotine sprays and the sixth of the lead arsenate series. Comparable materials such as Nico-Zin, the oil-nicotines, or the 155's, were sprayed on the same day, to assure uniform weathering in event of interruption by rain. Three hundred gallons were found to be sufficient to cover twelve old trees and nine young trees, less being required in a few plots where trees were missing.

TABLE VII

CODLING MOTH PROJECT

MASON, MICHIGAN

1935

Schedule of Cover Sprays
(10-day interval.)

1. Nico-Zin (20%), 2#; *Verdol, 1 gal.
2. Nico-Zin (20%), 2#; Verdol, $\frac{1}{2}$ gal.
3. Nico-Zin (20%), 2#; Orthol-K, $\frac{1}{2}$ gal.
4. Nico-Zin (20%), 2#; Superla, $\frac{1}{2}$ gal.
5. Nico-Zin (20%), 2#.
6. Base check, college schedule: lead arsenate, 3#; lime, 4#.
7. B. L. 40, $\frac{3}{4}$ pt.; Verdol, $\frac{3}{4}$ gal.
8. B. L. 40, $\frac{3}{4}$ pt.; Orthol-K, $\frac{3}{4}$ gal.
9. B. L. 40, $\frac{3}{4}$ pt.; Superla, $\frac{3}{4}$ gal.
10. B. L. 155 A, 5#; * Orthol-K, 1 gal.
11. B. L. 155 B, 5#.
12. B. L. 155 C, 5#; * Orthol-K, 1 gal.
13. Tank mix: B. L. 40, $\frac{3}{4}$ pt.; Bentonite, 4#. (first brood.)
B. L. 40, $\frac{3}{4}$ pt.; Orthol-K, $\frac{3}{4}$ gal. (second brood.)

* - Oil included in application at time of peak emergence only.

TABLE VIII
COVER SPRAYS
1935

[illegible]

Results

Nicotine Deposition. Analysis of the nicotine present on the foliage during the period of application was made by the method first used by Leonard (29) and later in New Jersey by Driggers and Pepper (11, 12). Samples were collected before and after the fifth nicotine spray on July 26 and 27, and before and after the seventh nicotine spray on August 16 and 19, and before and after the eighth nicotine spray on August 26 and 27. One hundred leaves per plot were picked before the spray was applied, and again after spraying. Discs were cut from these leaves with a punch having a diameter of one and a quarter inches and these samples were analyzed to determine the amount of nicotine in mgs., per sq. cm. $\times 10^{-3}$. The figures of the analysis are included in Table X.

TABLE X

MASON, MICHIGAN CODLING MOTH PROJECT

1935

Analyses of apple foliage (McIntosh) for Nicotine

Plot No.	5th Nicotine Spray		7th Nicotine Spray		8th Nicotine Spray	
	Before	After	Before	After	Before	After
1	1.11	2.42	1.45	1.77	1.32	3.25
2	1.29	2.79	1.57	2.26	1.05	2.52
3	1.38	3.53	1.81	2.25	1.27	5.31
4	1.59	3.03	1.87	3.15	1.10	5.25
5	0.57	1.72	1.51	1.36	0.20	1.45
7	0.44	1.28	1.02	1.05	0.16	1.65
8	0.57	1.16	1.03	1.50	0.00	1.02
9	0.87	1.65	3.08	1.46	0.37	1.50
10	1.08	2.40	1.42	2.81	2.23	1.79
11	0.40	2.14	1.42	2.06	0.74	0.95
12	0.59	2.19	1.49	2.52	1.42	2.06
13	2.94	3.91		5.85	4.10	6.15

Amounts shown are in mgs. per sq. cm. x 10⁻³

The Nico-Zin series with oil added retained for 10 days approximately three times as much nicotine as Plot 5, receiving Nico-Zin alone. The Nico-Zin oil plots, however, have less than twice as much nicotine immediately after the spray application has been made. In this respect the Nico-Zin oil combination seems very effective.

The amount of nicotine remaining at the end of the 10 day interval between sprays is approximately equal on the plot receiving Nico-Zin alone and on the oil-nicotine plots, according to the information in Table X. The B. L. 155 series, Plots 10, 11 and 12, indicate a varying amount of nicotine retained during the period between sprays. The amount is relatively low in the case of Plots 11 and 12, and relatively high in the case of Plot 10. The amount present immediately after spraying is approximately the same in all three plots, so the retention in Plot 10 must be more efficient.

The Effect on Foliage. The effect of the insecticidal materials on the tree, as manifested by the foliage, was again studied in 1935. The injury to the leaves on the non-bearing spurs, which are present and exposed to the spray during the entire season, was measured by determining the average number of leaves per spur early in the season, then comparing this number with the averages taken at intervals during the spraying.

The uniformity of the McIntosh block permitted this type of measurement, while variation in vigor between trees in the old block prevented its application there. Accordingly the data were obtained from the uniform, but more vigorous

and consequently less susceptible block of trees. The average number of leaves per spur was determined by counting 300 spurs per plot and computing the average. Three counts were taken at monthly intervals on the McIntosh block, and the percentage of leaves lost during each interval computed, as shown in Table IX.

Table IX, in general, shows no loss of importance, with the exception of Plots 4 and 9, both of which received Superla, at one-half and one-fourth per cent strength respectively. This is in marked contrast to the differences shown by the same index in 1934, but conditions were less favorable for leaf loss this year because of the regular rainfall. Also, the method best demonstrates true defoliating injury such as lead arsenate without a corrective, or oil after sulfur injury. Injury from oil only was noticed this season as a marginal burning, resulting eventually in a ragged, frayed leaf which adhered normally until late in the season, when the loss occurred which is indicated in the last count, Table IX, column 5.

Observations made during the summer on the McIntosh block indicated conclusively that the Nico-Zin series, including the plot of Nico-Zin alone, five pounds, caused a yellowish type of foliage, most noticeable by contrast with the unsprayed trees, or the B. L. 155 plots. The B. L. 155 series had the best general appearance of any of the spray treatments. The oil-nicotine plots naturally showed a darker green foliage, as is characteristic, but the inclusion of oil in the Nico-Zin plots did not mask the yellowish color at all. As the leaf counts indicated, the lead arsenate

TABLE IX

LEAF COUNTS - MCINTOSH - MASON, MICH.

1935

Plot No.	July 1-5 Leaves per twig	July 30-Aug. 1 Leaves per-% loss twig		Sept. 1 Leaves per-% loss twig	
1	6.09	5.83	4.25	4.33	28.90
2	6.11	5.89	3.60	4.34	28.97
3	6.20	5.91	4.68	4.50	27.42
4	6.16	5.67	7.95	3.90	36.69
5	6.12	5.92	3.27	4.07	33.50
6	6.27	5.75	9.25	4.25	32.22
7	6.16	5.88	4.55	4.07	33.93
8	6.25	5.97	4.48	4.16	33.44
9	5.98	5.79	.17	3.63	39.30
10	6.11	5.89	3.60	4.37	28.48
11	6.04	5.80	3.97	4.20	30.46
12	6.21	5.89	5.15	4.26	31.40
13	5.70	5.13	10.00	4.09	28.25

plot in the McIntosh did not lose any leaves.

The yellowing of the foliage on the Nico-Zin series was most evident in the McIntosh block, yet as has been stated, no leaf fall occurred. In the old orchard no injury from this material appeared until fairly late in the season when the Nico-Zin series and the oil-nicotine series experienced a considerable drop of yellowed leaves during the middle of August. The leaf fall at this time was sufficient to equal that which had occurred on the lead arsenate plot in the old block previously, though no particular leaf fall was occurring then on the lead plot. The leaf fall was most noticeable on Spies, and of course, occurred first on limbs which had been weakened from scale or shading.

The oil-nicotine plots in the old block showed darker foliage that was not in as desirable condition as the foliage on the B. L. 155 series, but showed no leaf loss until the early part of September, after which the leaf fall was so rapid as to be very noticeable by the first of October, both on the spurs and on the new growth. The plots receiving the B. L. 155 A, B, or C, with or without oil, had by far the best color and condition of foliage through the entire season, and the leaves persisted in healthy condition longer than those on any other treatment.

In contrast to the lead arsenate plot in the McIntosh block, which has been described as free from any leaf loss, the same treatment in the old orchard gave a considerable leaf drop, which began about the latter part of July and continued through the season, though at no time were any

great number of leaves falling.

At the time of Ben Davis harvest, late in October, the trees of this variety which had received Nico-Zin showed ragged bronzed foliage with considerable leaf loss, while the trees that received lead arsenate appeared healthier due primarily to the green color of the leaves which persisted.

The Effect on Fruit, Color. Observations made prior to the time of harvest of the McIntosh indicated the possibility of a color deficiency in the series of plots receiving Nico-Zin, but the effect was masked by considerable variations from tree to tree which might have been attributed to variation in strain, making it very difficult to draw definite conclusions as to the effect of these materials on color. Fruit from the oil-nicotine plots in general showed a poorer quality of color, almost a brick red, than the trees sprayed with lead arsenate or B. L. 155 A, B, or C. At the time the apples were ready to be harvested, a few warm nights accented the variation in color to such an extent that a measurement of the variation was attempted. Random samples of approximately one hundred apples were taken, including each tree in each plot. Each sample was then separated into Michigan "Fancy," Michigan "A," and Michigan "B" grade on the basis of color alone. The results are indicated in Table XI.

TABLE XI

Plot No.	Number Michigan			Percent Michigan		
	Fancy	A	B	Fancy	A	B
1	0	57	31	0	65	35
2	6	35	45	7	41	52
3	0	30	62	0	33	66
4	2	69	24	2	73	25
5	6	54	23	7	65	28
6	26	32	27	30	38	32
7	19	27	41	22	31	47
8	25	37	18	31	46	23
9	19	33	32	23	39	38
10	3	37	51	3	41	56
11	0	48	42	0	53	47
12	3	77	10	3	86	11
Unsprayed	23	20	30	32	27	41

Color is a requirement in Michigan "A" and Michigan "Fancy," while Michigan "B" requires no color. Fifteen percent of normal color is required on McIntosh for Michigan "A," and this grade is about the same as U. S. No. 1. Fifty percent of color is required for Michigan "Fancy" (31).

In consideration of Table XI, a remarkable correlation is evident between percentage of Michigan "Fancy" and the various series of materials. According to these data the effect of the Nico-Zin and B. L. 155 series of treatments was to eliminate the highly colored apples which would normally be included in Michigan "Fancy," most of which are dropped to Michigan "A". Plot 6, the lead arsenate plot, shows a small percentage of Michigan "B" and a percentage of Michigan "Fancy" very closely comparing to the results of the unsprayed trees. The oil-nicotine series apparently gave normal color, though no increase in Michigan "Fancy" can be attributed to the oil-nicotine treatments. The B. L. 155 series, while having as desirable type of color as any of the treatments, produced a very low percentage of Michigan "Fancy" apples. It must be pointed out, however, that the percentage of Michigan "A" apples in this series is relatively higher than in any other, particularly in Plot 12. Michigan "A" grade corresponds very closely with the U. S. No. 1 Grade, as far as color requirements are concerned. Therefore, it would seem that while the B. L. 155 series were deficient in Michigan "Fancy" apples, the increase in the number of

Michigan "A" would justify calling the color reactions on these treatments desirable. Some deficiency in color may have resulted from the greater percentage of healthy leaves remaining on the trees in the B. L. 155 plots at harvest.

The Effect on Fruit, Dropping. In conjunction with the observations on color of the McIntosh, a considerable drop of fruit was noticed on several plots. To determine the significance of this effect of the various schedules, the dropped apples were recorded in Table XII.

TABLE XII

PERCENTAGE OF DROP
MCINTOSH, MASON, MICHIGAN
1935

Plot No.	<u>1</u>	Replication <u>2</u>	<u>3</u>	Mean %
1	24.5	16.7	3.6	14.6
2	22.4	11.1	23.6	19.3
3	23.6	19.1	23.8	20.5
4	58.2	47.9	48.3	53.4
5	15.0	18.2	11.3	14.4
6	38.5	12.2	20.8	26.1
7	36.9	34.5	10.5	26.3
8	50.5	35.3	61.8	50.9
9	62.9	36.8	72.7	57.7
10	20.6	4.1	17.3	13.1
11	11.2	10.7	15.2	12.3
12	16.5	26.1	14.5	17.8
Unsprayed				26.1
			Average	<u>27.1</u>

The average drop for the variety as a whole was 27.1%. The only plots showing decided increase when compared with unsprayed trees were No. 4 and No. 9, receiving Superla in one-half and three-fourths per cent concentrations in all cover sprays; and No. 8, receiving three-fourths per cent Orthol-K. However, all schedules including oil in all cover sprays increased dropping. Nico-Zin used alone (Plot No. 5) or with one per cent oil in three sprays reduced dropping, as did the "155" series on Plots 10, 11 and 12. The additional dropping in Plots No. 4 and No. 9 may be attributed to the increased oil concentration at equal dilution, for the "soluble" type contains 95% actual oil, while the others, of the "mayonnaise" type may only contain 65-85% actual oil (3). Furthermore the soluble type was developed for use in combination with lead arsenate in which case the insoluble suspensoid is coated with oil, stabilizing the emulsion. In the absence of such a stabilizing action, when used with soluble nicotine sulfate or Nico-Zin in these experiments, difficulty is always experienced in obtaining complete emulsification.

The Effect on Photosynthesis. Photosynthetic effects of the different materials were advanced as a cause of the variations in color, and in dropping. Accordingly random samples of one hundred leaves were taken from each of Plots No. 2, 3, 4, 5, 6, 7, 8, 9 and the unsprayed trees, for analysis of carbohydrates present.

Samples were taken early in the morning of September 17th, and again just before dark. A circular disc was cut from the center of each, in the same manner as for nicotine analysis, to assure uniform size of samples.

These samples were analyzed for content of glucose, sucrose, starches and total carbohydrates, and the data are presented in Table XIII as percentages.

Considerable variations are indicated between treatments, but the differences are in many instances too small to show variations between plots. Therefore the data presented in Tables XI, XII, and XIII have been collected and arranged to best indicate variations, in Table XIV.

Relative Effect, All Types. In Table XIV the Plots receiving Nico-Zin with one-half per cent oil have been considered in the first column, and those receiving B. L. 40 with three-fourths per cent oil in column two. No consideration is given the variations due to use of different oils, for all three types of oils were used in each group. These data are to be compared with the lead arsenate standard, the unsprayed trees, and the plot receiving Nico-Zin alone. Data include the percentage of fruit remaining on the trees at harvest, which was highest in the Nico-Zin plot, and lowest in the plots receiving the heaviest oil concentration. Oil in both cases increased dropping, lead arsenate did not affect it, and Nico-Zin retarded it. The percentage of fruit having Michigan "A" color (over 15%) was increased slightly by oil-nicotine, considerably by Nico-Zin alone, but reduced by Nico-Zin and oil combined.

The total carbohydrates are in close relationship to

TABLE XIII
MASON, MICHIGAN CODLING MOTH PROJECT
1935
SUMMARY OF DATA ON CARBOHYDRATES

Treatment	Time	Percentage of			Total
		Glucose	Sucrose	Starches	
Unsprayed	A.M.	7.73	8.98	12.75	29.62
	P.M.	7.95	11.39	14.87	34.21
Number 2	A.M.	6.58	9.33	15.29	31.19
	P.M.	7.14	11.02	13.93	32.09
Number 3	A.M.	7.54	9.52	16.04	32.84
	P.M.	6.68	11.28	13.99	31.96
Number 4	A.M.	7.82	10.49	14.38	32.70
	P.M.	7.03	11.69	13.20	31.93
Number 5	A.M.	7.55	9.64	13.64	30.78
	P.M.	8.72	11.56	14.66	35.95
Number 6	A.M.	8.23	11.01	11.59	32.86
	P.M.	8.67	11.73	16.13	36.59
Number 7	A.M.	8.32	12.00	14.03	34.35
	P.M.	8.24	10.63	15.06	33.95
Number 8	A.M.	7.82	10.23	12.35	30.51
	P.M.	8.71	10.14	16.22	35.08
Number 9	A.M.	9.13	11.17	12.85	33.16
	P.M.	8.48	10.67	13.73	32.89

TABLE XIV

MCINTOSH BLOCK - MASON, MICHIGAN

September, 1935

Plots Numbered: Mat'ls. used in Cover Sprays:	2,3,4 Nico-Zin $\frac{1}{2}\%$ oil	7,8,9 B.L. 40 $\frac{3}{4}\%$ oil	6 Lead Ars. Lime	U No Cover Spray	5 Nico-Zin Alone
Percent of Picked Fruit:	69.3	55.0	73.9	73.9	85.6
Percent of U. S. #1 Color:	52	64	68	59	72
Increase % Total Carbohydrates from A.M.-P.M.*	-.75	1.30	3.73	4.59	5.17
Increase % Total in Glucose-Sucrose from A.M.-P.M.*	.59	-.28	.48	1.32	1.55
* Samples taken September 17th.					

color, with the Nico-Zin-oil the lowest, and only the Nico-Zin above the unsprayed.

The figures for glucose and sucrose have been combined, and are perhaps the most important factor presented, for in analysis of fruit their presence is correlated with quality (2), and pigmentation is also correlated with their presence (22). Again the addition of oil to Nico-Zin affected this material, lowering it from first place to last. The proportionate reduction in the oil-nicotine and lead arsenate plots is large because of the high starch content included in the total carbohydrate analysis of the leaves from these plots (Table XIII).

These data indicate a definite reduction in photosynthesis where oils were used, and additional reduction in color when Nico-Zin was combined with oil.

An observation worthy of mention in this respect is that the plot receiving Nico-Zin alone, in the old block, contained a Spy tree and a Baldwin that bore the most highly colored fruit of these varieties.

Additional Injury to Fruit. Injury to the calyx end of the apple was also observed, first as a green area in the calyx depression, later russeting on the same area. This injury occurred on all McIntosh plots receiving oil in all cover sprays to a considerable extent, and occasionally on Plot 1, which had 1% oil in three applications. No variation in the manifestation of this injury occurred except in degree, and was probably related to the actual oil content of the emulsion used, for Superla, with the greatest concentration of oil, caused the earliest development of the calyx injury.

The injury characteristic of Plots No. 4 and No. 9, re-

ceiving Superla oil in all cover sprays, is shown in Figure V.

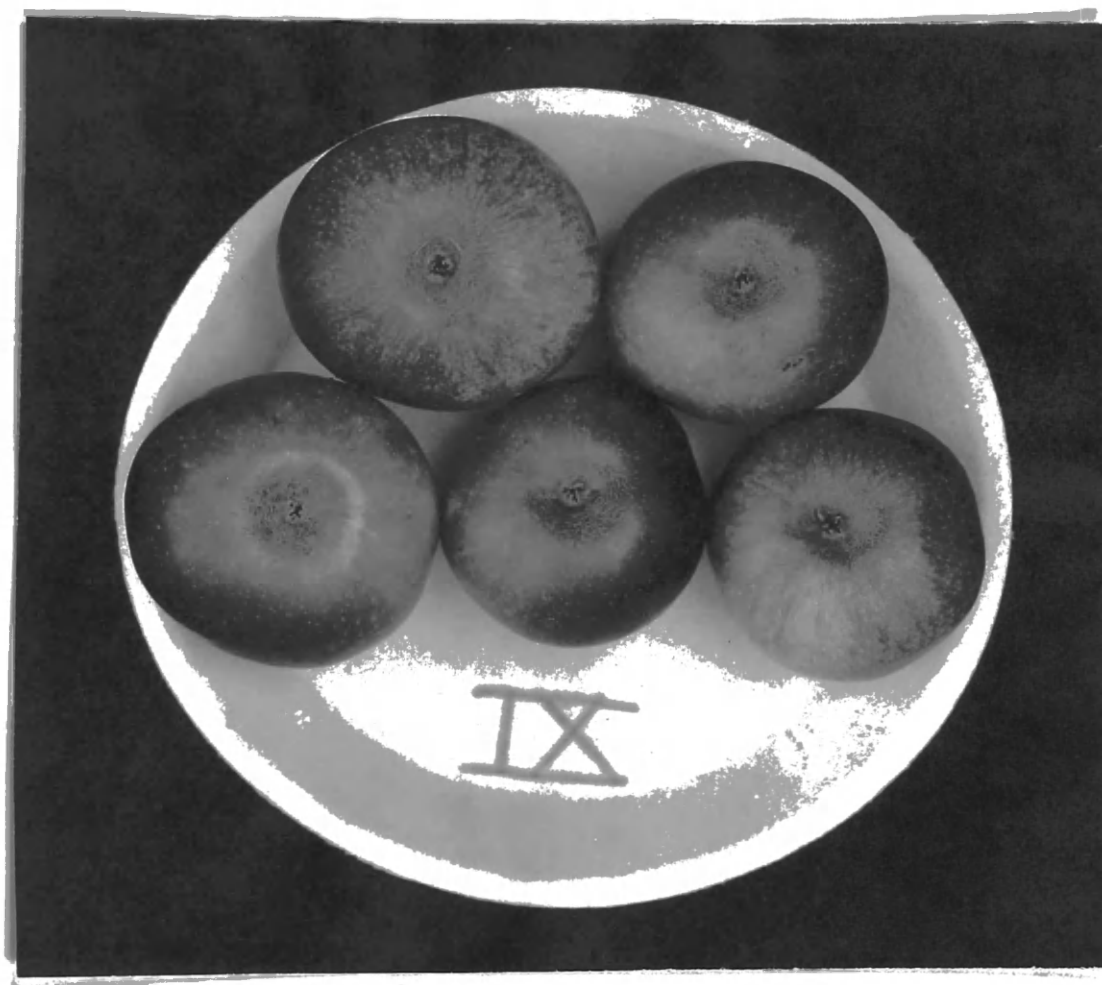


Figure V. Superla summer oil
on McIntosh.

The injury characteristic of Plots No. 3 and No. 7 caused by the inclusion of Orthol-K oil in all cover sprays is indicated in Figure VI.



Figure VI.

Orthol-K summer oil on McIntosh.

The injury resulting from the inclusion of Verdol oil in Plots 1, 2, and 7 is shown in Figure VII.

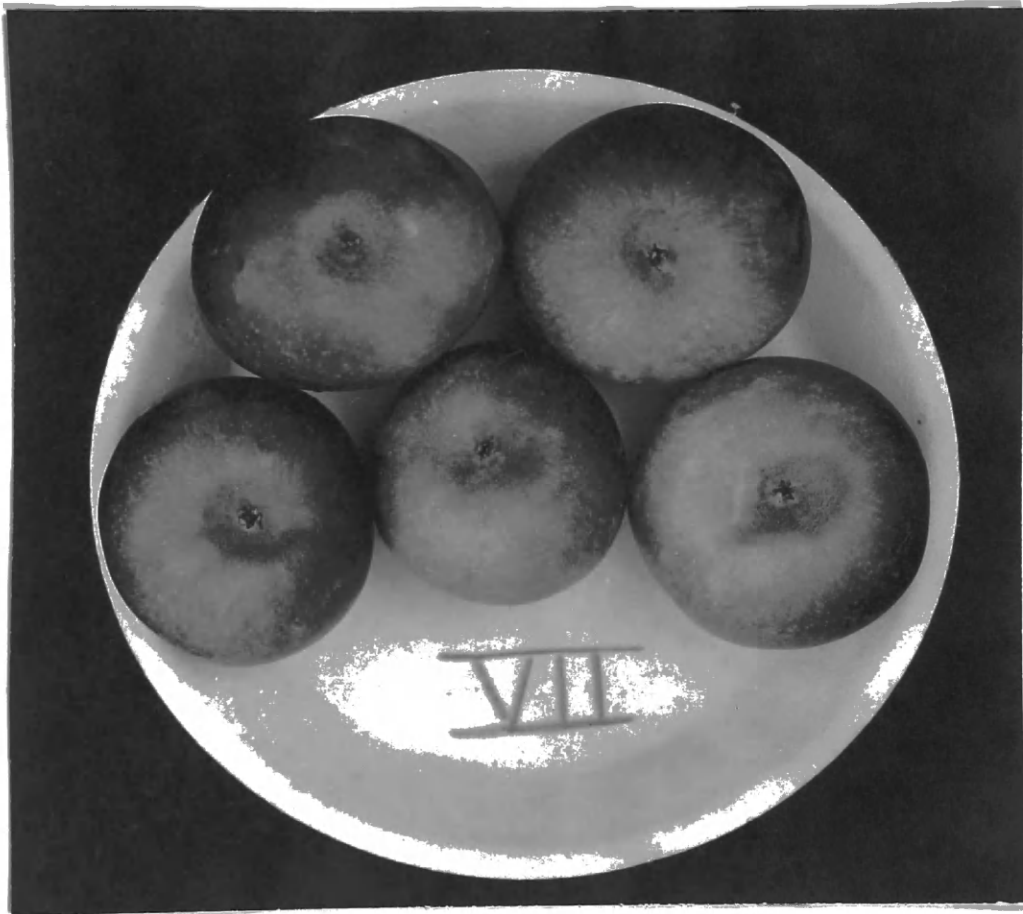


Figure VII.
Verdol summer oil on McIntosh.

This type of injury was manifest on the Spies in the old block in Plot 9, which received three-fourths per cent Superla, as a black specking of the calyx and the face of the apple exposed to the heaviest spray. The injury appeared about the first week in September and by the time of harvest most apples had outgrown the injury. Figure VIII illustrates the black specking of the surface exposed to the spray.



Figure VIII

Superla summer oil on Northern Spy.

Another type of oil injury was observed, but only occasionally, on Spies. This was enlarged and ruptured lenticils, as was mentioned by Cleveland (3). This is shown in Figure IX.

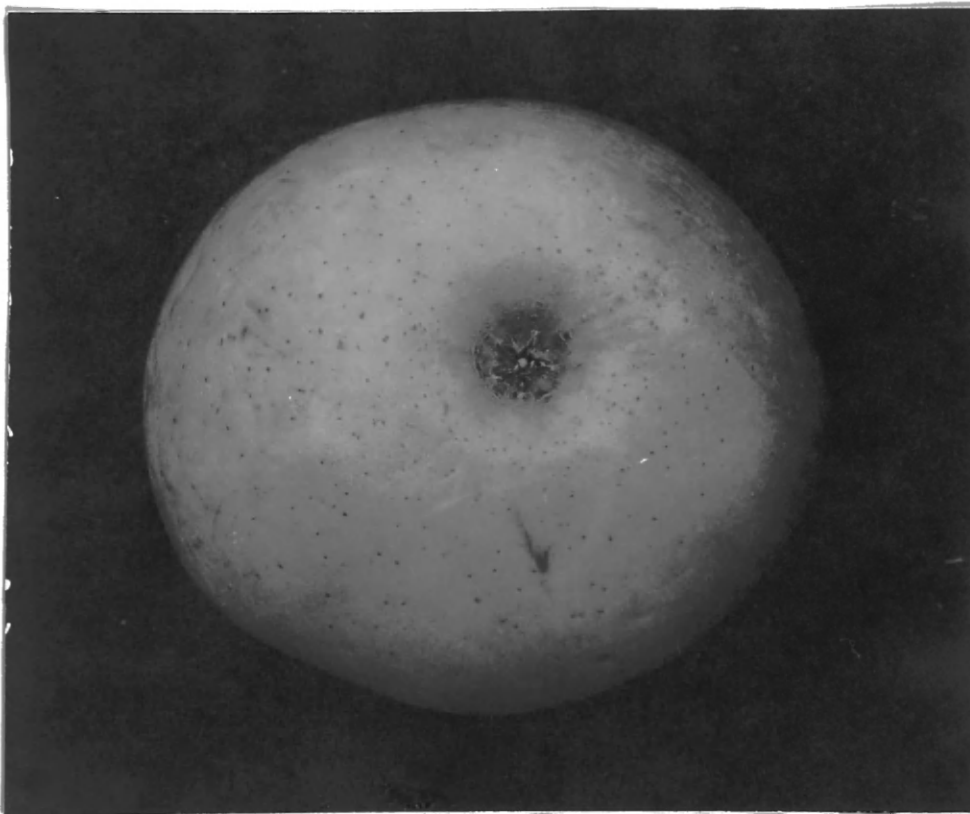


Figure IX.

Superla summer oil on Northern Spy.

A few examples of a peculiar type of injury on the plot sprayed with lead arsenate were observed. This injury occurs after the fruit starts to ripen, and is caused by the accumulation of arsenical residues in the calyx end of the apple with resultant formation of soluble arsenic, causing a sunken, black area in the calyx depression (13). This is illustrated by Figure X. The solid color of the fruit indicates the maturity of the apples injured in this manner.

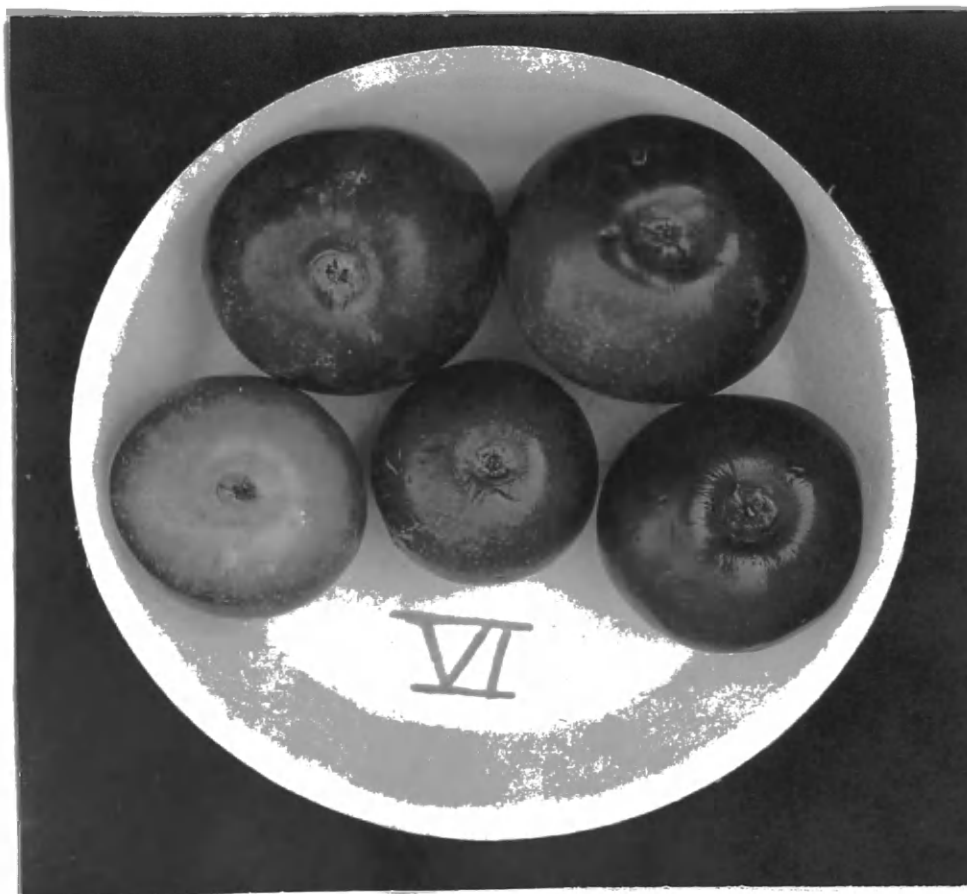


Figure X.

Lead Arsenate on McIntosh.

No uniform variation in color was observed in the old orchard, for while some variation was apparent between plots, it was not greater than the variation between trees in the same plot, because of the condition of the trees under experiment. However, the condition and finish of the fruit in the 155 plots was by far the best of any series.

Codling Moth Control

Population Conditions. Observations on the codling moth population during the summer were as detailed as possible for the available data on this important factor were limited. As has been mentioned, inefficient spraying during bearing years, and neglect during non-bearing periods, had prevailed. The orchard had not borne the previous year, and no information was available about the condition of earlier crops. Examination of the trees indicated that there had been high populations present, but no great number of worms were found in the cocoons under the bark flakes, by casual inspection.

In order to increase the population about 100 untreated corrugated paper bands containing larvae collected the previous season were distributed in the orchard. The number of larvae per band varied considerably, but was estimated to average about 100.

One band was placed in the center tree of each plot in the McIntosh block, and the rest were distributed in the old block, in trees which had blossomed fully. The bands were distributed about the first of June.

On the 8th of June, two pupae found on the trunk of one of the trees indicated that emergence had begun, at least

of the original infestation. However, the prevailing cold, wet weather prevented any considerable emergence, and certainly any egg deposition. On June 29th approximately 1000 moths obtained from an apple storage at Albion, Michigan were liberated in the old orchard, and about 1000 more were liberated in the McIntosh block on July 1st. Liberations were made late in the day and the majority of the moths flew readily from the container to trees at some distance, apparently in excellent condition. Still another liberation was made in the McIntosh block on the 7th of July, of about 500 moths.

The peak emergence of moths from the original orchard infestation and from the bands distributed was delayed by the cold weather until the 2nd of July. On this date favorable conditions caused large numbers to emerge, although flight conditions were still unfavorable, for bait pot collections during the following week were much lower than they should have been after such an emergence. The afternoon of July 2nd was spent in examining various trees in the old orchard, and from six to twelve moths were commonly observed on each tree, emerging from the bands, the crotch of the limbs, or the base of the trunk. Some larvae had tunneled into the wood in injured areas, such as where limbs had broken off, and there had wintered, safe from predators. Obviously, the original infestation had been underestimated, and in addition, the emergence from the bands was excellent. However, the emergence was at least two weeks later than customary, and rather than being distributed over a period usually necessitating several sprays, it was

concentrated during the period protected by the application of July 6th. Some emergence occurred during the rest of the month, and continued until the peak second brood emergence was reported by the Experiment Station on the 29th of July at East Lansing.

This emergence did not include individuals resulting from the peak flight of July 2nd, so the increase in the orchard population was relatively slight. During the four weeks following, the flight was below normal in the orchard, though a considerable flight was reported from points slightly south on the 18th to the 22nd of August. Some very young larvae were found during the week of 29th of August, but moth flight was retarded by temperatures of 65 degrees and below, for the next ten days. A flight reported in some sections of the State about the 15th of September was of no importance in the orchard.

Summarizing the codling moth population in the orchard for the season, it may be considered that the emergence of a satisfactory first brood population was delayed by unfavorable weather, and the flight interrupted, until the second brood represented only the first third of the generation. In other words, population build up during the summer was below normal.

Relative Control, on McIntosh. Results of counts on all apples from the McIntosh block are outlined in Tables XV, XVI, XVII, XVIII, XIX, XX. Results are computed on the basis of deep entries or shallow entries, per 100 apples.

TABLE XV

CODLING MOTH INJURY - MCINTOSH - MASON, MICHIGAN

1935

Plot No.	No. Apples		% Entries			% Entries
			1	2	3	*Weighted Mean
1	8518	Deep	.61	.96	1.81	1.15
		Shallow	1.05	1.38	.76	1.03
2	9927	Deep	1.10	1.52	2.41	1.80
		Shallow	.85	2.82	1.58	1.69
3	6988	Deep	.99	.62	1.11	1.03
		Shallow	1.10	2.48	.90	1.08
4	11577	Deep	.42	1.94	1.82	1.26
		Shallow	.52	1.01	1.03	.80
5	12423	Deep	5.75	7.08	2.21	4.83
		Shallow	2.18	6.82	3.82	3.66
6	13429	Deep	.88	2.51	.81	1.50
		Shallow	4.55	14.46	7.21	9.61
7	7236	Deep	1.35	2.40	1.54	1.74
		Shallow	1.93	1.97	4.26	2.82
8	9293	Deep	1.33	.26	1.70	1.76
		Shallow	1.46	1.64	2.56	1.95
9	8248	Deep	1.49	.26	.65	.78
		Shallow	1.16	1.33	1.12	1.20
10	11745	Deep	3.21	.20	.92	1.19
		Shallow	3.03	1.05	2.35	2.02
11	10745	Deep	4.18	4.04	4.43	4.22
		Shallow	3.99	4.07	2.43	3.52
12	11381	Deep	3.86	3.98	2.45	3.26
		Shallow	2.46	2.86	2.51	2.57
Unsprayed	4554	Deep	14.16			14.16
		Shallow	4.50			4.50

* Weighted mean - calculated by dividing total wormy fruit by total fruit.

In analyzing Table XV, certain gross characteristics appear. Several groups of plots show little variation in percentage of injury, either as deep or shallow injuries. In most cases this is due to the small variations in effectiveness between the toxicants in the different schedules. For instance, the striking example is that of the Nico-Zin series, in which the inclusion of oil, either one-half per cent in all covers, or one per cent in three peak applications, resulted in decrease of injury to a low but uniform figure, regardless of the type of oil used. Conclusions can best be drawn by combining the data in another grouping, thus eliminating consideration of insignificant variations.

Table XVI includes the same data, assembled as total injury.

The data in Table XVI show increased variation between plots, particularly when the observed means of the comparable groups of plots of Nico-Zin-oil, oil-nicotine, and B. L. 155's are collected in respective means, then compared with the Nico-Zin alone or the lead arsenate standard.

Statistical Significance of Differences in Control. The statistical treatment included in Table XVI is based on the analysis of variance as described by Snedecor (34). It is included to establish the significance of the data presented.

The general significance is obtained by comparison of the mean square of the variance between plots with that within plots, usually considered the experimental error. In this case the mean square between plots is 41.12 times as large as that within plots. This value (F) is influenced by the number of

degrees of freedom, and the significant figure in this instance would be 5.27. This is expected to be exceeded in random sampling from a homogeneous population only once in a hundred trials. Obviously when $F = 41.12$ the chances are remote that differences in Table XVI are due to random sampling.

The same relationship obtains in the mean squares as computed for each group of plots. In Table XVII the lead arsenate plot has been used as a standard and the relative control of the others indicated, with the significance of each.

By these criteria it is evident that the Nico-Zin with oil and nicotine sulfate with oil resulted in significantly less codling moth injury, all forms, than the standard, lead arsenate. The chances of these differences being due to random sampling are less than 1:100.

The B. L. 155 series gave less significantly better results, for the chances of the decrease in total injury of 4.36% being due to random sampling are only little less than 5:100. The Nico-Zin (used alone) failed to give a significant reduction in total injury.

In this respect it should be pointed out that the Nico-Zin was most efficient when used with oil, for the chances that the reduction of 6.72% injury when oil was included was due to random sampling are less than 1:100 ($F = 18.33$, significant at 7.20).

Control of Deep Entries. Separating the classes of injury and consideration of deep entries separately results in rearrangement of some schedules in relative control. In

TABLE XVII
RELATIVE CONTROL OF CODLING MOTH
MEAN % OF INJURY - AND SIGNIFICANCE.

Material	Plots	Obs. Mean	Degrees Freedom	Mean Square	$\frac{36.66}{x}$ F	F "Significant"	
						5:100	1:100
Lead Ar- senate	6	<u>10.14</u>	2	36.66			
Nico-Zin	5	<u>9.29</u>	2	16.87	2.17	19.00	99.01
"155"	10-12	<u>5.78</u>	8	5.18	7.08	4.46	8.65
Nicotine- oil	7-9	<u>3.15</u>	8	2.00	18.33	4.46	8.65
Nico-Zin- oil	1-4	<u>2.57</u>	11	.92	39.84	3.98	7.20

Table XVIII the relative control of deep entries is presented.

Statistical Significance of Differences in Control. Again the lead arsenate standard is separated, and all plots having less than two per cent deep entries are collected in one group and compared with the standard, as are those with over two per cent deep entries, in a second group. Only Plot 5, receiving Nico-Zin alone, and Plots 11 and 12, receiving B. L. 155 B and C respectively, are included in the second category. This separation is justified by the fact that the variation within these groupings is very small in relation to that between them. F (within groups) is equal to $59.67/.94$ or 63.48 , while the significant figure is 5.27 . The error in this grouping, then, is very small.

The mean square of variance between the means of the groups is 59.67 , while that within the groupings, the error, is $.94$. The value of F is 61.78 , while the value required for significance ($1:100$) is 5.27 . This entirely justifies the method of separation of the data.

There is no significant difference between the control of deep entries achieved by the Nico-Zin-oil, oil-nicotine, and B. L. 155 A schedules, and that of the lead arsenate. The value of F in this instance is $.37$, and to be significant should be at least 3.42 . Neither is the decreased control by Nico-Zin, B. L. 155 B or B. L. 155 C (Plots 5, 11, and 12) significantly poorer, because of the small number of degrees of freedom in Plot 6. However, if plot 6, not significantly different than from plots 1-4 and 7-10, be combined with them, the F value is hardly affected, but the

greater degrees of freedom give significance. The significant F figure under these latter conditions is 3.29, while the computed F is 5.14. The control in Plots 5, 11 and 12 is therefore significantly poorer than in Plots 1-4 and 6-10.

It is therefore evident that all treatments gave control of deep entries equal to that of the lead arsenate schedule, except Nico-Zin alone, B. L. 155 B and B. L. 155 C. It seems unnecessary to point out that the percent of fruit injured by shallow entries was an important factor in the production of clean fruit by the use of lead arsenate.

Relation of Nicotine Deposit to Control. Another factor which should be directly related to the degree of codling moth control achieved by various combinations of nicotine is the amount of nicotine deposited by each application on the leaves and fruit. This information is available in Table X, in which is collected results of analyses of foliage before and after spraying. By subtracting the amount usually present before spraying from that present after the application a figure representing the average amount applied per plot per application is obtained.

The similarity of these results within the different series of schedules has prompted the collection of the data for the various series and its expression in Table XIX as arithmetical means, and also as relative percentages.

TABLE XIX

CODLING MOTH CONTROL AND NICOTINE DEPOSITION

Material	Plot	*Nicotine Deposited		Injuries per 100 Apples	
		Mean	%	Mean	% Decrease
Nico-Zin $\frac{1}{2}\%$ Oil	1-4	1.72	100	2.57	72
B. L. 155 A. B. C.	10-12	1.10	64	5.78	38
Nicotine $\frac{3}{4}\%$ Oil	7-9	.89	52	3.15	66
Nico-Zin Alone	5	.75	44	9.29	0
* Difference between analyses made after spraying and before.					

The nicotine deposited by each application varies from 1.72 mgs. per sq. cm. $\times 10^{-3}$ in the Nico-Zin-oil group, taken as 100%, to .75 mgs. per sq. cm. $\times 10^{-3}$ in the case of the same material used alone. Only 44% of the nicotine deposited when the two materials were used together was deposited when the oil was omitted.

The additional nicotine deposited is reflected in the mean percentage of total injury recorded, for the addition of oil to the Nico-Zin effected a reduction in injury of 72% of that resulting from Nico-Zin alone.

The intermediate position of the B. L. 155 series is also in keeping with the nicotine deposited and the resultant injury.

The nicotine-oil group gave control proportionately higher than the analyses of deposited nicotine would indicate, but this control may be due to the use of $\frac{3}{4}\%$ oil in these plots, resulting in effective ovicidal action. It is generally accepted that $\frac{3}{4}\%$ concentration of petroleum oil is the least that is effective as an ovicide, so the $\frac{1}{2}\%$ oil concentration used in the Nico-Zin series did not have this effect.

Therefore it is apparent in the data presented that the control of codling moth, all types of injury, is directly proportional to the nicotine deposited by each application, except when oil is included in the application in ovicidal concentration.

Corroborative Results on Baldwin, Spy, and Ben Davis. The data obtained by examining the fruit from count trees of the three varieties in the old orchard, Baldwin, Spy, and Ben

Davis, are presented for each variety in Tables XX, XXI, and XXII, then all varieties are combined in Table XXIII.

In general it may be observed that greater variations occur in the data from these older trees. This is to be expected for the smaller number of replications introduces sampling errors that are not reduced, and may be magnified, by counting large numbers of fruits from each tree. In analyzing these data the results obtained in the carefully randomized McIntosh block should be used as the standard, and the general consistencies are most valuable results, rather than the wide variations.

In the Baldwin variety, Table XX, the proportion of deep entries is generally lower than in the McIntosh, Table XV, and the proportion of stings to worms is higher. This is characteristic of a less susceptible variety. The control achieved by the different schedules on this variety is much the same as in the McIntosh, though the differences between the Nico-Zin-oil and nicotine-oil series and the B. L. 155 and Nico-Zin alone series is not as great. The proportion of shallow entries remains high in the lead arsenate plot.

The results of the Spy counts, Table XXI, show very close relationship with those from the McIntosh. This susceptible variety again demonstrates the value of oil with Nico-Zin, the control in Plots 1-4 being far better than Plot 5. Plot 12 gave the best control of any of the B. L. 155 series, but in general the summary of plot relationship is the same as that recorded on McIntosh.

TABLE XX

CODLING MOTH INJURY - BALDWIN - MASON, MICHIGAN

1935

Plot No.	No. Apples	% Entries	Replication		Mean %
			1	2	
1	1339	Deep	1.57	----	1.57
		Shallow	5.38	----	5.38
2	2111	Deep	1.18	----	1.18
		Shallow	3.32	----	3.32
3	1910	Deep	.63	----	.63
		Shallow	1.83	----	1.83
4	2118	Deep	.90	----	.90
		Shallow	4.06	----	4.06
5	4982	Deep	2.20	.87	1.54
		Shallow	7.42	4.28	5.85
6	3112	Deep	1.25	.56	.91
		Shallow	6.77	13.71	10.24
7	991	Deep	.34	1.20	.77
		Shallow	4.51	5.78	5.15
8	1138	Deep	.54	7.01	3.78
		Shallow	5.79	18.63	12.21
9	2957	Deep	1.39	.95	1.17
		Shallow	3.40	4.59	4.00
10	3849	Deep	1.71	.93	1.32
		Shallow	8.95	4.47	6.71
11	4887	Deep	1.20	.55	.88
		Shallow	5.81	3.11	4.46
12	4879	Deep	2.73	1.36	2.05
		Shallow	5.69	5.41	5.55
13	5154	Deep	.83	1.49	1.16
		Shallow	4.61	6.35	5.48

TABLE XXI

CODLING MOTH INJURY - SPY - MASON, MICHIGAN

1935

Plot No.	No. Apples	% Entries	Replication		Mean %
			1	2	
1	4730	Deep	1.17	2.03	1.60
		Shallow	5.84	3.04	4.44
2	3412	Deep	1.79	1.99	1.89
		Shallow	3.72	4.65	4.19
3	2301	Deep	.50	.72	.61
		Shallow	4.71	8.94	6.83
4	702	Deep	3.18	3.69	3.44
		Shallow	5.31	4.62	4.97
5	4095	Deep	3.75	4.51	4.13
		Shallow	14.54	15.77	15.16
6	1605	Deep	1.00	-----	1.00
		Shallow	17.01	-----	17.01
7	1868	Deep	1.34	1.16	1.25
		Shallow	4.03	5.52	4.78
8	2132	Deep	1.12	1.81	1.47
		Shallow	4.73	3.62	4.18
9	4244	Deep	.47	1.84	1.16
		Shallow	2.22	3.23	2.73
10	1918	Deep	2.14	9.34	5.74
		Shallow	8.76	16.54	12.65
11	2778	Deep	1.79	4.46	3.13
		Shallow	13.87	7.38	10.63
12	5583	Deep	2.13	3.21	2.67
		Shallow	6.47	9.03	7.75
13	1004	Deep	3.39	-----	3.39
		Shallow	11.16	-----	11.16

TABLE XXII

CODLING MOTH INJURY - BEN DAVIS - MASON, MICHIGAN

1935

Plot No.	No. Apples	% Deep Entries	% Shallow Entries
1	2574	.08	1.40
2	1298	.46	.77
3	2188	.09	.82
4	1598	0.00	.38
5	1063	1.51	2.16
6	1352	0.00	8.43
7	2398	.25	.92
8	1648	.24	.97
9	1953	.31	.36
10	1682	.36	1.31
11	2896	1.66	2.76
12	1426	.56	2.38
13	1248	.30	2.88

TABLE XXIII
CODLING MOTH INJURY - MASON, MICH.
1935

Plot No.		% Entries				Mean %
		McIntosh	Baldwin	Spy	Ben Davis	
1	Deep	1.15	1.57	1.60	.08	1.10
	Shallow	1.03	5.38	4.44	1.40	3.06
2	Deep	1.80	1.18	1.89	.46	1.33
	Shallow	1.69	3.32	4.19	.77	2.49
3	Deep	1.03	.63	.51	.09	.59
	Shallow	1.06	1.83	6.63	.82	2.64
4	Deep	1.26	.90	3.44	0.00	1.40
	Shallow	.80	4.06	4.97	.38	2.55
5	Deep	4.83	1.54	4.13	1.51	3.00
	Shallow	3.66	5.85	15.16	2.16	6.71
6	Deep	1.50	.91	1.00	0.00	.85
	Shallow	9.61	10.24	17.01	8.43	11.32
7	Deep	1.74	.77	1.25	.25	1.00
	Shallow	2.82	5.15	4.78	.92	3.42
8	Deep	1.76	3.76	1.47	.24	1.81
	Shallow	1.95	12.21	4.18	.97	4.83
9	Deep	.79	1.17	1.16	.31	.86
	Shallow	1.20	4.00	2.73	.36	2.07
10	Deep	1.19	1.32	5.74	.36	2.15
	Shallow	2.02	6.71	12.65	1.31	5.67
11	Deep	4.22	.88	3.13	1.66	2.47
	Shallow	3.52	4.46	10.63	2.76	5.34
12	Deep	3.26	2.05	2.67	.56	2.13
	Shallow	2.57	5.55	7.75	2.38	4.56
13	Deep	----	1.16	3.39	.30	1.62
	Shallow	----	5.48	11.16	2.88	6.51

The results from the Ben Davis variety (Table XXII) are from only one replication in each plot. The control was excellent, for the trees were easily sprayed and the variety resistant to injury.

The data have little significance when considered alone, but when compared with the other results the same relationship of the plots is apparent.

Discussion of Relative Control

Table XXIII includes a summary of the control of each of the two classes of injury on each variety, and the average figure for all varieties.

As the lead arsenate was included for a standard of comparison, the control achieved by this material should first be considered. The mean percentage of deep entries was always comparable with the most effective schedules, but the mean percentage of shallow entries usually exceeded that obtained by the least effective schedule. The mean percentage of deep entries on lead arsenate sprayed plots (all varieties) is .85, that of shallow entries is 11.32.

The soluble and non-volatile series, of Nico-Zin, in plots 1 to 5, gave as good control of deep entries as the lead arsenate schedule, and much better control of shallow entries, except when oil was omitted (in Plot 5.) The inclusion of oil was very important, its omission usually resulted in twice to three times as much injury.

The soluble and volatile series, nicotine sulfate-oil emulsion, resulted in a high percentage of clean fruit, not significantly less than the Nico-Zin oil plots.

The insoluble and non-volatile series, bentonite-nico-

tine combinations called B. L. 155's, have been compared without consideration of rather large, but inconsistent, variations within the series. Omitting this variation, the control by this series surpassed that of the Nico-Zin used alone, but the percentage of each class of injury was greater than in other nicotine schedules. Compared with lead arsenate, it gave fairly significant increases in injured fruit.

Plot 13, in the old orchard only, was a schedule combining bentonite and nicotine in a tank mixed method, but no remarkable control is indicated. An objectionable gelatinous bentonite residue persisted until the fruit was harvested, defeating the purpose of this material as an insecticide.

SUMMARY

In summary, the season of 1935 was characterized by normal temperatures and ample rainfall. The codling moth population was unfavorably affected by climatic conditions, but a moderate population was established.

Three series of materials were tested, under varying conditions.

The first, containing the soluble and non-volatile material Nico-Zin, required the addition of oil (in less than ovicidal concentration) to effect excellent control of deep and shallow codling moth injury. The addition of oil resulted in decrease in color, and increase in rate of dropping. The material has great promise, if an innocuous spreader can be developed.

The second series, combining nicotine sulfate (Black

Leaf 40) with summer oil emulsions, gave excellent control of codling moth injury. No reduction in color, but an increase in rate of dropping, was observed. The nicotine deposit on this series was so low as to indicate considerable ovicidal effect from the concentration of summer oil used.

Some injury to the fruit resulted from any schedule using oil in all cover sprays, and was accompanied by a reduction in photosynthetic activity of the leaves.

The third series, bentonite-nicotine combinations (B. L. 155) gave somewhat poorer control, but in no way injured the fruit or foliage of the tree.

Lead arsenate was used as the standard of comparison, and gave excellent control of deep entries, but the high proportion of stings does not seem desirable in the production of high quality fruit, even though the death of the worm results.

CONCLUSIONS INDICATED BY EXPERIMENTAL RESULTS.

Tests of schedules utilizing the organic insecticide nicotine as the active principle were conducted in 1934 and 1935. Under conditions obtaining in Michigan during those two seasons, certain characteristics are demonstrated by the behavior of the different materials.

Codling moth control is entirely satisfactory when this material is used in cover sprays, provided the interval between sprays does not exceed the period of toxicity of each application. This affords a substitute insecticide for inclusion in the spraying program of growers who find it impractical to attempt removal of arsenical or lead residues.

No environmental effects were encountered in either of the two years which prevented some degree of control with any material tested. However, the data are too limited to make this a definite characteristic, for some materials were found ineffective elsewhere (28), under conditions which might be expected to occur here.

It has been shown that it is possible to modify the nicotine volatilization by certain combinations, and that the deposition of nicotine by each spray is proportional to the control of codling moth, except when materials used in modification are in themselves insecticides.

A definite effect of sprays applied to the foliage and fruit has been demonstrated, the toxicity resulting either from some components of the combinations applied, as in the case of sulfur, or oil in the oil-nicotine combination, or from the resultant combination as in the case of Nico-Zin-

oil, or by the position in the schedule of different materials, as in the case of oil following sulfur applications. The complete elimination of injury is also possible as in the case of the bentonite-nicotine combinations used in 1935.

SUMMARY

These experiments indicate that no more practical nicotine combination than summer oil and nicotine sulfate was tested. Control of both types of codling moth injury, and production of satisfactory quality fruit was best achieved by this material. However, other materials will give either better codling moth control, or less injury, or better quality fruit, or higher photosynthetic activity, with resultant increase in quality, or longer retention of toxicity.

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