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EFFECT OF SPRAY TREATMENT ON FOLIAGE INJURY, PEST CONTROL, AND YIELD AND QUALITY OF APPLES

By E. J. RASMUSSEN, W. TOENJES and F. C. STRONG

MICHIGAN STATE COLLEGE
AGRICULTURAL EXPERIMENT STATION
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EAST LANSING

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Effect of Spray Treatment on Foliage Injury, Pest Control, and Yield and Quality of Apples

By E. J. RASMUSSEN,[1] WALTER TOENJES, and F. C. STRONG

The toxicity of spray and dust materials to insects and disease organisms was at first considered the important property of fungicides and insecticides. In their early development, little consideration, if any, was given to the effect of these materials on the host. Bordeaux was one of the first materials found to be effective for apple scab control. It often caused severe defoliation and russeting of fruit and under certain weather conditions the injury caused by an application of bordeaux was more serious than that caused by the disease (3) (5).

Paris green (2) was one of the first materials suggested for codling moth control and, likewise, it sometimes caused severe injury to fruit and foliage. It became evident at the turn of the century that materials which would cause less injury to the plant and give a satisfactory control of pests must be developed if good crops of high quality apples were to be produced.

About 1907 lime-sulfur (3) was found to be effective for scab control and to cause less injury than bordeaux. It soon replaced bordeaux for scab control and continued to be the standard fungicide on apples for over 30 years.

The preparation of lead arsenate (2) about 1889 and the good results obtained with this material resulted in its entirely replacing paris green as a stomach poison on apples by 1906.

Later, about 1925, the work of Magnus (8) and Haller and Magnus (4) on the relation of leaf area to growth and composition of apples emphasized the importance of good foliage in the development of quality fruits. The work of Hoffman (6) (7) and Christopher (1) in 1933 showed that spray treatment influenced the capacity of apple foliage to manufacture plant food by interfering with the car-

[1]Resigned February 1947. Now Extension Horticulturist, University of New Hampshire, Durham.

bon dioxide intake. This work, along with the low price for apples and the need for economical production, helped to make research workers and orchardists recognize the need for still less caustic spray materials which would control orchard pests.

The effect of spray treatment on quality and finish of fruit, yield and foliage injury was recognized by the Department of Horticulture as an important one to the Michigan grower. Information on the effect of spray treatment on apples under field conditions appeared worthwhile and in 1937 the work here reported was started. The project was continued until 1946, though a progress report was made in 1943 (9).

SPRAYING EXPERIMENTS AT THE GRAHAM STATION

Preliminary spraying experiments were started in 1938. Two varieties, Northern Spy and Delicious, were used in these experiments.

EXPERIMENTS ON NORTHERN SPY

A block of 19-year-old Northern Spy trees which had been sprayed previous to 1938 with a lime-sulfur, lead arsenate schedule for a number of years, and which had a moderately low production record, sometimes bearing a commercial crop only once in 3 years, was divided into five plots in 1939 and sprayed with the materials outlined in Table 1. Each plot received the same treatment for 5 consecutive years.

Prior to this study it was observed that some of the most successful growers of Northern Spy in Michigan continued to apply bordeaux

TABLE 1—*Effect of several spray treatments on defoliation and on quality of Northern Spy apples, 1939 to 1943, inclusive*

Treatments	Average number leaves per 100 spurs	Percent					Weight 100 apples in pounds
		Scab		Finish			
		Early	Late	Rough skin	Russet	Smooth finish	
Lime-sulfur, 2–100	474	8.1	1.1	19.3	1.2	79.5	48.8
Lime-sulfur—wettable sulfur, 1–4–100	508	12.7	3.3	14.4	1.5	84.1	48.0
Wettable sulfur, 8–100	603	12.7	13.8	17.00	2.6	80.4	44.3
Kolofog, 6–100	585	17.6	24.1	13.4	1.1	85.5	42.4
Apple Coposil-lime, 2–4–100	643	29.0	3.6	37.7	5.8	56.5	48.5

Fig. 1. Northern Spy tree showing the typical vigorous and abundant foliage in the wettable-sulfur- and copper-lime-sprayed plots. This foliage remained on the trees until late in the season. Foliage of this type encourages uniform distribution and production of fruit throughout the tree. Compare with Fig. 2. (Photographed October 15, 1945.)

for scab control and that this variety appeared more resistant to copper injury than some other varieties, as Jonathan and McIntosh. Consequently, in setting up the preliminary spray program for 1938, bordeaux was included as was also a new proprietary copper material which shortly before had appeared on the market. A third plot was sprayed with liquid lime-sulfur.

The effect of these materials, applied in 1938, on the 1939 yield is of interest. The lime-sulfur plot yielded an average of 87 pounds of fruit per tree in 1939, the bordeaux plot 121 pounds per tree, and the proprietary copper plot 519 pounds per tree. These results gave the first indication that fungicides influence fruit bud formation and yields the season following their application.

Starting in 1939, the spray schedule was revised. Bordeaux was excluded from the program because of the rather severe fruit russeting it caused in 1938. Several forms of wettable sulfur were included

in the new program. All fungicide applications were started in the delayed dormant period and were continued at 8- to 12-day intervals until the first or second cover application. All plots were completely sprayed on the same day whenever possible. Lead arsenate and fixed nicotine were included for codling moth control when needed. About 20 gallons of spray was applied per tree at each application. The old lime-sulfur timing schedule was followed in all plots because the main interest in the project was to determine the effect of the several materials used on yield and quality of fruit.

The effect of spray treatment on quality of Spy apples, on defoliation, and on scab control likewise is shown in Table 1. The average number of leaves per 100 spurs, during late August or early September, was largest on the copper-sprayed trees and smallest on the lime-sulfur-sprayed trees, 643 to 474, respectively. The Northern Spy variety being susceptible to arsenical injury, the arsenical correc-

Fig. 2. Northern Spy tree showing the comparatively sparse foliage in the lime-sulfur plot. Premature defoliation caused by lime-sulfur, particularly on the less vigorous lower and inside branches, is largely responsible for the less uniform distribution of fruit throughout the tree and the lighter tree yields obtained. Fruit produced on this kind of branches is smaller in size and lacks desired color. Compare with Fig. 1. (Photographed October 15, 1945.)

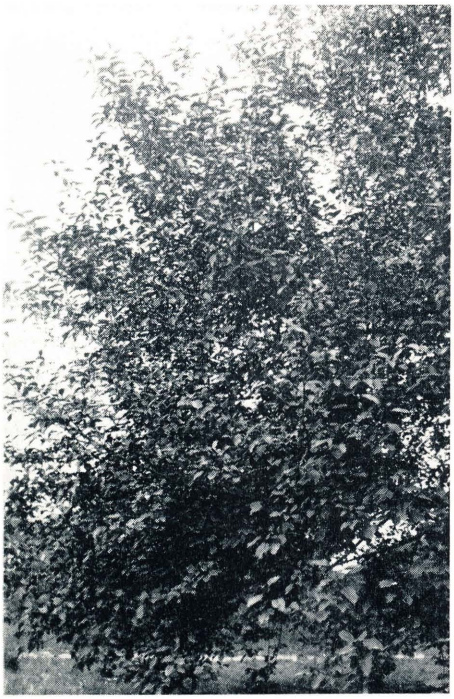

Fig. 3. Close-up sectional view of a Northern Spy tree representing the type of foliage found in the plots sprayed with the less caustic fungicides. Compare with Fig. 4. (Photographed October 15, 1945.)

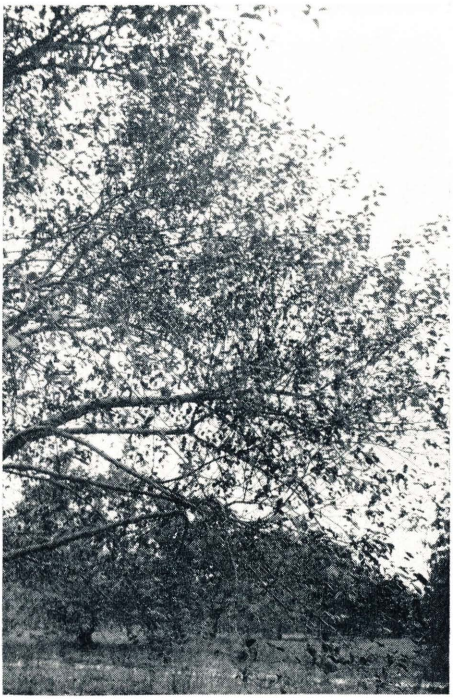

Fig. 4. Lime-sulfur spray injury was responsible for this typical premature defoliation on Northern Spy. Trees and branches in this condition do not induce maximum and consistent fruit production. Compare with Fig. 3. (Photographed October 15, 1945.)

tive action of the copper-lime combination was partially responsible for this difference. The foliage on the copper-sprayed trees also was larger and darker green in color when compared with that of the lime-sulfur plots. There was more defoliation on the wettable-sulfur-sprayed trees when compared with that on the copper-sprayed trees but not so much as in the lime-sulfur-sprayed plots.

The control of apple scab varied from year to year and with different treatments. The amount of scab-infected fruit shown in Table 1 is not so serious as it first appears since a fruit was considered infected regardless of size or number of scab spots. Much of the scab occurred as late-season or pin-point infection which did not materially affect the market value of the fruit.

Lime-sulfur gave the best control of scab, with an average of 9.2 percent scabby at harvest time. The average amount of scabby fruit on trees sprayed with other materials varied from 16.0 to 41.7 percent. Late infection was most serious on the wettable-sulfur- and Kolofog-sprayed plot, indicating that these materials were not effective over as long a period as the other products. These results on scab control emphasize the importance of more frequent and timely applications when using the less caustic materials.

The amount of russet and poor finish on the fruit also varied in different years and with different treatments. Less fruit with a smooth glossy surface was produced on trees sprayed with the copper materials, 56.5 percent compared with 79.5 percent on the lime-sulfur plots, and 80.4 percent on the wettable-sulfur-sprayed trees. It was observed that the trees with the light crops produced a larger percentage of the fruit with a rough finish than did trees producing heavy crops, also, that somewhat more fruit russeting occurred in the copper-sprayed plot during the cooler seasons than in the warmer seasons.

The finish of the fruit is important especially if it is to be placed in storage, since fruit with a glossy smooth skin loses less moisture in storage, consequently shrivels less and has a better appearance. The effect of finish on Spy apples on storage quality is shown in Table 2.

The effect of spray treatment on the yield of Northern Spy is shown in Table 3. During the 5-year period, trees sprayed with lime-sulfur, 2 gallons in 100, produced an average of 1,674 pounds of fruit per tree. Trees sprayed with a combination of lime-sulfur and wettable sulfur yielded 2,130 pounds, or an increase of 27.2 percent more than the lime-sulfur plot. The plots receiving spray applications of

TABLE 2—*Effect of finish on apple storage quality, 1941 Northern Spy*

Quality of finish	Percent loss in weight			
	Oct. 25	Dec. 12	Feb. 12	Mar. 12
Slight to heavy russet	harvested	4.55	9.35	12.00
No russet, smooth, glossy finish	harvested	3.95	6.28	7.63
Difference in percent loss		0.60	3.07	4.37

This greater percentage loss in weight on russeted fruit of 3.07 and 4.37 on February 12 and March 12 may seem small when considered on a bushel basis; but when figured on a 1,000-bushel crop, it represents a loss of over 30 bushels by February 12 and nearly 44 bushels by March 12.

TABLE 3—*Effect of spray treatment on yield of Northern Spy, 1940 to 1944, inclusive*

Plot No.	Spray treatment, 1939-43, inclusive	Average tree yield in pounds, 1940-44, inclusive	Percent yield increase over Plot No. 1
1	Lime-sulfur, 2–100	1,674	
2	Lime-sulfur—wettable sulfur, 1–4–100	2,130	27.3
3	Wettable sulfur, 8–100	2,151	28.5
4	Kolofog, 6–100	2,263	35.2
5	Apple Coposil-lime, 2–4–100	2,570	53.5

the less caustic wettable sulfur and Kolofog materials, produced 2,151 and 2,263 pounds respectively, an increase of 28.5 and 35.2 percent. The largest average yield per tree in this experiment was obtained on the trees sprayed with Apple Coposil and lime; here the increased yield amounted to 53.5 percent greater than in the lime-sulfur plot.

The close planting in the orchard made it necessary to remove half of the trees in the spring of 1944. The plots were then rearranged in such a way that the new treatments crossed the former plots. Some information, in addition to that acquired in the preceding 5 years, could then be obtained as to the residual effect of the previous spray treatments on the performance of the trees sprayed with a different material.

The residual effect of the 1944 spray treatment first became evident in the spring of 1945 when the trees came into bloom. Trees sprayed in 1944 with the less caustic wettable sulfur and copper materials had a heavy bloom, while those sprayed with lime-sulfur had only a light-to-moderate bloom. Following the same spray program again in 1945, similar differences among plots in the amount of bloom present in 1946 were once more in evidence as shown in Fig. 5.

Tree yields for 1945 and 1946 are given in Table 4. The light crop in 1945 was due to low temperatures which killed many of the blossom buds, and to the very unfavorable pollinating conditions which followed during the balance of the blooming period. However, the differences in the tree yields among plots are more or less in proportion to the abundance of blossom buds present in the different plots during the spring of 1945. Further, the amount of bloom in 1945 indicates that the previous spray treatments, applied prior to 1944, did not

1 2 3 4 5

Fig. 5. Air view of Northern Spy trees showing varying amounts of bloom in the different spray plots in 1946, following application of different fungicides in 1945. Rows 1 and 4 from left, showing the heaviest bloom, were sprayed with Coposil-lime 2-4-100. Rows 2 and 5 with somewhat lighter bloom received wettable sulfur sprays 8-100. The row in the middle was sprayed with liquid lime-sulfur 2-100. The extremely light bloom in the liquid lime-sulfur plot in 1946 was not typical of previous years. However, it does demonstrate what effect caustic fungicides can and do have on the formation of fruit buds and ultimate yields. (Photographed May 9, 1946.)

appear to influence the performance of the trees for more than one year following, since the different treatments are in the same order in relation to production of fruit as they were in the previous experiment.

TABLE 4—*Residual effect of spray treatment on yield of Northern Spy*

1944 spray treatment	1945 average tree yield in pounds	1945 spray treatment	1946 average tree yield in pounds
Lime-sulfur, 2–100	29	Lime-sulfur, 2–100	381
Wettable sulfur, 8–100	97	Wettable sulfur, 8–100	1,063
Apple Coposil-lime, 2–4–100	184	Apple Coposil-lime, 2–4–100	1,314

TABLE 5—*Summary of spray treatment on Delicious, average 1940-44, inclusive*

Treatment	Percent					Number leaves per 100 spurs	Weight 100 apples in pounds
	Good finish	Russet		Scab			
		Light	Severe	Early	Late		
Lime-sulfur, 2–100	81.4	16.1	2.5	5.7	5.4	562	40.3
Lime-sulfur, 1–100	93.9	5.2	0.9	9.3	20.4	595	32.8
Wettable sulfur, 8–100	93.3	5.5	1.2	11.8	14.9	655	29.6
Flotation sulfur paste, 14–100	92.3	7.7	1.0	7.9	13.3	669	30.7

EXPERIMENTS ON DELICIOUS 1940-44

A block of 16-year-old Red Delicious trees was divided into four plots and sprayed with different concentrations of lime-sulfur and of wettable sulfur as shown in Table 5.

The Red Delicious variety is not easy to grow under Michigan conditions. It requires more attention to cultural practices than such varieties as McIntosh and Jonathan. Under ordinary treatment the foliage is often small and the tendency is toward biennial bearing. Probably one of the reasons for poor foliage is the injury caused by the potato leafhopper, especially to leaves on shoot growth. The injury results in dwarfing and curling of the leaves. The Delicious is also a favorite of red mite, and the feeding injury of this pest may contribute to poor foliage.

The effect of lime-sulfur on quality of fruit, size of foliage, and amount of defoliation is similar to that found on Spy when compared with other sulfur fungicides. Trees sprayed with lime-sulfur 2-100 produced fruit of poorer quality and yielded less than trees sprayed with wettable sulfurs. Lime-sulfur applied at the rate of 1 gallon to 100 gallons of spray gave poor control of scab and caused nearly as much defoliation as lime-sulfur 2-100. Trees sprayed with wettable sulfur and flotation sulfur paste produced fruit of good finish and keeping quality but these materials were not so effective as lime-sulfur for scab control. Late scab infections caused more injury to the fruit in 2 years out of the 5 than did early infection. Later and more frequent application of wettable sulfurs would no doubt have reduced the loss from this disease.

TABLE 6—*Effect of spray treatment on yield of Delicious, 1940 to 1944, inclusive*

Plot No.	Spray treatment, 1939-43, inclusive	Average tree yield in pounds, 1940-44, inclusive	Percent yield increase over Plot No. 1
1	Lime-sulfur, 2–100	1,223	
2	Lime-sulfur, 1–100	1,593	30.2
3	Wettable sulfur, 8–100	1,619	32.4
4	Flotation sulfur paste, 14–100	1,666	36.2

The effect of spray treatment on the yield of Delicious for the years 1940 to 1944 inclusive, follows the same general trend as that found on Northern Spy. Trees sprayed with 2 gallons of lime-sulfur in 100 likewise had the lightest bloom and produced the smallest yields, as shown in Table 6. Although reducing lime-sulfur 1 gallon in 100 increased the tree yield by 30.2 percent over that of the former treatment, it was not satisfactory in other respects, as previously mentioned. The wettable sulfur and flotation sulfur plots yielded 32.4 and 36.2 percent more fruit, respectively, than did the trees sprayed with lime-sulfur 2 gallons in 100. In the case of the flotation sulfur plot the increase in yield over the wettable sulfur plot probably should not be attributed solely to the material used. The trees in this plot were growing adjacent to rows of mixed varieties of apples which would provide more favorable conditions for cross pollination of the blossoms.

The increased yields obtained from the trees sprayed with the milder and less caustic materials are significant. The results decidedly bring out the fact that fungicides which severely injure apple foliage will likewise materially reduce potential fruit yields. Good orchard practices that will promote and maintain apple trees in a vigorous condition, carrying an abundance of healthy and uninjured foliage throughout the season, are essential for maximum and consistent production of apples. Practices that do not encourage or bring about these conditions, reduce the ultimate profits to the grower.

SPRAYING EXPERIMENTS AT PAW PAW 1942-44

In 1942 the project was expanded to include experimental work in commercial orchards at Paw Paw in order to obtain similar information on varieties other than Spy and Delicious.

The project at Paw Paw was outlined to run for 5 years, but because of a crop failure in 1945 it was discontinued after 3 years.

This work was conducted in the orchards of John G. Woodman and Warren Woodman. Four varieties, McIntosh, Jonathan, Spy and Rhode Island Greening, were included.

A comparison was made of lime-sulfur and wettable sulfur in relation to yield, finish of fruit, and scab control. A lead arsenate-zinc sulfate-lime schedule and a lead arsenate-fixed nicotine schedule was included for codling moth control.

In 1942 and 1943 Magnetic 70 paste, 7 to 10 pounds to 100 gallons, was used on Jonathan and McIntosh; flotation sulfur paste 10 to 14 pounds to 100 gallons was used on Jonathan, McIntosh, Spy, and Rhode Island Greening; Magnetic dry wettable sulfur, 5 to 10 pounds to 100 gallons on Rhode Island Greening; 3M dry wettable sulfur 5 to 8 pounds to 100 gallons; and lime-sulfur 1½ to 2 gallons to 100 gallons on all four varieties. In 1944, 3M dry wettable sulfur was substituted for the Magnetic 70 paste.

The spray schedule outlined in "The Spraying Calendar," Michigan Extension Bulletin 154, was followed as closely as possible. The number of applications of a fungicide varied from 6 to 11 per season depending upon weather conditions, and rate of growth of the fruit and foliage. More applications were made during cool seasons when the growth was slow than during warm seasons when the growth was rapid. The wettable sulfur schedule for example in 1943 which produced a McIntosh crop 11 to 12 percent scabby, but all marketable, and almost a perfect crop on other varieties, consisted of a delayed-dormant, April 27; pre-pink, May 4; early pink, May 10; pink, May 13; in-bloom, May 22; calyx, May 27; first cover, June 7; second cover, June 25; and a fifth cover, August 11. No fungicide was used in the third- and fourth-cover applications. The early pink spray consisted of a double-strength wettable sulfur to the upper half or third of the tree only, because there had been considerable rainy weather. Ten to 15 gallons of spray was applied per application per tree, the larger amount being applied later in the season when there was more foliage on the trees. The excellent control of scab on such varieties as Jonathan and Rhode Island Greening indicate that such a heavy spray schedule as outlined for McIntosh would not be necessary.

There was some leafhopper and red mite injury in the orchards in some seasons but not enough to warrant control measures.

The effect of spray treatment on yield on McIntosh, Jonathan, Spy, and Rhode Island Greening is shown in tables 7, 8, 9, and 10.

TABLE 7—*Average yield per tree in bushels, picked and dropped McIntosh apples. Sprayed with lime-sulfur and wettable sulfur schedules*

Year	Materials applied					
	Lime-sulfur			Wettable sulfur		
	Average number bushels per tree			Average number bushels per tree		
	Picked	Drops	Total	Picked	Drops	Total
1942	13.4	6.5	19.9	15.9	7.4	23.3
1943	9.1	3.4	12.5	15.7	8.0	23.7
1944	17.5	6.3	23.8	15.1	4.9	20.0
Average for 3 years	13.3	5.4	18.7	15.6	6.7	22.3

TABLE 8—*Average yield per tree in bushels, picked and dropped Jonathan apples. Sprayed with lime-sulfur and wettable sulfur schedules*

Year	Materials applied					
	Lime-sulfur			Wettable sulfur		
	Average number bushels per tree			Average number bushels per tree		
	Picked	Drops	Total	Picked	Drops	Total
1942	12.4	2.3	14.7	15.5	2.1	17.6
1943	10.5	0.8	11.3	15.2	2.3	17.5
1944	12.2	0.3	12.5	9.7	0.5	10.2
Average for 3 years	11.7	1.1	12.8	13.5	1.6	15.1

TABLE 9—*Average yield per tree in bushels (42 pounds per bushel) of picked and dropped Northern Spy apples, sprayed with lime-sulfur and wettable sulfur schedules*

Year	Materials applied					
	Lime-sulfur			Wettable sulfur		
	Average number bushels per tree			Average number bushels per tree		
	Picked	Drops	Total	Picked	Drops	Total
1942	11.59	2.66	14.25	12.27	2.5	14.77
1943	2.8	.....	2.80	6.38	0.16	6.54
1944	9.83	1.88	11.71	11.47	1.37	12.84
Average for 3 years	8.07	1.51	9.58	10.04	1.34	11.38

TABLE 10—*Average yield per tree in bushels (42 pounds per bushel) of picked and dropped Rhode Island Greening apples, sprayed with lime-sulfur and wettable sulfur schedules*

Year	Materials applied					
	Lime-sulfur			Wettable sulfur		
	Average number bushels per tree			Average number bushels per tree		
	Picked	Drops	Total	Picked	Drops	Total
1942	4.40	.....	4.4	6.33	.....	6.33
1943	5.97	0.23	6.2	6.86	0.34	7.20
1944	10.43	0.67	11.1	16.60	1.1	17.70
Average for 3 years	6.93	0.30	7.23	9.93	0.48	10.41

The biggest loss in crop as shown in these tables is the large amount of dropped fruit every year on some varieties. This drop amounted, on the average, to nearly 30 percent on McIntosh, 10 on Jonathan, about 15 on Spy, and about 5 percent on Rhode Island Greening. The reason for the small amount of drop on this latter variety is because it was not necessary to wait for color in order to obtain good market quality. The crop was usually harvested just before any dropping of the fruit was anticipated.

The effect of spray treatment on yield on all varieties is similar to that found on Spy and Delicious in the experiment at the Graham Station. Lime-sulfur, when applied at the concentration and the interval used, caused a marked reduction in yield on all varieties. It has often been stated that the McIntosh variety is resistant to spray injury but it was found that the wettable-sulfur-sprayed plots produced nearly 20 percent more fruit for the 3-year period than did the lime-sulfur plots. In 1943 the yield was nearly double on the wettable-sulfur-sprayed trees when compared with the lime-sulfur-sprayed trees. The greatest increase in yield was in the Rhode Island Greening where the wettable sulfur plots produced 44 percent more fruit per tree than did the lime-sulfur plot. The Spy and Jonathan trees sprayed with wettable sulfur produced on the average for the 3 years about 18 percent more than the trees sprayed with lime-sulfur.

The reduction in yield on all varieties, attributed to the use of lime-sulfur sprays, is no doubt due to a dwarfing of foliage and reduction in food manufacture for a period after each application and to defoliation. Material and spray schedules which will produce the best foliage also produce the largest crops of good quality fruit.

EFFECT OF SPRAY TREATMENT ON SCAB CONTROL, ON FRUIT, AND ON DEFOLIATION

The effect of spray treatment on scab control on fruit and defoliation is shown in tables 11, 12, and 13.

TABLE 11—*Effect of spray treatment on scab control on fruit and on foliage injury of the McIntosh variety*

Year	Materials applied								
	Lime-sulfur			Wettable sulfur			Flotation sulfur paste		
	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs
	Early	Late		Early	Late		Early	Late	
1942	2.6	15.3	764	1.2	4.0	805	5.7	18.3	801
1943	0.9	10.5	738	6.6	6.2	848	5.1	12.7	800
1944	1.0	0.2	840	2.6	.....	832	4.5	.....	825
Average for 3 years	1.5	8.6	781	3.5	3.4	828	5.1	10.3	809

Leaf counts made Sept. 4, 1942; Sept. 16, 1943; Aug. 17, 1944.

TABLE 12—*Effect of spray treatment on scab control on fruit and on foliage injury of the Jonathan variety*

Year	Materials applied								
	Lime-sulfur			Wettable sulfur			Flotation sulfur paste		
	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs
	Early	Late		Early	Late		Early	Late	
1942	0.3	.....	731	0.3	.....	759	0.3	.....	793
1943	0.3	.....	619	0.2	.....	789	0.5	.....	728
1944	trace	.....	621	0.7	.....	766	trace	.....	729
Average for 3 years	0.2	.....	657	0.4	.....	771	0.3	.....	750

Leaf counts made Sept. 4, 1942; Sept. 16, 1943; Aug. 17, 1944.

TABLE 13—*Effect of spray treatment on scab control on fruit and on foliage injury of the Rhode Island Greening variety*

Year	Materials applied								
	Lime-sulfur			Wettable sulfur			Flotation sulfur paste		
	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs	Percent scab		Number leaves per 100 spurs
	Early	Late		Early	Late		Early	Late	
1942	.....	.....	566	.....	.....	528	.....	.....	603
1943	.....	.....	392	.....	.....	358	.....	.....	382
1944	trace	.....	583	trace	.....	570	.....	.....	620
Average for 3 years	trace	.....	514	trace	.....	485	.....	.....	535

Leaf counts made Sept. 5, 1942; Sept. 15, 1943; Aug. 18, 1944.

The amount of scab infection varied from year to year, and with the different varieties. As previously stated, 6 to 11 applications of a wettable sulfur were applied per season for scab control. Five to 8 applications of a fungicide were applied to the lime-sulfur plots. Magnetic 70 paste was used on McIntosh in 1942 and 1943. It gave better control of scab than either lime-sulfur or flotation sulfur paste and caused less defoliation than lime-sulfur. In 1944 lime-sulfur gave slightly better control of scab on McIntosh than 3M dry wettable sulfur or flotation sulfur paste. No scab was found on Rhode Island Greening with any of the treatments. Magnetic dry wettable sulfur, a material which has not been generally suggested for scab control, was found to cause the greatest amount of defoliation as compared with the other spray treatments used on Rhode Island Greening. This variety is subject to defoliation in late summer and it occurs to about the same degree regardless of spray treatment. No satisfactory explanation has been given as to the cause of this defoliation.

The fruit of the Jonathan variety is somewhat resistant to scab infection although the foliage is susceptible, and may be severely infected in some years. The spray schedules used in these experiments gave excellent control of scab on both fruit and foliage on Jonathan. All of the treatments yielded fruit practically free from scab. The lime-sulfur schedules, however, caused more defoliation than the wettable sulfur schedules (567 leaves per 100 spurs compared with 750 leaves per 100 spurs on the wettable sulfur plots).

TABLE 14—*Percentage of McIntosh apples infected with scab on trees sprayed with different fungicides*

Materials applied	Amount in 100 gallons of spray	Percent of fruit infected
Flotation sulfur paste and Orthex	8 to 14 lb.—1 pt	1.8
Lime-sulfur	2 gal.	2.1
3M wettable sulfur and Orthex	5 to 8 lb.—1 pt	2.3
Fermate	1½ lb.	2.4
3M wettable sulfur	5 to 8 lb.	2.8
Dithane	1½ lb.	4.2
Flotation sulfur paste	8 to 14 lb.	7.1

EXPERIMENTS IN 1944 WITH SEVERAL FUNGICIDES

Although it was not a difficult year in which to control apple scab, in 1944 this disease caused some injury to fruit. The failure by many growers that year to control scab was likely due to poor coverage or improper timing, since all of the materials applied in the experimental plots gave satisfactory control.

Table 14 summarizes the results of experimental spraying on McIntosh for scab control in 1944.

All of the materials gave a commercial control of apple scab. The plots sprayed with wettable sulfur, Fermate and Dithane received seven applications. The lime-sulfur plots received three applications of lime-sulfur and three applications of a wettable sulfur. All plots received an in-bloom spray. This was the first year that Orthex was used as a flocculator and deposit builder with wettable sulfur. It increased the effectiveness of flotation sulfur paste for scab control. The fruit on trees sprayed with flotation sulfur paste and Orthex showed 1.8 percent scab, while trees sprayed with the paste only, 7.1 percent of the fruit was infected. The use of Orthex with 3M wettable sulfur did not improve its value significantly in scab control. Fermate and Dithane were comparable to wettable sulfur in scab control. None of the materials caused any noticeable defoliation.

EXPERIMENTS IN 1945 WITH SEVERAL FUNGICIDES

Table 15 is a summary of the results of experimental work in 1945 on scab control on McIntosh.

Because of a crop failure in 1945 in this orchard, due to bud-killing temperatures and poor pollinating weather during the blooming period, the effect of the material had to be measured on the foliage. Since there was no crop, the first-cover application applied on May 11 was the last spray applied for scab control. At this time the foliage was practically free from scab infection. Growth of the leaves, however, was not complete on May 11 and later favorable weather for scab development resulted in severe infection to the foliage and defoliation of many of the leaves formed after that date. In the spraying calendar it has previously been suggested that sprays for the control of scab on foliage should be continued through the first- or second-cover application. From the results of this year's work a better recommendation would be to continue the scab sprays as long as there is any increase in leaf growth. It is not safe for any of the foliage to be left unprotected as long as there is a source of scab spores either in the old leaves or as a new infection on the foliage on the trees.

The data in Table 15 show that all materials except Isothan Q15 and flotation sulfur paste when used without a sticker gave similar control. Puratized N5E is a promising new material but because it contains mercury it cannot be considered safe to use until more is known about the amount of residue deposited when several sprays are applied for scab control. Fermate was used for 4 consecutive years in Michigan for scab control, and is comparable to wettable sulfurs. Dithane was used for the first time in liquid form this year. It caused some dwarfing of foliage and requires further testing. Isothan Q15 is of no value in scab control in its present form.

TABLE 15—*Effect of several fungicides on scab control on McIntosh foliage, 1945*

Materials applied	Amount in 100 gallons of spray	Percentage of foliage scabby on June 8
Lime-sulfur	2 gal	12.8
Puratized N5E	½ pt	7.3
Fermate	1½ lb	12.7
Dithane, zinc sulfate, lime	2 qt.—1½ lb	14.8
3M wettable sulfur	5 to 8 lb	19.2
3M wettable sulfur and Orthex	5 to 8 lb.—1 pt	6.8
Flotation sulfur paste	10 to 14 lb	32.8
Flotation sulfur paste and Orthex	10 to 14 lb.—1 pt	13.5
Isothan Q15	1 pt	35.3

FINISH OF FRUIT

The finish of the fruit (that is the glossiness or roughness or amount of russet on the surface of the apple) is as important in the appearance and keeping quality of the apple as is the control of orchard pests. Fruit with a smooth, glossy surface is more attractive and keeps longer in storage because it does not lose moisture as fast as fruit with a rough or russeted surface. The effect of spray on the finish and storage quality of Spy apples is shown in Table 2.

The finish of the fruit in the spray plots at Paw Paw varied from year to year. In 1942 the finish was excellent on all of the varieties. In 1943, McIntosh apples showed a cork-like russet on 21.5 percent of fruit on trees sprayed with wettable sulfur, and 32.4 percent on fruit on trees sprayed with lime-sulfur. A similar amount of poorly finished fruit was found on Jonathan. Baldwin and Delicious were

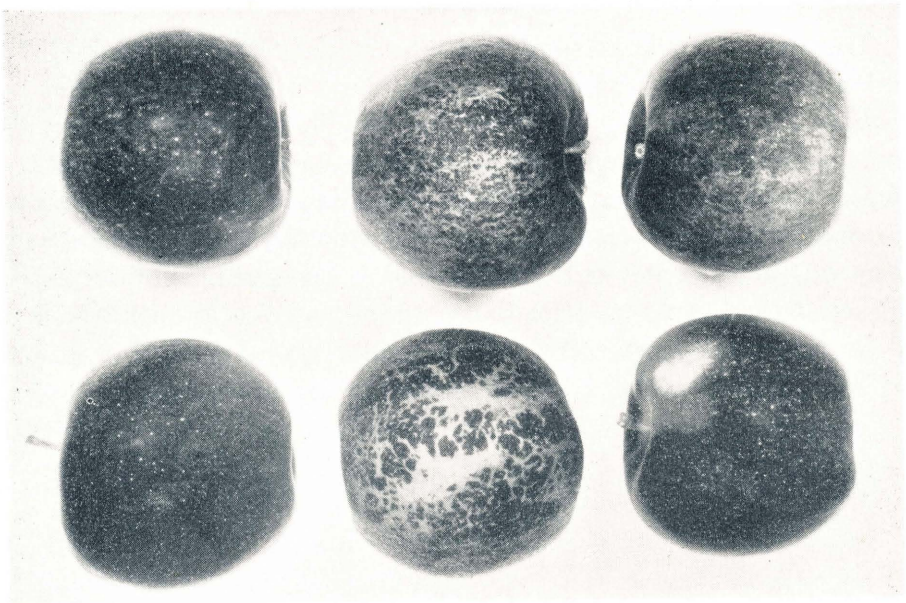

Fig. 6. Spray injury on Jonathan. The glossy finished fruits on the left were sprayed with sulfur fungicides throughout the season. The two heavily russeted fruits in the middle received three early applications—pre-pink, pink, calyx—of a proprietary copper-wettable sulfur-lime combination, and a sulfur fungicide in the cover spray. The two apples on the right were sprayed with a sulfur fungicide in the early applications, and a proprietary copper-wettable sulfur-lime combination in two cover applications.

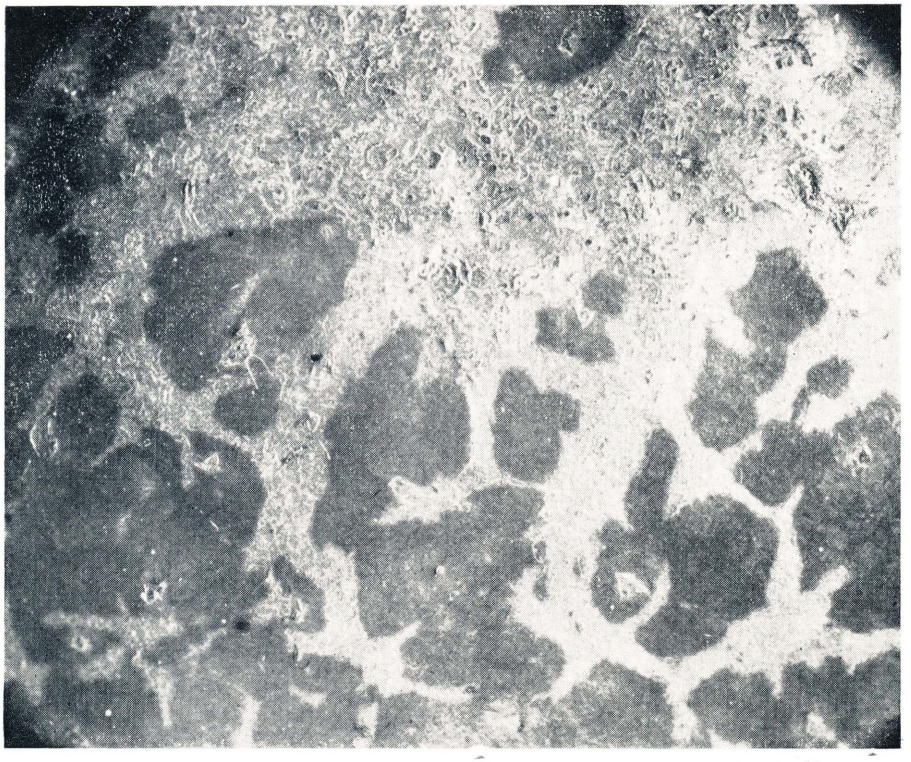

Fig. 7. Spray injury on McIntosh. The dark areas are glossy and smooth, and the wax-like surface retards the loss of moisture from the fruit. The light areas are rough and cork-like in appearance, and show many checks and cracks. These areas have lost the normal moisture protecting surface found on fruit with a glossy finish. (Enlarged about 5 times.)

severely russeted in 1943, while Spy and Rhode Island Greening were practically free from such injury. Spray treatment influences the finish of apples. The less caustic materials cause less injury. (Figs. 6-7.) Weather conditions, however, appear to be the biggest factor influencing the amount of russet or roughness of the surface of apples since the finish of apples varies more from year to year than it does from the effect of different spray treatments.

EXPERIMENTS ON THE APPLICATION OF MATERIAL FOR PROLONGING THE HARVEST PERIOD 1944

The early dropping of fruit, especially on such varieties as McIntosh before they have attained the desired amount of color, causes a greater loss to the grower than injury from scab, codling moth or

spray injury. The development of materials (forms of naphthalene acetic acid) which will delay the dropping of apples has made it possible to reduce this loss in some seasons. High temperatures at harvest time such as occurred in 1944 are favorable for early ripening, and it is under such conditions that the use of these "stop drop" sprays are most effective. The results of experimental spraying of McIntosh, using different concentrations of materials, are shown in Table 16.

TABLE 16—*The effect of pre-harvest sprays of naphthalene acetic acid at different concentrations on McIntosh in delaying the pre-harvest drop*

Treatment	Number of apples picked up per tree at intervals in hours indicated										Percent of crop in drops
	24	72	96	144	168	192	216	240	268	288	
Check	42	125	75	61	51	91	81	106	146	106	28.2
10 ppm	36	77	41	24	6	10	8	9	40	46	9.5
20 ppm	42	60	24	9	5	7	9	20	47	34	8.5
35 ppm	39	71	29	9	4	7	8	14	40	20	7.7
50 ppm	51	68	28	7	4	5	6	8	34	27	7.7

The percentage of the crop in the drops was calculated on the average of 3,126 apples on a tree when sprayed.

The tree sprayed with 10 ppm., which is the recommended concentration, received two applications, the first September 8, the second September 15. The trees receiving the higher concentrations received one spray September 8. Harvesting was started September 11 and finished September 22. Twenty to 25 gallons of spray was applied per tree per application. From the data it is seen that the sprays did not become effective in retarding the dropping of apples until 72 to 96 hours after application, and that they then remained effective for 7 to 8 days. The average drop per tree during the harvest period of the check trees was 5.5 bushels or 28.2 percent of the crop; of the trees receiving two sprays of 10 ppm., 1.8 bushels or 9.5 percent; of the trees receiving one spray of 20 ppm., 1.6 bushels or 8.5 percent, and of the trees receiving one spray of 35 ppm. and 50 ppm., 1.5 bushels or 7.7 percent of the crop. The unsprayed trees lost more apples during the first 5 days of the experiment than did the sprayed trees during the 11-day harvest period. A spray of 20 ppm. was as effective as two applications of 10 ppm. Sprays containing concentrations of 20 ppm. and higher became effective sooner than sprays containing 10 ppm.

COST OF SPRAY TREATMENT

Since the control of diseases and insects in an orchard is the most expensive orchard operation prior to harvest, information on the cost of materials used in the different spray treatments in 1943 is of interest. Table 17 shows the average cost of material, and the number of gallons of spray applied per tree and per bushel of picked fruit and total yield.

TABLE 17—*Average number of gallons applied per season, and average cost of materials per tree and per bushel picked and total yield of plots sprayed with different spray treatments*

	Spray treatment			
	Lime-sulfur five sprays, Wettable sulfur four sprays		Wettable sulfur eleven sprays	
	Number of gallons applied	Cost	Number of gallons applied	Cost
Per bushel total yield	9.3	$0.081	6.1	$0.058
Per bushel picked yield	12.5	0.108	8.4	0.081
Per tree	113.5	0.987	131.6	1.26
Value of fruit	.....	$13.65	.....	$23.55

Because of the large yield on the wettable sulfur-sprayed plot, even though the materials cost more per gallon ($0.0096 compared with $0.0087) the cost of spray material per bushel of fruit was about $0.0025 less. The increased value of fruit per tree was $9.90 on the trees sprayed with wettable sulfur, while the increase in cost of materials was only $0.27.

SUMMARY AND CONCLUSIONS

An evaluation of all pest control materials applied to plants in regards to their effect on yield and quality of fruit and on injury to foliage should be considered as much a measure of their value as an evaluation of their effectiveness for pest control. Spray treatment influences productivity and quality of apples as well as pest control.

Trees sprayed with the less caustic materials such as wettable sulfur, proprietary copper compounds, and some organic fungicides

at 3- to 7-day intervals, depending on weather conditions and rate of growth, produced larger yields and were as free from disease and insect injury as trees sprayed with lime-sulfur. Lime-sulfur caused a reduction in yield on all varieties sprayed in these tests, varying from 27.3 to 53.5 percent.

Varieties vary in their susceptibility to injury to the fruit from various spray materials. Copper compounds cause severe russeting of McIntosh and Jonathan apples. Northern Spy and Delicious are more tolerant. Most varieties, when grown for fresh fruit market, will produce good yields of better quality fruit if sprayed with a timely schedule of wettable sulfur or some of the new organic fungicides than with copper compounds or the more caustic materials.

Russeted fruit loses weight more rapidly in storage than fruit with a glossy finish and, consequently, is not so satisfactory for storing for late spring market.

Varieties such as Spy when grown for processing, where high yields are desired and good finish and storage quality are not factors, can be profitably sprayed with copper compounds throughout the entire fungicidal spray season.

The use of the less caustic materials, such as wettable sulfur and the organic fungicides, for scab control requires more timely and thorough applications than lime-sulfur, but the increased yield and larger annual production more than offsets the extra cost of such materials.

There is a need for materials which are more specific in scab control on apples than our present mild fungicides in years when weather conditions are favorable for disease development. Until such a material is found, the use of the more caustic materials such as lime-sulfur may be warranted in an occasional early application during the primary infection period when sprays have not been timely enough to prevent infection. An occasional early application will not be likely to cause any marked reduction in yield. Applications made later in the season to "burn out" scab infection is a poor orchard practice since they often cause severe defoliation and may be responsible for a reduction in blossom bud formation for next year's crop. Thorough, and timely, spray applications during the primary infection period is the key to apple scab control.

The development of more effective specific materials for pest control which are less injurious to plants and the development of better

equipment for application will make it possible to obtain better pest control and increased production of good quality fruit. What effect will these developments have on future apple production? Keener competition can be expected, along with increases in production. Will the trend in the East and Middle West be toward the production of more high-grade fruit in the areas adapted to the highly colored varieties, such as McIntosh, Jonathan, and Delicious, by the use of such orchard practices as thinning, pruning, proper use of fertilizers and good application methods? That is a problem that each grower will have to solve for himself.

The biggest loss in the production of a crop of McIntosh is due to the dropping of the fruit just prior to harvest. This drop can be delayed by the application of hormone sprays or dusts. Timing of the hormone application is important since 3 to 4 days are required before they become effective after which they remain effective for 7 to 8 days. They should be applied a day or 2 before the drop is anticipated. Hormone sprays are more useful in delaying the dropping of apples when warm weather occurs just prior to or during the early part of the harvest season than during the cool seasons.

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