STATE COLLEGE OF WASHINGTON
AGRICULTURAL EXPERIMENT STATION
PULLMAN, WASHINGTON

DIVISION OF ENTOMOLOGY AND ZOOLOGY

Tolerance of San Jose Scale to Sprays

By
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BULLETIN No. 174
(Technical Paper)
FEBRUARY, 1923

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*In co-operation with the United States Department of Agriculture.
**In co-operation with Chelan County and dairy farm Organizations.

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TOLERANCE OF SAN JOSE SCALE TO SPRAYS

By

A. L. Melander, Entomologist

INTRODUCTION

Historical.—The San Jose scale has been present in Washington for approximately forty years. Introduced in the Walla Walla region and the older orchards on the Snake River it has spread in the meantime to most of the orchards of the valleys of the Columbia River and its tributaries, following that region known biologically as the Upper Sonoran life zone. It rarely, if ever, occurs at an elevation above 2000 feet, and in Western Washington is barely able to maintain itself, occurring on only a few trees in the inland southern part of the state.

Fruit growers, years ago, found the application of a lime-sulphur spray the most satisfactory control measure. Formerly this spray was commonly used at the rate of 1 lb. of sulphur to 2 lbs. lime to ¾ lb. salt to 3 gallons water. Investigations by C. V. Piper and R. W. Thatcher in 1902, reported in Washington Bulletin No. 56, showed that salt was unnecessary and that four times as much lime was being used as was chemically needed. This investigation indicated also that weaker sprays were equally efficient, a formula of 1 lb. sulphur, ½ lb. lime to 5 or 6 gallons water giving results almost identical with those from the customary spray. In even as brief a period as a week after the application examination showed almost complete destruction of the scale. The experiments upon which these findings were based were carried on in a Snake River orchard that had been rendered commercially unproductive because of heavy infestation of San Jose scale.

During the next ten years fruit growers here and there expressed dissatisfaction with the results from lime-sulphur. At first the omission of salt was held responsible, then the lack of excess lime, then the general usage of factory manufactured clear cold concentrate which was displacing the hot home-made lime-sulphur, and lastly that the San Jose scale was becoming tolerant to annual baths of lime-sulphur until a progressive immunity was developed.

The Spraying Project.—Beginning in 1908 the writer undertook a series of experiments to determine whether the San Jose scale varied in its susceptibility to lime-sulphur and whether races were being selectively bred that manifested an increasing tolerance to this insecticide. This has been continued each year to date and has brought out many interesting data which are here abridged and summarized, the discussion being presented in the chronological order in which the experiments were conducted. Naturally the plan of the experiment changed during its course. The early field examinations with hand lenses to determine the relative effectiveness of the several treatments gave way to a careful accounting for every insect, examined in the laboratory under the binocular microscope. Treatments found useless were discarded. Concentrations of sprays were altered, and from time to time insecticides of local interest were given comparative trials.

All the spraying was done with Bordeaux nozzles at about 175 pounds pressure. The branches selected for counting were drenched, probably more than in commercial spraying, to insure actual wetting of every individual scale. The problem was not to measure thoroughness of application but to test the relative effects of various insecticides. Obviously branches picked at random in an orchard commercially sprayed would lack that assurance of careful covering which was necessary for this undertaking. About three weeks after the application sample branches were obtained from each experiment and the scales were examined by crushing with dissecting spears under the binocular microscope. The condition of each whether living or dead was recorded by tally counters operated by the feet. Only the immature black overwintering scales were examined and recorded, as in Eastern Washington the mature scales are all winter-killed. Flat, non-mealy, dried scales were not considered, as such had died long before the experimental applications. In nearly every instance the samples were divided into two parts and examined by the entomologist and the assistant entomologist, thus obtaining a check on each other. Since personality in interpretation did not appear to be as disturbing as the differences in individual branches the numbers of scales examined have been here added together, irrespective of who made the counts, in order to secure as many representative cuttings as possible and to insure brevity in presentation.

Acknowledgments.—In conducting this investigation many people have been called upon for assistance. The State Fruit Inspection Service has time and again rendered the greatest aid in locating suitable orchards. To Messrs. Chas. Andrus, Forbes E. Bailey, C. P. Clausen, W. L. Close, P. S. Darlington, M. L. Dean, F. E. DeSellem, George Ferguson, I. R. Fletcher, Charles Galbraith, Frank George, Chas. W. Hauck, Geo. Isaman, E. B. Kelley, Harry L. Miller, T. O. Morrison, Luke Powell, Chas. L. Robinson, R. C. Stockdale, S. W. Usher, C. L. Whitney, J. B. Wiley, C. B. Wood, E. G. Wood and others of the State Horticultural Division we express our appreciation of their courtesies despite numerous intrusions upon their time. Manufacturers and dealers in spray materials have given friendly aid in these experiments. To the owners of the various orchards who have often suffered financial loss from the application of a weak or an untried insecticide, our gratitude is due. The authorities of the Experiment Station, Directors R. W. Thatcher, Ira D. Cardiff and E. C. Johnson, have been particularly sympathetic and have made it possible to defray from the Adams research funds the major expenses of the investigation. The Assistant Entomologists of the Experiment Station, at first M. A. Yothers and later Anthony Spuler, have helped in making all applications and have shared in the tedious labor of classifying the many thousands of scales recorded in the following pages.

Polysulphid Sprays.—When sulphur and lime are boiled in a small quantity of water a chemical reaction sets in resulting in the formation of new materials, the polysulphids of calcium, which give a reddish-yellow color to the liquid. The polysulphids, represented by the chemical formulae CaS_3, CaS_4, and CaS_5, are not stable substances. They are eager for oxygen, with which they unite, to become converted first into calcium thiosulphate, or CaS_2O_3, and ultimately into calcium sulphate, or $CaSO_4$. It is this affinity for oxygen which is supposed to give lime-sulphur at least part of its insecticidal value, for if the oxygen is furnished by the insect which has been sprayed death results from chemical suffocation. Similar reactions take place when sulphur is boiled with potash, lye, or baryta, forming the polysulphids of potassium, sodium or barium.

Progressive Immunity.—Curves plotted from the early information regarding the action of lime-sulphur sprays on San Jose scale indicated that year by year this insect was becoming increasingly tolerant to this universally used insecticide, particularly in the Snake River Valley. Whether this indication was due to faulty information, to insufficient data, or to an actual progressive acclimatization it is now impossible to determine. As will be shown by the subsequent pages the scale in the lower Clarkston flats has throughout the investigation manifested an astounding resistance to polysulphid sprays, but this resistance had reached its apparent maximum by the time the investigation was begun.

Judging from the changing nature of many other species there is no inherent reason why the San Jose scale should not become altered in its ability to withstand the action of an insecticide. Algae living in hot springs, the petroleum fly that develops in crude petroleum, insects breeding in the hypertonic water of alkali lakes or of brine vats are outstanding examples of the possibility of survival in a changed environment that would have originally been fatal. Experimentally it has been possible to produce altered races of bacteria and protozoa by subjecting them generation after generation to solutions of increasing toxicity. Quayle has recorded the existence of local races of orange scale insects tolerant to the usual fumigation with cyanide-gas.

When scales are sprayed wih lime-sulphur they are virtually all subjected to a new environment. If the bath were absolutely lethal all scales should succumb. But it is a matter of repeated experience that scales do not all die at the same rate and that here and there some particularly vigorous individuals remain alive and growing until after the lime-sulphur has dissipated its insecticidal properties. Thus among individuals inherently varying in tolerance there are a few per 1000 or per 10,000 that are completely resistant and these are selected through the action of the spray to be the sole progenitors of subsequent generations. If each generation were sprayed such survivors could plausibly produce a race upon which lime-sulphur would ultimately have little or no effect. But where four summer generations or so are permitted to breed with no inhibiting sulphur effects other than might come from the thin crust of residue the advantage gained would become lost by regression. There is also the possible explanation to consider that tolerance to lime-sulphur need not be hereditary. The individuals that become acclimatized to a lime-sulphur coating may be somatically modified without genotypic selection. Each wintering generation would then reacquire its tolerance.

Restricted Distribution.—That the San Jose scale manifests different behavior in different districts is apparent. The continued devastation year after year at Clarkston, despite heavy spraying, is in sharp contrast to the easy control of the species about Wenatchee. We have observed the present innocuousness of the San Jose scale in its original home in the Santa Clara Valley of California, where the race is apparently dying out. Outside of the austral life zones the species has rarely obtained a foothold. In the State of Washington the transition life zone is virtually free of San Jose scale. We have repeatedly endeavored to raise the species at Pullman, invariably without success. Literal millions of scales have been brought to Pullman only to perish. We have tied scores of scaly apples on trees; we have time and again intertwined scaly branches on young apple trees; we have tried to graft scaly scions; we have painstakingly transferred thousands of new-born young on to potted trees in the insectary; and yet every attempt has failed to acclimatize the scale to Pullman conditions. A few of the transferred scales in the insectary have lived to complete part of their development, but have covered themselves with a loose, fuzzy, whitish exudation wholly unlike the normal flat scale. Why some scales can withstand the drastic action of a spray treatment yet all succumb to the subtile influences of the transition life zone is still a mystery. The bearing of the restricted distribution on the application of horticultural quarantine laws is obvious.

Characteristics of the Habitat of the San Jose Scale.—Within the austral life zone in Washington, following the valleys of the Columbia River and its tributaries, conditions are remarkably homogeneous. Although Clarkston is some two hundred and fifty miles distant by river from Wenatchee or Yakima, this distance does not connote a similar great divergence in altitude, climate, soil, rainfall, aridity of atmosphere, severity of winter, summer temperature, length of growing season, amount of wind, etc. To one unfamiliar with the physiography of Washington the differences in response to spraying manifested by the San Jose scale might be ascribed to environmental differences due to the great distances between the localities. However, distance has had its main effect in the isolation of biological strains, rather than in the development of varied living conditions. The following table, presenting some of the data that concern the environment at the several stations where the experiments were conducted, shows the similarity in weather conditions despite the spread of the localities.

Table 1. Climatological Data on Spraying Localities

A. Physiographic Statistics

Locality	Altitude	Longitude	Latitude	Annual Precipitation	Annual Mean Temp.
Clarkston-Lewiston	757	117 02′	46 25′	13.50	53.2
Walla Walla	975	118 20	46 04	17.16	53.4
Yakima	1067	120 31	46 36	8.96	50.8
Wenatchee	743	120 19	47 25	13.57	49.4
Kennewick	370	119 07	46 12	6.46	53.9
Prosser	661	119 46	46 13	8.37	51.8
Sunnyside	747	120 00	46 20	6.79	50.8
Cashmere	797	120 28	47 31		
Moxee	1000	120 31	46 37	8.9	
Pullman	2536	117 10	46 44	21.39	47.4

B. Minimum Temperatures

Year	Station	Jan.	Feb.	Dec.	Last Frost Spring	First Frost Fall
1912	Wenatchee		18	11		
	Lewiston-Clarkston		25	21		
	Yakima-Moxee		16	13		
	Walla Walla		27	23		
1913	Wenatchee	−3	−3	21		
	Lewiston	2	−1	15		
	Yakima-Moxee	−1	−7	15		
	Walla Walla	12	5	17		
1914	Wenatchee	7	−1	3	Apr. 27	Nov. 6
	Lewiston	29	5	8	Mar. 28	Nov. 7
	Yakima-Moxee	8	13	−9	Apr. 29	Oct. 22
	Walla Walla	26	10	8	Feb. 18	Nov. 15
1915	Wenatchee	1	14	−1	Mar. 26	Oct. 24
	Lewiston	17	25	11	Mar. 26	Nov. 7
	Yakima-Moxee	−13	14	1	May 15	Sep. 28
	Walla Walla	12	27	12	Mar. 26	Nov. 7
1916	Wenatchee	−15	3	−7	Apr. 23	Oct. 2
	Lewiston	−13	4	4	Mar. 24	Oct. 5
	Yakima-Moxee	−14	9	−11	May 11	Sep. 28
	Walla Walla	−7	9	5	Mar. 14	Oct. 8
1917	Wenatchee	−1	6	4	Apr. 22	Oct. 17
	Lewiston	8	20	27	Mar. 30	Oct. 18
	Yakima	0	10	15	May 5	Oct. 17
	Walla Walla	9	14	20	Mar. 30	Oct. 18
1918	Wenatchee-Trinidad	9	7	11	Apr. 4	Oct. 25
	Lewiston	6	16	6	Apr. 3	Nov. 12
	Yakima	7	10	7	May 19	Oct. 29
	Walla Walla	10	16	13	Apr. 3	Nov. 8
1919	Wenatchee-Trinidad	7	17	−19	May 5	Sep. 27
	Lewiston	5	16	−23	Apr. 12	Oct. 10
	Yakima	4	16	−24	Apr. 12	Sep. 29
	Walla Walla	9	24	−14	Apr. 15	Oct. 24
1920	Wenatchee-Trinidad	11	23	20	Apr. 4	Oct. 31
	Lewiston	12	23	26	Apr. 8	Oct. 23
	Yakima	10	20	12	Apr. 9	Oct. 15
	Walla Walla	12	24	15	Apr. 3	Oct. 31
1921	Wenatchee-Trinidad	11	17	11	Mar. 14	Oct. 23
	Lewiston	18	14	16	Apr. 8	Oct. 23
	Yakima	10	15	6	Apr. 26	Sep. 12
	Walla Walla	12	19	11	Apr. 4	Oct. 23

Relation of Winter Weather to Vitality of Scale.—The relation of severity of winter weather to the vitality of scale during the subsequent spring is shown by comparing the temperature record with the mortality data. The temperature at Wenatchee usually ranges a few degrees colder than at Clarkston and since Wenatchee scales are less sturdy the inference might be drawn that the difference is due to colder weather. Again, the scale at Clarkston was most easily destroyed during the spring of the years 1914, 1916 and 1920, when the minimum temperatures attained 5, -13 and -23 degrees respectively. At Clarkston the scale manifested most resistance during 1915, 1917 and 1919, when minimum temperatures registered 8, 4 and 5 degrees respectively. Such evidence would indicate a definite correlation between winter weather and subsequent vitality of the San Jose scale. While in general this is undoubtedly true, the evidence over a period of years at Wenatchee shows in part negative correlation, and therefore lessens the absolute value of this conclusion. At Wenatchee best results were had during the years 1915, 1919 and 1921, when minimum temperatures reached 1, 7 and 11 degrees. The scales showed greater resistance to sprays in 1913, 1917 and 1918, when minimum temperatures preceding the spraying were -3, -7 and 4 degrees, respectively.

The Spraying Experiments

Experiments of 1908 and 1910.—The experiments of Piper suggested that the degree of concentration of lime-sulphur was not all important, inasmuch as a spray used at half the customary strength gave efficient returns. Shortly afterward the Division of Chemistry of the Washington Experiment Station collected numerous samples of lime-sulphur as prepared and successfully used by various fruit growers of the Wenatchee district. Strange to say, owing to the difficulties of home preparation, not one of these samples analyzed to the expected strength. The fact that sprays weaker than 4 degrees Beaume were being extensively employed led the present entomologist in 1908 to try out in a preliminary way at Clarkston various concentrations of lime-sulphur with a view of determining the most economical effective strength to recommend for San Jose scale. The results observed two weeks later are summarized in the following table.

Table 2. Experimental Spraying at Clarkston, 1908

Material	Formula*	Average % Alive
Factory-made lime-sulphur	1:8	5
Factory-made lime-sulphur	1:11	1.2
Factory-made lime-sulphur	1:14	1.4
Factory-made lime-sulphur	1:17	3
Home-made lime-sulphur	1:2:4	80
Home-made lime-sulphur	1:1:4	0
Home-made lime-sulphur	1:1:5	0
Home-made lime-sulphur	1:1:6	Many alive

*In the following tables dilutions of factory-made lime-sulphur are given in parts of concentrate to parts of water; home-made lime-sulphur in pounds of sulphur, pounds of lime, to gallons of water; dry sulphid preparations in pounds of material to gallons of water.

The erratic nature of lime-sulphur was shown by this experiment. For instance, in the first test a dilution of 1:8 gave complete kill on three trees and but 80 per cent. kill on the fourth. Two trees sprayed with one-half this strength (1:17) showed much better returns than the fourth tree mentioned.

In 1910 similar experiments were conducted at Walla Walla. Again individual trees were drenched with the spray to be tested and in about two weeks representative areas of the bark were examined under the hand lens and by crushing the immature insects the percentage of mortality was determined. The results of these tests are summarized in Table 3.

Table 3. Experimental Sprayings at Walla Walla, 1910

Material	Dilution	Average % Alive
Factory-made lime-sulphur	1:17	6
Factory-made lime-sulphur	1:9	10
Factory-made lime-sulphur	1:11.5	26
Factory-made lime-sulphur	1:14	24
Factory-made lime-sulphur	1:16	10
Orwood	1:8	65
Orwood	1:10	18
Orwood	1:12	62
Orwood	1:14	28
Check	unsprayed	60

Orwood was a wood distillation product consisting mainly of crude pyroligneous acid. Applied at full strength to a branch of a blossoming peach tree it killed the branch but not the Lecanium scale insects on the branch. Full strength lime-sulphur similarly applied did not injure either the branch or the Lecaniums. Orwood used 1:5 on peach branches, however, did no harm. It was this experiment that an overzealous reporter heralded in the morning newspaper as having killed or injured every tree treated with Orwood, and the afternoon newspaper, elaborating on the morning account, announced that the entire orchard was destroyed. Truly the peach branch had multiplied during the day. Libel suit by the manufacturers of this innocuous material was averted only by the editorial retraction that an investigation disclosed that there was no foundation for these statements and that it was strange that a state official should thus pervert the facts!

Experiments in 1912.—Beginning with 1912 the experiment was expanded and results were thereafter computed on the basis of microscopic dissections. The introduction of several specific remedies for San Jose scale enabled a comparison between treatments with standard lime-sulphur and with the newer sprays. Through cooperation with several of the district fruit inspectors sprayed branches were secured and where full data were forthcoming the results from checking such branches are worthy of record. In order to condense the statistical information as fully as possible only the most pertinent data are enumerated in the following tables.

Table 4. Results of Spraying for San Jose Scale, 1912

A. Experimental Spraying at Clarkston (Examination 17 days after application)

Material used	No. Scales Examined	% Alive
Check	1472	97.0
Lime-sulphur 26 deg.	882	74.4
Lime-sulphur 5.3 deg.	371	85.7
Lime-sulphur 4.5 deg.	789	73.3
Lime-sulphur 3 deg.	2430	93.7
Lime-sulphur 2 deg.	983	78.8
Lime-sulphur 1½ : ½ :5 (3 deg.)	833	96.0
Lime-sulphur 1:2:5 (3 deg.)	983	97.8
Lime-sulphur & $FeSO_4$	1440	93.7
Lime-sulphur & NaCl	449	46.7
Lime-sulphur & CaO	1096	63.3
Crest, 4%	731	79.5
Crest, 2%	568	63.0
Scalecide, 10%	544	16.4
Scalecide, 5 %	1214	58.4

B. Growers' Applications

Locality	Material Used	Days Interval	No. Scales Examined	% Alive
Yakima	Lime-sulphur, 3 deg.	17	1270	14.8
Sunnyside	Crest, 2%	12	480	83.3
Prosser	L-S., 2:1:9=3½ deg.	20	2443	0.4
Prosser	Crude oil emuls., 12%	18	614	0.0
Kennewick	Rex L-S., 1:11	4	913	1.4
Wenatchee	Rex L-S., 1:9	9	990	0.9
Wenatchee	Rex L-S., 1:10	6	377	6.6
Wenatchee	Rex L-S., 1:10	12	1891	0.6
Walla Walla	Rex L-S., 1:8	20	218	25.0
Wawawai	L-S., 15:15:50, hot	28	957	0.7
Clarkston	Lime-sulphur 6 deg.	76	415	21.7
Clarkston	L-S., 3:4:10, 3 applications		807	52.8

In explanation of the formulae in Table 3, the lime-sulphur was furnished by the Rex Spray Company; 1:2:5 indicates 1 lb. sulphur and 2 lbs. lime boiled and diluted to make 5 gallons; Crest spray was manufactured in Seattle, its principal ingredient being fir oil; the last citation for Clarkston represented three successive hot applications during March, the second one week after the first and the third two weeks later, the scales being counted April 12.

A perusal of the data of Table 4 shows that in 1912 the San Jose scale at Clarkston behaved in a different way from the scale elsewhere in Washington. It was so remarkably resistant to lime-sulphur of whatever strength that even seventeen days after the spraying the insects showed but little effect from their polysulphid bath. At Walla Walla the scale showed partial tolerance but in the other districts of Washington the San Jose scale was held in practical control by treatments of lime-sulphur. It must be mentioned that Table 4 includes only those counts where the time between spraying and counting was known. Forty additional samples were examined from other localities, submitted by the fruit inspectors a reasonable time after the applications had been given, but as the exact date of spraying was not known the data are not here presented. These samples, however, confirmed the previous conclusion. In every instance Clarkston scales showed remarkable resistance as compared with those from other localities.

Experiments in 1913.—The fact that lime-sulphur is generally a valuable treatment for San Jose scale, and that while formerly it was effective at Clarkston it does not now afford complete control, caused the entomologists to conduct the investigation with a view to the possibility of a progressive immunity being established in the lower Clarkston district. In order to have definite means of comparison identical solutions were applied by the Experiment Station entomologists in March, 1913, at Clarkston, Walla Walla, Kennewick, Sunnyside, Yakima and Wenatchee. Samples from the sprayed trees were examined three times at approximately biweekly intervals. Discussions of some of the results of the 1913 experiments have been given in the Journal of Economic Entomology, Vol. VII., pp. 167-172 (Apr. 1914) and in the Tenth Report Washington State Horticultural Association, pp. 134-141 (1914). The data from the counts are presented in Table 5. It will be noticed in this table and elsewhere that sometimes a thousand and more scales are insufficient to establish a rate of mortality in conformity with expectancy. Such discrepancies, due to local differences in vigor of scale or host, emphasize the need of many counts, repeated year after year, in order to determine the absolute value of treatments.

Table 5. Experimental Sprayings, 1913

A. Clarkston. (3977 Checks, average 71% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	5739	91	3248	68	5470	10
Lime-sulphur, 3 deg.	5999	94	4408	72	2816	13
Lime-sulphur, 2 deg.	1898	28	2440	76	3332	23
Lime-sulphur, 1:2:5	1270	72	2127	60	4494	16
Lime-sulphur, 1:½:5	4668	68	4178	74	5378	21
Soda-sulphur, 3 deg.	1277	94	....	..	1928	6
Orchard misc. oil 5%	9095	4	8420	0.5	9993	0.0
Spramulsion, 1:15	5948	63	4335	42	6293	12
Fuel oil emuls., 10%	4991	22	3214	0.4	5122	0.0
Crest, 1:40	4882	21	597	27	1153	52

B. Walla Walla. (823 Checks, 44% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	1053	76	2150	14	1200	0
Lime-sulphur, 3 deg.	1009	58	1860	23	2000	0
Lime-sulphur, 2 deg.	469	54	786	17	1500	0
Lime-sulphur, 1:2:5	740	36	1274	9	1000	0
Lime-sulphur, 1:½:5	397	39	1027	14	....	..
Orchard oil, 5%	533	35	1757	3	....	..
Fuel oil emuls.	1559	9	1550	0	....	..
Rex L-S., 3 deg.	1176	52	688	9	....	..
Crude oil emuls.	1192	7	803	0	6685	0

C. Kennewick, (352 Checks, 88% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	2180	41	3695	0.5	....	..
Lime-sulphur, 3 deg.	1581	37	3480	0.3	....	..
Orchard oil, 6%	1566	40	2765	0.0	....	..

D. Prosser.

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 3 deg.	894	89	1425	5	....	..
Lime-sulphur, 2 deg.	1230	83	1096	30	....	..
Lime-sulphur, 1:2:5 deg.	2677	89	1338	1	....	..
Lime-sulphur, 1:½:5 deg.	758	76	1277	1	....	..
Soda-sulphur, 3 deg.	2146	95	1418	1	....	..
Fuel oil emuls.	3302	71	2500	0	....	..

E. Sunnyside. (1832 Checks, 93% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	726	60	1322	6	665	0.0
Lime-sulphur, 3 deg.	566	78	1023	3	930	0.5
Lime-sulphur, 2 deg.	1130	76	1251	4	2280	0.0
Lime-sulphur, 1:2:5	1303	58	1616	4	4090	0.0
Lime-sulphur, 1:½:5	4643	93	4061	2	14,745	0.3
Orchard oil, 5%	2161	13	3400	0	10,620	0.0
Crude oil emulsion	1456	91	1900	0	7865	0.4
Spramulsion, 6%	1469	50	2376	7	3534	2.4

F. Yakima. (1020 Checks, 93% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	4652	55	3454	38	14,021	0.2
Lime-sulphur, 3 deg.	2970	79	2639	43	....	..
Lime-sulphur, 2 deg.	1737	76	2114	39	2621	0.6
Lime-sulphur, 1:2:5	1546	50	1278	22	937	0.2
Lime-sulphur, 1:½:5	3503	87	3958	32	9310	0.1
Orchard oil, 5%	2120	6	3000	0	3150	0.0
Spramulsion, 6%	1921	44	1521	2	2410	2.5
Crude oil emulsion	570	60	2800	0	3760	0.0

G. Wenatchee. (1048 Checks, 78% alive.)

Material	15 Days Scales	% Alive	30 Days Scales	% Alive	45 Days Scales	% Alive
Lime-sulphur, 5 deg.	2463	34	1063	30	....	..
Lime-sulphur, 3 deg.	2108	55	1268	59	....	..
Lime-sulphur, 2 deg.	2203	50	970	14	....	..
Lime-sulphur, 1:2:5	2275	0.7	690	6	....	..
Lime-sulphur, 1:½:5	3864	24	1727	34	....	..
Orchard oil, 5%	3532	0	2960	0	....	..
Spramulsion, 6%	3123	6	2185	11	....	..
Fuel oil emuls.	3730	1	2060	0	....	..

Experiments in 1914.—During the spring of 1914 the Entomologist was absent on leave and the spraying experiments were conducted and recorded by M. A. Yothers. Table 6 summarizes the results obtained.

Table 6. Spraying Experiments, 1914

A. Clarkston. (755 Checks, 91% alive.)

Material	Interval 15 Days No. Scales	% Alive	28 Days No. Scales	% Alive
Lime-sulphur, 5 deg.	2697	6.3	2787	1.1
Lime-sulphur, 3 deg.	2498	7.0	1745	3.0
Lime-sulphur, 2 deg.	....	..	3287	2.3
Lime-sulphur, 2 deg. and lime	3007	6.4	3527	1.5
Soda-sulphur, 3 deg.	1517	85.7	2022	11.4
Orchard misc. oil, 1:15	6950	0.0	5000	0.0
Spramulsion, 1:15	2086	75.0	1171	30.0
Spramulsion, 1:10	4373	3.0	2552	1.4
Fuel oil emuls., 1:10	6710	0.0	6620	0.0
Redwood's spray, 1:10	2518	9.4	2520	4.0
Crest, 1:40	3016	91.2	1658	83.5

B. Walla Walla.

Material	Interval 15 Days No. Scales	% Alive	28 Days No. Scales	% Alive
Lime-sulphur, 5 deg.	2663	7.5	2377	1.1
Lime-sulphur, 3 deg.	4379	16.2	6090	1.5
Lime-sulphur, 2 deg.	1878	42.7	1638	10.2
Lime-sulphur, 1:½:5(2.5 deg)	2494	11.8	1926	1.3
Soda-sulphur, 3 deg.	2359	89.5	1709	13.7
Orchard misc. oil, 1:15	6795	0.0	5000	0.0
Orchard misc. oil, 1:20	8970	0.06	5000	0.0
Spramulsion, 1:15	2680	86.5	891	20.0
Crude oil emuls., 1:10	6077	0.6	1740	1.4
Redwood's spray, 1:10	2937	12.3	3266	1.3
Crest, 1:40	2622	91.0	1510	86.5

C. Sunnyside.

Material	Interval 13 Days		Interval 27 Days	
	No. Scales	% Alive	No. Scales	% Alive
Lime-sulphur, 5 deg.	4137	6.5	4299	0.5
Lime-sulphur, 3 deg.	3069	11.8	3820	1.3
Lime-sulphur 3 deg. & lime	3147	2.4	3862	0.4
Lime-sulphur, 1:½:5	1569	12.0	4059	1.1
Soda-sulphur, 3 deg.	2918	87.1	3607	2.7
Orchard misc. oil, 1:15	10,785	0.0	7740	0.0
Orchard misc. oil, 1:20	6745	0.0	6195	0.0
Spramulsion, 1:10	3427	12.1	4683	1.1
Fuel oil emuls., 1:10	8535	0.0	6640	0.04
Crude oil emuls., 1:10	9490	0.0	6445	0.0
Redwood's spray, 1:10	2320	16.2	4827	0.4
Crest.	3188	91.0	2060	86.4

D. Yakima.

Material	Interval 13 Days		Interval 27 Days	
	No. Scales	% Alive	No. Scales	% Alive
Lime-sulphur, 5 deg.	3431	3.8	2920	0.5
Lime-sulphur, 3 deg.	1081	25.8	3743	0.5
Lime-sulphur, 1:½:5	1693	22.5	2745	1.1
Soda-sulphur, 3 deg.	2054	84.5	3048	2.1
Orchard misc. oil, 1:15	4675	0.0	1907	0.3
Orchard misc. oil, 1:20	4445	0.2	1070	0.4
Crude oil emuls., 1:10	3841	0.5	2600	0.4
Redwood's spray, 1:10	1505	28.3	2078	1.1

E. Commercial Spraying at Clarkston.

Material	Interval	No. Examined	% Alive
Lime-sulphur, 3 deg.	9 days	1432	2.2
Fuel oil emuls. (Laundry soap)	9 days	5005	0.0
Fuel oil emuls. (Whale-oil soap)	9 days	4150	0.0
Fuel oil emuls.	14 days	6295	0.1
Fuel oil emuls.	14 days	4275	0.0
Fuel oil emuls.	14 days	4470	0.0
L-S., 1:7, 2 applications	16 days	2544	4.1
L-S., 1:7	16 days	2512	5.1
Lime-sulphur, 5 deg.	29 days	2160	10.5
Lime-sulphur, 1:5	26 days	1836	11.8
L-S., 3 deg. (Kept in insectary)	31 days	328	16.7

Notes.—Fuel oil or crude oil emulsion was based on 1 qt. oil, 5 ozs. fish oil soap and 0.8 oz. lye, boiled with sufficient water and then diluted. The Orchard Brand miscible oil was obtained from the Thomson Chemical Company, Baltimore. Spramulsion was prepared by the Roger's Chemical Company, San Francisco. Redwood's spray was a sulphid-containing emulsion locally manufactured in the Yakima Valley. Crest Spray, a wood distillation product, was prepared by the Crest Chemical Company, Seattle, and was used at prescribed strength.

Observations.—Fuel oil, the residue after the volatile gasoline and kerosene have been removed from crude oil, is difficult to emulsify. Hence where growers have tried to utilize fuel oil their spraying has usually been spotted. Some parts of the bark have been drenched with oil with entirely effective results against the scale insects, but with doubtful safety to the trees, while adjacent portions have been wet with water and a little emulsifier. In such areas the scales show little or no effect from the spraying. Such irregularity in spread from a poorly made emulsion has caused many a grower to abandon the usage of home-made oil sprays.

On September 11 an inspection was made of the trees sprayed in the Clarkston experiments. All the trees showed much scale on twigs, leaves and fruit. Apparently the oil-treated trees were more nearly freed of scale in the spring, but summer invasions negatived the results, the scale insects being better able to thrive on the oil-cleaned bark than on trees still showing the residue of lime-sulphur. Throughout the lower Clarkston district the San Jose Scale was abundant, rendering nearly all fruit unmarketable.

Experiments of 1915.—In the spring of 1915 more attention than previously was given to this project. Additional materials and concentrations were tested and results were tallied at three biweekly periods with a further count later at Clarkston and Yakima. As heretofore Clarkston scales showed a most remarkable resistance to polysulphid sprays, while Wenatchee scales showed great susceptibility to spraying. In fact at Wenatchee great difficulty was experienced in finding sufficient scale insects for experiments. The data of Table 7 summarize the results.

Table 7. Spraying Experiments, 1915

A. Clarkston (1239 Checks, 88.4% alive.)

Material	20 days Total Scales	20 days % Alive	35 days Total Scales	35 days % Alive	50 days Total Scales	50 days % Alive	70 days Total Scales	70 days % Alive
L-S., 10 deg.	1083	58.6	1214	41.6	510	27.5	637	43.3
L-S., 5 deg.	651	35.4	969	42.2	493	39.3	656	45.2
L-S., 3 deg.	494	92.1	1058	58.7	1363	47.2	681	45.5
L-S., 2 deg.	531	69.2	790	63.3	719	61.4	604	32.5
L-S., 1:½:5	403	92.9	983	50.3	477	60.5	701	49.2
L-S., 1:2:5	825	72.2	590	37.5	771	61.6	679	60.2
S-S., 3 deg.	622	85.6	846	52.1	927	67.8	625	44.3
S-S., 2 deg.	582	97.0	937	68.4	804	66.8	649	46.3
S-S., 1½ deg.	651	84.5	1682	58.8	500	62.4	705	59.4
Synthetic S. S.	386	96.2	982	76.5	510	70.6	400	69.2
Colloid S.	925	81.2	1065	66.8	671	84.0	578	58.9
NaOH, 3 deg.	252	75.8	660	63.8	501	82.2	419	88.7
Hypo, 3 deg.	622	85.6	....	...	....	...	....	...
Orchard em., 5%	1493	8.3	813	5.5	513	2.9	622	3.2
D. S. O., 10%	739	29.6	422	0.0	870	0.2	685	0.0
D. S. O., 5%	....	37.5	671	11.5	541	4.6	....	...
Misc. No. 1, 10%	425	2.6	543	0.0	549	0.0	436	0.0
Misc., No. 1 5%	1330	46.6	1220	6.5	927	1.6	618	0.6
Buggo, 5%	305	84.0	477	88.4	494	88.1	427	53.7
Crude oil, 10%	709	32.7	399	0.8	923	17.1	1008	6.8
Crude oil, 8%	395	6.3	836	3.6	695	9.5	505	5.3
Crude oil, 5%	666	49.8	403	9.4	466	65.7	679	3.5
Fuel oil, 10%	980	10.7	267	1.5	521	1.7	769	2.6
Fuel oil, 5%	725	3.7	817	5.3	532	27.9	454	3.5
Crest, 10%	945	24.0	441	96.7	833	81.3	723	80.8
Crest, 5%	783	84.3	840	88.2	898	89.4	671	77.4
Dake powder	323	97.3	505	87.3	1142	93.2	425	84.5
Check	1239	88.4	238	98.4	537	94.2	512	54.8

B. Yakima (Sprayed March 7.)

	21 days Total Scales	21 days % Alive	38 days Total Scales	38 days % Alive	51 days Total Scales	51 days % Alive	83 days Total Scales	83 days % Alive
L-S., 5 deg.	524	33.2	243	21.0	1049	4.1	505	10.1
L-S., 3 deg.	870	45.2	1551	21.8	1068	1.1	517	3.3
L-S., 2 deg.	454	34.1	228	36.8	869	3.0	700	7.7
L-S., 1:½:5	....	...	1073	10.5	912	4.6	527	8.3
S-S., 3 deg.	893	34.5	1147	41.8	840	9.6	699	24.9
$Na_2S_2O_3$, 3 deg.	610	82.0	508	65.3	455	49.0	479	47.2
$NaHSO_3$, 3 deg.	481	47.4	591	40.6	866	58.4	489	35.4
NaOH, 3 deg.	642	86.5	520	44.6	303	59.7	530	57.0
Redwood's, 1:10	1000	28.6	679	12.2	855	4.9	602	7.3
Redwood's, 1:20	649	58.6	629	34.0	895	7.9	789	23.4
Orchard oil, 5%	1043	1.4	710	0.6	1059	0.3	600	0.0
Crude oil, 10%	1257	26.2	846	20.1	887	16.6	783	31.7
Crude oil, 5%	785	50.5	794	26.1	1116	27.2	703	31.2
Dormant sol. oil, 6%	....	...	1066	0.0	....	...	....	...
Check	795	86.4	684	83.5	714	66.5	751	73.9

C. Yakima (Sprayed March 26)

	21 days		33 days		62 days	
	Total Scales	% Alive	Total Scales	% Alive	Total Scales	% Alive
Lime-sulphur, 3 deg.	1339	27.5	336	24.1	273	26.4
Lime-sulphur, 2 deg.	290	22.4	105	47.6	146	49.3
Lime-sulphur, 1 deg.	548	20.4	323	47.4	337	34.5
S-S., 3 deg.	246	41.8	436	31.0	467	48.3
S-S., 2 deg.	616	49.0	447	48.4	226	43.3
S-S., 1 deg.	259	75.0	420	61.2	339	37.7
NaSx, 3 deg.	654	34.4	766	28.1	649	46.5
NaSx, 1 deg.	749	39.4	583	28.6	1217	26.2

D. Walla Walla (Sprayed March 5)

	20 days		38 days		55 days	
	Total Scales	% Alive	Total Scales	% Alive	Total Scales	% Alive
L-S., 5 deg.	932	49.5	1162	35.7	703	37.3
L-S., 3 deg.	631	53.9	1212	31.9	798	23.3
L-S., 2 deg.	668	57.8	1250	32.3	1364	26.1
L-S., 1:½:5	222	58.1	1004	36.8	743	50.3
S-S., 3 deg.	689	31.8	1959	25.5	732	33.4
S-S 2 deg.	722	26.1	936	42.7	856	45.2
Orchard oil, 5%	772	0.9	1380	0.0	1168	0.0
Crude oil, 10%	1010	10.0	1086	2.5	943	2.8
Crude oil, 5%	682	25.0	1000	10.2	851	58.7
Check	885	90.8	643	93.5	845	75.8

E. Wenatchee (Sprayed March 11)

	20 days		37 days		61 days	
	Total Scales	% Alive	Total Scales	% Alive	Total Scales	% Alive
L-S., 5 deg.	550	44.5	697	2.3	367	1.4
L-S., 3 deg.	1034	24.5	615	0.8	379	1.6
L-S., 2 deg.	532	48.8	639	3.0	317	2.2
L-S., 1:½:5	518	37.3	648	2.5	272	1.8
S-S., 2 deg.	433	39.2	723	1.1	114	1.8
Orchard oil, 5%	583	0.0	700	0.0	293	0.0
Crude oil, 10%	520	2.5	540	0.0	423	0.0
Crude oil, 5%	321	0.3	686	21.6	....	...
Check	481	35.8	353	66.9	239	45.2

F. Sunnyside (Sprayed March 5)

	22 days		39 days	
L-S., 5 deg.	642	10.3	325	12.0
L-S., 3 deg.	430	4.4	340	15.9
L-S., 2 deg.	556	22.6	173	26.0
L-S., 1:½:5	639	8.6	145	2.1
S-S., 3 deg.	625	4.8	859	18.2
S-S., 2 deg.	418	7.4	284	24.3
Orchard oil 5%	874	0.3	1020	0.0
Crude oil, 10%	1109	2.5	898	6.0
Crude oil, 5%	660	0.0	1176	7.0
Check (Poplar)	679	83.2	706	92.7
Apple	731 at date of spraying = 27.6 alive			

G. Commercial Spraying at Walla Walla; interval 10 days.

Material	Total	% Alive
Buggo, 14%	390	0.5
D. S. O., 7%	643	0.0
L-S., 3½ deg.	516	62.0
L-S., 5 deg.	476	52.3

Notes.—Soda-sulphur, abbreciated S-S. in the tables, was used at the rate of 1½ lbs. to 5 gallons, testing 3 degrees B., and 1 lb. to 5 gallons, testing 2 degrees. The soda-sulphur used was the Niagara Soluble Sulphur Compound. Inasmuch as this insecticide was being given wide publicity, an extensive factory being established at Seattle for its general use at ultra-weak dilutions, more attention than previously was given to this material in the experiments. A synthetic soda-sulphur was tried, made at the suggestion of George Olson, Washington Station Chemist, according to the following formula:

Freshly ppt. sulphur liquid	2 qts.
Hypo ($Na_2S_2O_3$)	2 ozs.
Lye (NaOH or KOH)	1 oz.
Sodium sulphite (Na_2SO_3)	½ oz.
Water	1 qt.

These ingredients were also tried separately. Precipitated collodial sulphur was prepared by adding a little more than 4 ozs. hydrochloric acid to the quart of concentrated lime-sulphur, previously diluted 1 to 13. It will be noted that neither the synthetic compound, nor its ingredients, showed any practical insecticidal value and at Clarkston the factory-made product likewise gave a negative reaction.

Buggo, a California oil product, could not be well emulsified. Similar experience was reported by various fruit growers, although good results were said to be obtained in California with this brand. Dake tree powder was administered in a ¾-inch auger hole in the trunk. It proved to be worthless. Crest, used at 5 per cent and 10 per cent strength, altho its accompanying directions prescribed 1:50 for winter spray, gave no appreciable benefit. Particularly at Sunnyside, where the water is heavily charged with alkali, it was found difficult to emulsify crude oil. Results from spraying with crude oil emulsion were generally erratic. Spots where many live scales were found adjoined areas where the kill was perfect. It appeared as if with the heterogeneous emulsion the oil of the more concentrated portions failed to spread to the scales wet with the more watery portion on subsequent drying.

An abridgment of the records of 1915 was published in the Journal of Economic Entomology, Volume 8, pp. 475-480, Oct. 1915. Discrepancies in percentages between those given in previous publications and here are due to differences in the method of interpreting data. In the articles the percentages obtained independently by Mr. Yothers and the writer were averaged without regard to the number of scales examined. In the present discussion the living and dead scales were totaled, irrespective of who made the examination, and then the final percentages were computed.

Experiments in 1916.—Experiments on the vitality of the San Jose scale were continued in 1916 at Clarkston, Walla Walla and Yakima. The materials used and the comparative effects of the treatments are set forth in Table 8.

Table 8. Spraying for San Jose Scale, 1916

A. Clarkston (Sprayed March 27; Checks 92.4% alive)

Material	Interval 28 days Total Scales	% Alive	48 days Total Scales	% Alive
Lime-sulphur, 10 deg.	1256	0.2	1153	0.5
Lime-sulphur, 5 deg.	1485	2.1	1861	1.2
Lime-sulphur, 3 deg.	3171	3.8	1719	3.1
Lime-sulphur, 2 deg.	1284	2.9	750	1.2
S-S., 5 deg.	207	12.1	653	4.3
S-S., 3 deg.	1077	6.9	1347	6.2
S-S., 2 deg.	1303	20.4	1404	7.6
S-S. liquid, 5 deg.	754	5.8	681	0.0
S-S. liquid, 3 deg.	1103	6.0	882	3.5
S-S. liquid, 2 deg.	1103	6.0	1204	3.5
B. T. S., 3 deg.	799	13.3	939	17.8
Orchard oil, 5%	1214	0.0	1340	0.1
D. S. O., 6%	606	37.3	984	7.7
D. S. O., 4%	572	41.3	696	48.6
D. S. O., 3%	810	56.2	780	44.1
Misc. oil, 5%	807	25.9	421	20.9
Ker. emuls., 10%	1208	3.8	934	1.8
Ker. emuls., 5%	947	17.7	148	23.0
Crude, 5% & K., 5%	600	0.0		
S. S., 1½ deg. & oil, 3%	1313	10.0	982	3.4
Check	912	79.5	778	76.0

B. Walla Walla (Sprayed March 30; Checks 26.2%)

Material	Interval 30 days Total Scales	% Alive	56 days Total Scales	% Alive
Lime-sulphur, 5 deg.	984	0.8	958	4.1
Lime-sulphur, 3 deg.	929	4.1	778	6.0
Lime-sulphur, 2 deg.	1019	4.4	572	4.4
S-S., 5 deg.	940	8.0	533	2.6
S-S., 3 deg.	1264	9.2	912	5.5
S-S., 2 deg.	649	9.5	519	5.4
D. S. O., 6 deg.	1246	0.2	262	0.0
D. S. O., 5 deg.	1178	0.9	361	0.6
D. S. O., 4 deg.	1015	9.8	459	0.4
Misc. oil, 5%	977	0.7	1055	0.0
L-S., 2 deg. & Nic.	2746	9.4	1307	6.5
S-S., 1 deg. & Oil 3%	1101	1.2	825	0.0
Check	1246	39.4	678	55.8

C. Yakima (Sprayed April 1; Checks 65.3%)

	Interval 30 days		52 days	
	Total Scales	% Alive	Total Scales	% Alive
Lime-sulphur, 10 deg.	763	0.0	732	0.0
Lime-sulphur, 5 deg.	999	0.3	1014	0.4
Lime-sulphur, 3 deg.	1107	1.2	793	3.0
Lime-sulphur, 2 deg.	950	0.2	792	1.1
Sludge, 10 deg.	972	0.2	971	0.6
Sludge, 5 deg.	709	0.9	953	2.0
Sludge, 2 deg.	899	1.2	534	1.1
S-S., 3 deg.	938	2.0	716	0.1
S-S., 2 deg.	756	2.1	1037	0.4
S-S. liquid, 2 deg.	787	2.7	918	1.8
S-L., & Nicotine	1026	2.8	775	3.2
S-S. & oil	720	1.1	900	2.3
B. T. S., 3 deg.	894	8.4	1277	6.3
D. S. O., 6 deg.	1134	0.0	1309	0.2
D. S. O., 5 deg.	888	0.9	292	0.3
D. S. O., 4 deg.	1030	0.8	769	0.5
Check	416	55.1	783	58.3

D. Commercial Spraying, Clarkston

Material	Sprayed	Interval	Total	% Alive
L-S., 7 deg.; K. em., 1%	Mar. 9 & 27	54 days	1055	15.3
L-S., 6 deg.	Mar. 2 & 16	60 days	867	2.9
D. S. O., 6%	Mar. 16	47 days	1098	17.1
K. em., 1½%	Mar. 8	53 days	835	19.3
K. em., 1%	3 applications	May 2	960	2.7

Notes.—In making lime-sulphur more or less insoluble sludge always accumulates. This material consists of impurities and oxidized lime-sulphur and holds a considerable amount of liquid in absorption. Some growers have been utilizing such sludge in spraying and it was to determine what insecticidal value it possessed that the tests were made. The sludge was mixed with water to dilute to proper hydrometer test. The ten degree sludge practically whitewashed the trees.

The addition of nicotine to the dormant spray of lime-sulphur is a common recommendation. This combination was tested to determine if nicotine increased the insecticidal value of a dilute lime-sulphur when used on San Jose scale. A 0.1 per cent solution of nicotine sulphate (Blackleaf 40) was added to a 2 degree lime-sulphur, but no betterment was observed.

Soda-sulphur liquid was prepared by boiling together one part of sulphur with 0.75 part lye, the heat of slaking the lye causing spontaneous chemical combination.

Barium-sulphur, abbreviated in the tables B. T. S., from the trade name barium tetrasulphid, did not prove to be a dependable treatment for San Jose scale.

During the spring of 1916 a propaganda advocating the use of a 1 per cent kerosene emulsion in dormant treatment for scale was heralded through the Clarkston district. In the tests a 5 per cent emulsion of kerosene proved utterly ineffective.

The most widely used miscible oil in 1916 was Dormant Soluble Oil (abbreviated D. S. O.) manufactured by the General Chemical Company of San Francisco. The formula used at that time did not produce nearly as reliable an oil as the Orchard Brand made from Pennsylvania crude oil.

Owing to the difficulty of emulsifying heavy crude oil, a mixture thinned with equal parts of kerosene was tried at 10 per cent strength at Clarkston, with perfect success.

The material tabulated as Miscible Oil 5 per cent was an experimental oil furnished by the California Spray Chemical Company.

Observations.—By the time of the second count the males were emerging at Clarkston.

Red spider eggs hatched on trees treated with lime-sulphur, but the young mites soon died. Eggs were killed when sprayed with oil or soda-sulphur liquid.

Winter-kill was greater than usual. At Wenatchee on April 4 an examination of 1051 scales showed only 18 per cent alive, the survival varying on different branches between 0.6 per cent and 46 per cent. Hence no spraying was attempted at Wenatchee.

An examination during September of the experimental trees at Clarkston showed severe infestation of fruit, foliage and branches on all trees. Those relatively freest of scale had been treated with kerosene emulsion 7 per cent, lime-sulphur 5 degrees and 3 degrees, and soda-sulphur liquid 2 degrees. Owing to free movements of young scales in spreading from tree to tree observations made at the end of the summer are not regarded of much value in determining relative value of spray treatments in experimental plots.

Experiments of 1917.—Spraying experiments were continued during the spring of 1917 at Clarkston, Yakima and Wenatchee. Dry lime-sulphur, Scalecide and a spray oil manufactured at Hood River were added to the materials tested. The results of the several treatments are given in Table 9.

Table 9. Experimental Spraying, 1917

A. Clarkston, (Sprayed March 31; Checks 89.4% alive)

Material	17 days		42 days		69 days	
	Total	%Alive	Total	%Alive	Total	%Alive
Lime-sulphur, 12 deg.	969	20.0	856	34.7	760	11.6
Lime-sulphur, 5 deg.	973	43.3	988	10.0	1028	14.1
Lime-sulphur, 4 deg.	1316	83.1	677	13.9	1057	11.7
Lime-sulphur, 3 deg.	1430	87.6	366	18.0	1233	13.8
Lime-sulphur, 5 deg.	1223	90.5	645	19.9	970	9.1
Dry L-S., 1:4	1758	89.0	1008	17.0	1073	22.3
Dry L-S., 1:5	1428	91.3	1078	15.1	1012	20.2
Dry L-S., 1:6	1666	89.5	948	17.3	1023	23.4
S-S., 1:4	1081	71.7	1168	22.2	1123	13.8
S-S., 1:5	1456	82.8	1128	22.5	1166	33.3
S-S., 1:6	1590	88.4	975	22.2	1193	20.9
Orchard oil, 5%	1671	1.6	1274	0.9	1255	0.3
D. S. O., 6%	1325	2.8	1235	0.0	1546	0.8
D. S. O., 5%	1701	4.2	1150	0.0	1420	2.5
Scalecide, 6%	1780	2.9	1070	0.0	1028	0.4
Scalecide, 5%	1518	2.8	1611	0.2	1065	0.0
Hood River oil, 6%	1599	1.9	1031	0.3	1008	1.1
Hood River oil, 5%	1661	3.1	1295	0.5	1515	0.5
Check	788	90.0	1038	52.6	816	55.3

B. Yakima (Sprayed April 8)

	25 days		51 days	
Lime-sulphur, 10 deg.	1273	3.1	1314	0.0
Lime-sulphur, 5 deg.	879	8.0	1117	0.8
Lime-sulphur, 3 deg.	1279	7.9	1173	1.5
Lime-sulphur, 2 deg.	906	5.1	1349	3.8
S-S., 1:4	1521	11.4	1021	2.1
S-S., 1:6	678	22.7	1199	2.9
D. S. O., 6%	828	0.0	1138	0.0
D. S. O., 5%	1671	0.0	985	0.0
Check	960	67.8	1223	50.3

C. Wenatchee (Sprayed April 10; 1201 Checks, 49.7%)

	24 days		51 days	
Lime-sulphur, 5 deg.	661	9.4	365	0.5
Lime-sulphur, 3 deg.	2037	13.8	1253	1.0
Lime-sulphur, 2 deg.	1136	16.7	1601	0.7
S-S., 1:5	636	30.0	293	2.0
D. S. O., 6%	666	0.0	504	0.4
D. S. O., 5%	1107	0.0	702	0.0
Check	465	68.7	180	1.1

Owing to the dearth of living scales in sufficient abundance for experiment at Wenatchee part of the spraying was repeated at Cashmere, nine miles up the Wenatchee River. The table combines the results at both places.

Experiments in 1918.—During the late fall of 1917 a heavily infested apple tree was transplanted from Clarkston to Wenatchee and another from Wenatchee to Clarkston. This exchange of trees was made to determine whether winter climate or inherent differences affected the susceptibility of scale to lime-sulphur wash.

Ultra-strong polysulphid sprays were tried at Clarkston to see if the San Jose scale there could be exterminated by any practical lime-sulphur spraying. Owing to a general impression that late sprayings are most effective some tests were put on at Clarkston on April 22 when early varieties of apples had the center flowers fully open, late varieties were beginning to leaf out and the San Jose males were in the black-eyed prepupa condition. The effect of the late spraying on the scale insects is tabulated below. On the trees the soda-sulphur caused much leaf scorching, the oil slight scorching and the lime-sulphur no visible harm. New growth replaced leaf injury and there was no diminution in the setting of fruit so that no permanent harm was done. The experiments for the year are summed up in Table 10.

Table 10. Spraying Experiments, 1918

A. Clarkston. (Spraying March 12; 439 checks, 78.5%)

Material	21 days		42 days		72 days	
	Total	%Alive	Total	%Alive	Total	%Alive
Lime-sulphur, 12 deg.	584	11.8	962	14.9	678	16.4
Lime-sulphur, 8 deg.	622	12.8	570	7.2	494	22.1
Lime-sulphur, 5 deg.	607	20.8	734	18.7	449	13.8
Lime-sulphur, 4 deg.	542	25.0	887	26.4	966	22.0
Lime-sulphur, 3 deg.	551	22.3	670	23.0	600	26.0
Lime-sulphur, 2 deg.	613	19.6	771	24.8	899	16.5
Dry L-S., 1:2	547	9.2	716	10.0	679	29.2
Dry L-S., 1:3	509	14.7	827	23.0	553	19.9
Dry L-S., 1:4	334	31.2	527	24.3	551	21.5
Dry L-S., 1:5	223	18.8	572	29.6	697	28.0
S-S., 1:2	541	10.9	708	17.8	916	20.9
S-S., 1:4	533	27.2	702	23.0	729	22.9
S-S., 1:5	509	10.9	1049	22.9	626	25.2
D. S. O., 6%	547	0.0	1090	0.0	2351	0.0
D. S. O., 5%	574	0.2	356	0.6	265	0.0
D. S. O., (1916) 5%	473	0.2	407	0.0	....	...
Scalecide, 6%	511	0.0	685	0.0	....	...
Scalecide, 5%	553	0.0	650	0.0	5002	0.0
Wen'chee tree L-S., 3 deg.	131	10.0	648	5.7	237	11.4
Check	604	88.8	592	73.3	593	54.8

B. Clarkston (Sprayed April 22)

	30 days		51 days	
	Total	% Alive	Total	% Alive
L-S., 4 deg.	665	23.0	302	25.5
L-S., 3 deg.	932	26.9	409	22.2
S-S., 1:4	593	13.0	232	17.2
S-S., 1:5	813	40.3	332	34.1
D. S. O., 5%	924	1.5	...	...

C. Walla Walla (Sprayed March 15; 412 checks, 78.2%)

	22 days		46 days	
	Total	%Alive	Total	%Alive
Lime-sulphur, 10 deg.	635	0.6	1292	0.7
Lime-sulphur, 5 deg.	791	1.1	1350	1.1
Lime-sulphur, 4 deg.	1968	7.2	2842	1.1
Lime-sulphur, 3 deg.	2468	11.9	3572	1.3
Lime-sulphur, 2 deg.	774	5.7	1892	0.9
Dry L-S., 1:3	883	2.1	1666	1.6
Dry L-S., 1:4	2020	6.9	1989	4.2
Dry L-S., 1:5	939	9.8	1528	7.1
S-S., 1:3	837	6.8	1276	2.8
S-S., 1:4	1092	10.0	1338	10.3
S-S., 1:5	807	4.0	751	5.5
D. S. O., 6%	1343	0.4	1777	0.4
D. S. O., 5%	1350	3.1	3066	0.5
Scalecide, 6%	507	0.0	550	0.0
Scalecide, 5%	800	0.0	1800	0.0
Check	488	85.0	777	28.2

D. Yakima. (Sprayed March 16; 551 checks, 90.2%)

	22 days		44 days	
	Total	%Alive	Total	%Alive
Lime-sulphur, 12 deg.	1155	0.4	2015	3.2
Lime-sulphur, 5 deg.	1055	0.7	1538	4.4
Lime-sulphur, 4 deg.	1282	0.5	1149	5.1
Lime-sulphur, 3 deg.	2395	0.9	2504	5.3
Lime-sulphur, 2 deg.	1576	6.2	2223	5.3
Dry L-S., 1:3	1094	2.8	1046	6.3
Dry L-S., 1:4	814	2.6	976	5.7
Dry L-S., 1:5	1127	2.3	1051	3.9
S-S., 1:3	1023	5.8	1330	4.9
S-S., 1:4	1012	16.1	1448	5.4
S-S., 1:5	1350	4.1	1336	7.2
D. S. O., 6%	2450	0.0	4566	1.2
D. S. O., 5%	1250	0.0	1510	0.0
Scalecide, 6%	1175	0.0	1470	0.0
Scalecide, 5%	920	0.0	1560	0.0

E. Wenatchee. (Sprayed March 20; 764 checks, 87.7%)

	23 days		50 days	
	Total	%Alive	Total	%Alive
Lime-sulphur, 4 deg.	1622	12.8	918	0.1
Lime-sulphur, 3 deg.	471	4.7	460	10.9
Lime-sulphur, 2 deg.	697	14.3	1418	12.5
Dry L-S., 1:4	1001	24.0	841	3.7
S-S., 1:4	1134	22.2	1729	2.3
S-S., 1:5	876	29.1	1048	6.5
D. S. O., 5%	946	0.1	660	0.0
Scalecide, 5%	810	0.0	630	0.0
Clarkston tree, L-S., 3 deg.	935	21.8	624	14.5
Check	701	65.8	604	41.1

F. Commercial Spraying, Walla Walla

	Sprayed	Interval	To'l.	% Alive
Lime-sulphur, 6 deg.	5 Apr.	19 days	686	1.9
L-S., 5 deg. & 6 deg.	20 Mar. & 15 Apr.	35 days	330	2.1
D. S. O., 6%	5 Apr.	19 days	2400	0.0

Notes and Observations.—The winter of 1917-18 was unusually open, which might account for the great vigor of the Clarkston scales during their growth. Winter mortality at each place visited was less than usual; at Clarkston three old last year's scales were found alive in the spring, an unduplicated observation in Washington.

Freezing weather during April selectively destroyed many male scales at Walla Walla while in the pupa state. An analysis of the males on the check tree April 30 showed dead pupae at the rate of four to each live pupa or transformed male.

Red spider eggs were all destroyed by soda-sulphur, 12 degree lime-sulphur and the oil sprays. Ten per cent of the eggs were alive at the time of the first count at Clarkston when 8 degree lime-sulphur had been used, and an increasing number lived through the weaker washes. However, the hatched young mites soon died on the trees treated with lime-sulphur. Aphid eggs were found hatched even after being sprayed with 6 per cent oil.

The ineffectiveness of polysulphid sprays in assuring complete control of scale is seen by the general distribution of the living growing insects. Even though visibly coated with encrusted spray scales here and there were completing their metamorphosis. It is not the possibility of poor application that can account for living scale.

The dropping off of the scale covering with resultant death of the unprotected insect is particularly marked with the stronger polysulphid sprays. Hence the anomaly appears in the tables of poorer results from strong sprays and of lessened effect at the last counts. By the time of the June 12th counts at Clarkston the abrasion of the insects had progressed so far as to invalidate the data with respect to the absolute value of the sprays.

Two factory brands of lime-sulphur were tried in comparison, the Rex, manufactured at Yakima, and the Petrie, made at Clarkston. The results are combined in the tables, but eight paired counts of tests of 2.3 and 4 deg. showed an average of 4.6% alive for Rex and 6.9% for Petrie, a differential of 2.3% in favor of Rex spray. The Rex is made with chemical excess of sulphur to test 33 deg. and is especially rich in the higher polysulphids. Petrie spray was cooked with chemical excess of lime and originally tested 27 degrees.

There is considerable difference in the opening of the spraying season at the places selected. Scales resumed growth at Clarkston about March 30, at Walla Walla about April 3, Yakima and Wenatchee about April 10. Red spider eggs were largely hatched at Walla Walla by April 6 but at Yakima had not begun hatching by April 9. On April 30 the male scales at Yakima had reached the pupa stage.

Table 11. Spraying Experiments, in 1919

A. Clarkston. (Sprayed March 5; 789 checks, 88% alive)

	29 days		44 days		70 days	
	Total	%Alive	Total	%Alive	Total	%Alive
Lime-sul., 12 deg.	1129	68.0	1214	29.0	1183	39.6
Lime-sul., 8 deg.	1110	64.6	937	34.6	857	43.0
Lime-sul., 5 deg.	822	71.6	1085	32.5	902	37.5
Lime-sul., 3 deg.	1905	66.0	2087	51.0	2081	43.8
Lime-sul., 2 deg.	1106	66.8	1198	53.9	1023	56.5
Dry L-S., 15:50	1108	66.8	1329	51.3	1095	43.8
Dry L-S., 10:50	954	76.7	919	55.0	512	39.5
Dry L-S., reboiled	822	58.5	888	47.4	1128	34.9
S-S., 15:50	1049	55.0	1002	35.1	1212	39.7
S-S., 10:50	829	52.6	1014	61.3	1171	48.7
D. S. O., 6%	1021	7.4	1937	1.4	1123	2.9
D. S. O., 5%	1291	9.4	1319	4.5	1186	9.0
Scalecide, 6%	1075	0.6	1525	0.3	1032	0.2
Scalecide, 5%	1070	1.6	1347	0.5	1374	0.3
Hood River, 6%	1206	0.1	1235	0.4	1421	0.0
Hood River, 5%	1558	0.1	1554	0.2	960	0.0
Check	995	83.0	1020	78.8	1057	47.0

B. Walla Walla. (Sprayed March 17 and 19; 500 checks, 84.4%)

	27 days Total	% Alive	66 days Total	% Alive
Lime-sulphur, 5 deg.	1080	8.9	1088	0.7
Lime-sulphur, 3 deg.	1114	14.1	805	8.1
Lime-sulphur, 2 deg.	1090	14.0	976	5.7
Dry L-S., 15:50	993	33.5	250	2.8
Dry L-S., 10:50	1093	28.4	770	17.5
S-S., 15:50	1249	24.7	613	7.0
S-S., 10:50	1199	28.2	421	19.0
D. S. O., 5%, A	1537	0.1	890	0.0
D. S. O., 5%, B	1322	7.6	1079	2.7
Scalecide, 5%, A	1893	0.1	985	0.5
Scalecide, 5%, B	1030	3.7	1480	0.0
Hood River 5%, A	1377	0.0	1900	0.0
Hood River 5%, B	1716	0.1	1470	0.0
Crude, 5%, A	919	18.5	1020	14.5
Carb. 5%, A	1369	69.7	165	9.1
Carb. 5%, B	1176	74.4	738	28.9
Carb. 15%, B	936	77.0	801	21.4
Crest 5%, B	1183	64.6	883	57.6
Crest 2%, B	1080	62.6	504	49.6
Check	878	74.0	240	51.3

C. Yakima. (Sprayed March 20; 500 checks, 68.6% alive)

	Alive	Total	% Alive
Lime-sulphur, 5 deg.	3	1093	0.3
Lime-sulphur, 3 deg.	128	1189	10.8
Dry L-S., 15:50	269	1082	24.9
Dry L-S., 10:50	249	840	29.6
S-S., 15:50	162	1088	14.9
S-S., 10:50	73	1031	7.1
D. S. O., 5%	0	662	0.0
Hood River, 5%	0	1129	0.0
Scalecide, 5%	0	305	0.0
Crest, 10%	152	1051	14.5
Crest, 5%	107	383	28.0
Crest, 2%	469	999	47.0
Carbolic, 5%	403	1156	35.0
Carbolic, 2%	93	321	28.9
Check	260	695	37.4

D. Wenatchee (Sprayed March 25; 320 checks, 61% alive)

	28 days Total	% Alive	47 days Total	% Alive
Lime-sulphur, 5 deg.	815	2.8	1105	3.9
Lime-sulphur, 3 deg.	1282	1.6	965	0.5
Lime-sulphur, 2 deg.	816	3.3	1068	2.2
Dry L-S., 15:50	116	14.7	313	11.2
Dry L-S., 10:50	105	15.4	165	5.5
S-S., 15:50	479	8.1	384	4.7
S-S., 10:50	301	16.3	714	10.5
D. S. O., 5%	983	5.1	424	6.4
Hood River, 5%	532	0.4	378	0.3
Scalecide, 5%	941	4.2	1070	0.7
Check	856	78.2	1030	73.2

Observations and Comments.—The interchange of small scaly trees was repeated between Clarkston and Wenatchee. The Clarkston tree transplanted to Wenatchee showed 75 per cent of 513 unsprayed scales alive on March 25th when the tree was sprayed with 3 degree lime-sulphur. Four weeks later an examination of 1228 scales showed 4.7 per cent alive. This mortality is much greater than would be expected by Clarkston scales undisturbed at Clarkston, but it should be noted that the percentage of scales alive is three times as great as with Wenatchee scales similarly treated. Much more striking, however, are the results from transplanting the Wenatchee tree to Clarkston. At spraying time an examination of 538 scales from this tree showed 75 per cent alive. Four weeks after spraying with 3 degree lime-sulphur 548 scales showed but 4.3 per cent alive whereas 66 per cent of Clarkston scales were still alive with the same treatment. At the time of the second count, 44 days following spraying all the Wenatchee scales had died, but how much of this mortality to ascribe to racial susceptibility and how much to the weakened condition of the transplanted host tree it is impossible to decide.

In the midst of the applications at Walla Walla a light drizzle set in, intermittently lasting for two days and interrupting the spraying operations. Those applications marked A were given before the rain, those B after it, but while the bark was still damp. It will be noted that better results were obtained when the trees were dry; in the case of the heavy oil emulsions perfect results being secured even though rain fell on the trees almost immediately following the applications.

Crest spray, which lately had not been exploited, was revived by a reorganized company, somewhat modified, called Standard Fir Oil Spray, and was advocated at 2 per cent strength. Even at 10 per cent strength it did not compare with weaker emulsions based on crude oil.

Standard Carbolic Emulsion, manufactured in Western Washington, was recommended by its producers at a dilution of 1:70. Even at three times this strength it failed to eradicate the scale.

Unfortunately through a mistake the experimental trees at Yakima were all resprayed by the owner with lime-sulphur six days before the counts were made. Some allowance in interpreting results should therefore be made for this extra treatment. Scales killed by the emulsions of crude oil had died shortly after the application, but polysulphid sprays kill gradually. This error prevented the securing of later counts.

At the time of the first count, the male scales were in the black-eyed prepupal stage of development, red spider eggs had hatched, and apple blossoms were beginning to show pink. By the time of the second count adult males were emerging.

Experiments in 1920.—Spraying experiments were interrupted in the spring of 1920 because of the unusual and excessive winter mortality of the scales. In October, 1919, before the scale insects were fully ready for hibernation the temperature suddenly dropped to 12 or 14 degrees Fahrenheit. Again, in mid-December record-breaking cold weather occurred, with minimum temperatures as indicated in the following table. Hence the winter-kill of scales was unprecedented for Eastern Washington. This condition has been reported by Mr. Spuler of this Experiment Station in the Journal of Economic Entomology, December, 1920, pp. 443-444. Obviously with so small a scattering of living scales available on which to base records, the interpretation of comparative spraying experiments would be subject to so much error as to lose its practical value. It is for this reason that no spraying was done, and for this reason also that 1920 testimonials produced to show the efficiency of any scalecide should be severely discounted.

It is perhaps unfortunate that spraying could not have been carried on and enough extra counts made to compensate for winter-kill, in order to settle a question discussed by many fruit growers. It will be noted that winter-kill was more effective than the usual spraying in reducing the San Jose scale. Hence many fruit growers argued that spraying in the spring of 1920 would have been a needless expense because the individual scales hardy enough to withstand the winter freezes would be the same ones that would resist an insecticide. On the other hand the fruit inspectors held that it should be possible practically to annihilate the scales because the weakened condition of the survivors would render them particularly susceptible to an insecticide.

Table 12. Winter Mortality of Unsprayed San Jose Scale

Locality	Total Examined	% Alive	Minimum Temperature
Clarkston	10,144	5.4	-26
Walla Walla	12,816	3.2	-36
Yakima	8,595	1.5	-24
Wenatchee	5,409	1.8	-16
Spokane	2,485	19.2	-15
Prosser	2,545	0.0	-30
White Salmon	2,093	17.8	

The excessive cold of December, 1919, produced evidence of danger following oil spraying. As this case has been frequently quoted in the Northwest it may be referred to because of its bearing on the series of sprayings here reported. Part of the Indian Cache Ranch, located about three miles from Clarkston, was sprayed in the fall of 1919 with Scalecide. The following spring the oil-treated trees showed excessive injury, whereas the unsprayed trees escaped. From this and other similar occurrences the admonition must be made not to apply an oil spray in the fall. Even if applied in the spring an improperly emulsified spray of crude oil may cause injury, as in the case of the last drainings from the spray-tank, particularly if the tank had previously been used for lime-sulphur, but with reasonable care it should be possible to use a good mineral oil-emulsion as a dormant spray in Washington with an assurance of safety, providing the preceding winter was not excessively cold, and providing the application is made before active growth begins and after the danger of late severe freezing is past.

Apparently little is known with certainty regarding the condition under which oil might induce injury. In general it is held that an oil coating inhibits evaporation and hence when followed by a freeze the separation of excessive moisture from the cellular protoplasm becomes an irreversible reaction. Low temperature lessens sap pressure, and hence when oil is applied soon after a freeze there is greater possibility of penetration.

A tree as an organism responds to differing conditions of environment in varying degree from year to year. Oil injury is probably related to winter hardiness, and such factors as variety, maturity of tissues, soil moisture, and malnutrition due to red spider or other depredations, may be as cogent as winter temperatures in influencing injury. Oil injury is not feared in California but in Northern and Atlantic States has sometimes been a serious matter. We have sometimes noticed a retarded opening of buds on trees sprayed with strong emulsions.

Because of the difficulty of obtaining crude petroleum oil and because of the skill needed in emulsifying it we have ceased to advise the general home manufacture of crude oil sprays. Among the prepared miscible oils on the market there is much variation as this report shows. However, in those districts where a 3 degree or 4 degree lime-sulphur is not giving satisfactory results, the judicious use of a good miscible oil is to be recommended.

Experiments in 1921.—The excessive winter-kill of December, 1919, still showed its effects in the spring of 1921 in that many of the dead scales remained adherent to the branches throughout the intervening time. Often branches that at first sight seemed incrusted with scales showed only dead insects left from the fall of 1919 when subjected to close examination. There was moreover a decided dearth of live scales in many orchards. Seemingly the set-back from the severe freeze was followed by slow recovery. Under such circumstances evidence as to the absolute value of an insecticide needs to be based on more than a cursory inspection, and orchardists' testimonials adduced in 1921 should be discounted almost as severely as those from the year before.

In the following tabulations, as would also be true to a less extent in the preceding, the number of scales examined was usually far in excess of the number recorded, because those killed in the freeze of the winter before were disregarded as furnishing no information as to the value of this season's spraying. Hence data are few for certain branches received for tabulation although the sender supposed that an abundance of scale was submitted.

Table 13. Spraying Experiments, 1921

A. Clarkston. (Sprayed March 29; buds opening.)

Material	30 Days Interval Total	% Alive
Lime-sulphur, 5 deg.	866	45.0
Lime-sulphur, 3 deg.	332	17.1
Lime-sulphur, 2 deg.	820	61.0
Dry L-S., 15:50	129	46.5
Dry L-S., 10:50	828	55.5
S-S., 10:50	223	34.5
B. T. S., 10:50	843	72.2
L-S., glue, oil	1075	24.5
Scalecide, 6%	1494	10.4
Dormoil, 6%	1101	0.1
Spramulsion, 6%	198	0.5
D. S. O., 6%	1115	10.8
Check	770	78.0

B. WallaWalla. (Sprayed March 22; 418 checks, 78% alive),

Material	44 Days Interval Total	% Alive
L-S., 5 deg.	783	16.4
L-S., 3 deg.	863	34.5
L-S., 2 deg.	409	19.3
Dry L-S., 20:50	250	30.8
S-S., 10:50	187	40.0
Dormoil, 6%	127	26.0
Dormoil, 5%	262	5.3
Dormoil, 6% poor	606	41.8
Check	1041	67.8

C. Yakima. (Sprayed March 25)

	24 Days Total	%Alive	36 Days Total	%Alive
L-S., 5 deg.	316	1.2	530	1.9
L-S., 3 deg.	332	3.6	100	14.0
L-S., 2 deg.	610	0.0	685	6.3
Dry L-S., 15:50	494	5.9	600	27.5
Dormoil, 6%	518	0.0	350	40.1
Spramulsion, 6%	325	3.3	815	37.5
Spramulsion, 5%	300	0.0	435	0.0
Check	550	1.8	1343	53.5

D. Wenatchee (Pears, sprayed April 2; 551 checks, 70.7% alive)

	Interval 28 Days		Interval 37 Days	
	Total	%Alive	Total	%Alive
Lime-sulphur, 5 deg.	1324	4.1		
Lime-sulphur, 3 deg.	1050	2.5		
Lime-sulphur, 2 deg.	1363	10.2		
Dry L-S., 15:50	1235	27.6		
Dry L-S., 10:50	....	...	1343	8.5
S-S., 15:50	1069	19.4		
S-S., 10:50	1270	26.0		
B. T. S., 15:50	1400	15.9		
B. T. S., 10:50	1444	44.6		
L-S., glue, oil	....	...	1309	25.8
S-S., oil	....	...	1870	11.4
Spramulsion, 5%	1094	9.5	861	4.0
Dormoil, 5%	1379	1.4		

Notes.—The water used at Walla Walla for diluting the insecticides came from a shallow well and was hard. The sample of Dormoil could scarcely be emulsified with this hard water, even under careful manipulation, although identical oil emulsified well at the other localities.

The lime-sulphur, glue and oil combination was devised by Paul R. Jones as a means whereby these incompatible insecticides could be mixed. The ratio of oil, lime-sulphur and water was 1:4:40. The glue, used 1 lb. to 5 gallons of oil, was first soaked, heated till dissolved, and then worked into the miscible oil. After diluting the lime-sulphur the prepared miscible oil was added. This mixture as tested at Clarkston and Wenatchee did not show an increased efficiency.

Spramulsion, which had been off the Washington market for some years, was revived by the Sherwin Williams Company. It was too light an oil to compete with the heavier miscible oils.

At the time the counts were made males were pupating at Clarkston and Wenatchee, and emerging at Walla Walla. It seems remarkable to witness the unchecked growth of females and the pupation and emergence of males on branches heavily encrusted with polysulphid coatings.

Red spider eggs had hatched when sprayed with lime-sulphur 3 degrees, barium-sulphur 15:50, and soda-sulphur; nearly all had hatched under the glue combination; while Dormoil and Spramulsion produced nearly a perfect kill.

Experiments in 1922.—Spraying experiments in 1922 were confined to Clarkston, the applications being made on April 6. The materials used and results obtained are given in the following table.

Table 14. Spraying Experiments at Clarkston, 1922

	Interval 26 Days		Interval 52 Days	
	Total	%Alive	Total	%Alive
Lime-sulphur, 12 deg.	1277	12.8	1133	9.2
Lime-sulphur, 8 deg.	1047	10.1	328	12.2
Lime-sulphur, 5 deg.	1405	29.0	1160	20.9
Lime-sulphur, 3 deg.	409	16.4	501	21.2
L-S., 1:½:5	1287	21.3	989	15.0
L-S., 1¼:½:5	1183	27.8	567	18.0
Dry L-S., 30:50	1019	20.8	1197	17.2
Dry L-S., 15:50	....	...	1130	14.6
B. T. S., 30:50	1089	19.1	1344	23.4
B. T. S., 15:50	1523	19.5	593	14.5
L-S., 5 deg., caseinate	1157	20.0	968	17.2
L-S., 3 deg. caseinate	1142	20.5	538	13.7
L-S., 3 deg., casein, oil	772	3.4	384	1.5
Dormoil, 6%	1239	0.0	....	...
Spramulsion 10%	1181	0.0	....	...
Spramulsion 6%	1435	0.0	1121	0.6
Scalecide, 6%	1300	0.0	....	...
Ortho oil, 10%	1202	14.4	1278	21.3
Ortho oil, 6%	1130	19.5	1225	18.1
Keresol, 10%	1196	14.2	960	13.7
Keresol, 6%	1182	52.2	888	39.4
Check	394	63.7	2223	57.4

Notes on 1922 Spraying.—Among the oil sprays much difference in behavior was noticed. Scalecide and Dormoil were good, as formerly; Spramulsion was changed by its manufacturers to a much heavier miscible oil to its decided advantage; Ortho miscible oil was hard to emulsify and did not afford a uniform coating; Keresol was too light a product to use against the resistant scales of Clarkston;

one brand was not applied because of impossibility to emulsify, even under most persistent manipulation.

A prepared casein powder was used as a spreader with lime-sulphur at the rate of one pound to one hundred gallons; and also to permit a mixture containing three degree lime-sulphur and 5 per cent Scalecide. As far as the evidence goes there was a slight improvement in spread and effectiveness in the case of the lime-sulphur, but a slight impairment in the efficiency of the oil.

Even with 12 degree lime-sulphur, where the scales were incrusted with a heavy coating of the insecticide, many were growing in a way to leave no doubt of their remarkable resistance. While some that had resumed growth were dying from effects of the spray, their bodies then beginning to show a browning and their shells a stunting, the fact remains that even seven weeks after the application of a 12 degree lime-sulphur nine per cent of the scales were alive and growing, and most of these were as large, juicy and clear yellow as their unsprayed neighbors. At this writing the State's Fruit Inspector for the Clarkston district reports that his region is overrun with San Jose scale, the limbs of the orchard trees are greasy with scales, apple and pear fruit is entirely unsalable, the scales even spreading to the fruit of the cherry. As long as Clarkston fruit growers are placing their dependence on lime-sulphur, no matter how strong, the control of the scale in that region is hopeless.

SUMMARY

Tolerance to Sprays.—The adoption of lime-sulphur as a general spray for San Jose scale has been attended with varying success. Chemical and entomological studies by this Station have shown that in those districts where lime-sulphur is efficient a solution containing 1 lb. sulphur and ½ lb. lime to about 5 gallons water is as reliable as solutions of greater density or different composition.

Whenever scale insects are sprayed with lime-sulphur they die at varying rates. Some few are killed by the first shock of chemical deoxygenation. Most linger on, some for days, some for weeks, some for months. Among individuals varying so greatly in susceptibility, here and there are some so vigorous as to resist entirely the destructive action of this spray. A varying number of individuals escape in probably every locality, in part making necessary the annual repetition of dormant spraying; sometimes the number of survivors is a very appreciable percentage of the whole scale population.

If compulsory lime-sulphur spraying, which subjects virtually every scale to its action, thus eliminates the weaklings and selects the progenitors for future generations, a modified breed of tolerant scales could plausibly be developed. To determine if tolerance is progressively increasing the project reported was undertaken.

The Experimental Project.—Scales were given the dormant spraying to furnish the needed data for advancing conclusions. Clarkston, Walla Walla, Yakima and Wenatchee proved to be representative districts and information was based mainly on scales from these points. The following comparative aspects were considered:

a. Lime-sulphur at various strengths in one locality.
b. Lime-sulphur at a given strength in several localities.
c. Lime-sulphur and various other polysulphid sprays, e. g., dry lime-sulphur, soda-sulphur, barium-sulphur, home-made sprays, thiosulphate formulae.
d. Lime-sulphur and various oil sprays, to test strength, brands, localities.

In general, weak solutions used near the limits of effective dilution were used, with the idea of measuring relative value rather than of effecting complete control.

While the main project undertook to measure the amount and rate of mortality, incidentally information of utmost practical value was secured regarding brands, effective prescriptions, time of application, methods of spraying, effect on insects other than San Jose scale, relative costs, locality differences in emulsification of oils, amount of winter-kill, extent of danger from use of oils, etc., which has kept the Washington spraying program abreast of the times.

Methods.—Since this project was not to be a test of thoroughness of spraying but a determination of the effects of the spray, the applications were **not** done in a large commercial manner, but instead a few thousand scales previously located on representative trees were carefully drenched. At intervals within two or three months after the spraying sample young scales were dissected under the binocular microscope and the rate of mortality recorded. Later counts were found to be of less value because of abrasion of dead scales. Although a thousand and more of scales were examined for each record and percentages are given to tenths of one per cent, the figures do not carry the accuracy they imply. According to the nature of the sample secured for examination the figures might vary considerably. Scales from water sprouts or from vigorous trees are sturdy. Those from scale-poisoned trees or following a severe winter are weak and die more readily. Hence is apparent the necessity of repeated checking, over a period of years, to draw satisfactory deductions as to the absolute value of an insecticide.

Interpretations.—Statistical curves have been worked out for many of the experiments. A few characteristic ones are combined and presented in the accompanying chart. A comparison of these curves shows the range of difference in their reactions to the common insecticides manifested by the local strains of the San Jose scale.

CONCLUSIONS

With Regard to Sprays Based on Sulphur.—

Sprays like lime-sulphur, soda-sulphur and barium-sulphur manifest a prolonged and progressive insecticidal action.

Lime-sulphur and soda-sulphur have greater insecticidal value than barium-sulphur.

Factory-made lime-sulphur is as satisfactory as home-made, and is more dependable in composition.

Although different formulas for lime-sulphur might show theoretical advantages or disadvantages, yet in practice any differences in results have not been consistent.

The exact concentration to use is much less important than thoroughness of application, because of:

a. Excessive and unusual prolificness of the San Jose scale.

b. Within reasonable limits, the similarity in results from varying concentrations.

The addition of lime, lye, nicotine, or casein spreader to lime-sulphur does not materially alter its effectiveness.

There is no experimental evidence to show that dry lime-sulphur is superior to liquid.

Individual scales resistant to a bath of lime-sulphur are almost equally tolerant to a second application.

With Regard to Oil Sprays.—

Good emulsions based on crude oil are quicker and more dependable sprays for San Jose scale than are sprays based on sulphur, such as lime-sulphur, or barium-sulphur and are less disagreeable to apply.

Lack of standardization has been a serious drawback to the universal acceptance of oil sprays. Under a given trade name miscible oils sometimes vary in composition, in physical properties and in insecticidal effect.

Poor results from oil spraying are to be expected if trees are wet at time of application, but it is not a serious matter if rain comes shortly after the application is made.

A poorly emulsified oil, or one with insufficient insecticidal value, is less effective than a low-grade lime-sulphur, probably because the oil-cleaned and softened bark affords a better breeding ground than the residual coating from a sulphid spray.

Well emulsified oils, used as a late dormant spray, following a normal winter should be depended on as safe to the trees. Fall spraying with oil is not recommended because of the possibility of heavy winter freezes and consequent injury to the trees.

Emulsions based on wood distillation products instead of crude petroleum oil have little insecticidal value.

With Regard to Control in General.—

Because the San Jose scale holds the record for rapid breeding a treatment to be considered effective must accomplish practical extermination. A remedy that results in 60 per cent kill is no better than one that produces but 40 per cent, because both are useless. But a spray that kills 60 per cent of the scales should not be confused with faulty application of an efficient insecticide that reaches but 60 per cent of the scales.

The most reliable determination of the absolute or relative value of compared insecticides is not a late summer inspection of fruit, foliage or bark, but a microscopic examination of actually sprayed scales about one month after the application. Before one month the spray might not have produced its maximal effect, later the dropping of dead scales disturbs the proportion of living to dead scales, still later the free movements of young scales make deductions untrustworthy. Late summer inspections, however, are a valuable gauge of the thoroughness of application.

The best time for spraying for San Jose scale is when buds begin to swell. Later the swollen buds cover some scales out of reach of spraying. When foliage begins to appear dormant sprays may cause burning. This is especially true with soda-sulphur and crude oil emulsions.

A relative scarceness of living scales following a severe winter is not necessarily due to successful spraying. Excessive winter-kill shows its effects even into the second winter in a diminished number of live scales per tree.

The fact that a treatment has been declared effective in one locality is no assurance that it will be universally effective Recommendations based on Atlantic Coast or Middle West conditions are not of necessity applicable to the scale district of Washington, any more than Wenatchee recommendations would suit Clarkston. Following a severe winter ultra-weak sprays show apparently good results.

The locality, winter conditions, and presence of other pests than scale should determine the kind of spray to select and the concentration best to use. The most efficient concentration is not a fixed prescription.

Where lime-sulphur is giving good results, it will possibly be given preference as a dormant spray. Where a 3 or 4 degree lime-sulphur is giving imperfect control the use of oil sprays is recommended.

With Regard to the San Jose Scale.—

There is much variation among different individual scales in susceptibility, tolerance or resistance to sprays, particularly to sprays based on sulphur, such as lime-sulphur, soda-sulphur, or barium-sulphur.

The amount of tolerance differs from locality to locality, and from year to year.

There is more difference in the rate of kill and the total number of scales that die when comparing Clarkston and Wenatchee scales sprayed with regulation strength of lime-sulphur, than when comparing scales at either locality sprayed with lime-sulphur ranging from 2 to 27 degrees.

Winter mortality varies with severity of winter and with local vigor of scale. A temperature of -30 degrees F. destroys more scales than the usual spraying does. In a mild winter 98 per cent of the young scales may survive.

The abundance of scales at Clarkston and the relative scarceness at Wenatchee is probably largely due to a natural vigor possessed by the Clarkston scales, as manifested by a positive tolerance to lime-sulphur, and a corresponding weakness of the Wenatchee scales, as manifested by susceptibility to sprays. The difference is probably due less to external factors, like spraying methods, minimum winter temperatures, optimum summer weather, action of parasites, number of summer generations, or condition of host plants.

There is no positive evidence that the San Jose scale is at present becoming more and more resistant to polysulphid sprays. This is possibly the effect of hereditary regression since the annual spraying with lime-sulphur exerts selection on only one of the season's many generations. Or possibly, acclimatization to lime-sulphur is an annual acquirement, not necessarily heritable.

The distribution of the San Jose scale in Washington, and probably elsewhere, coincides with the area where peaches are successfully grown. The San Jose scale is unable to thrive under conditions at Pullman, although determined efforts have been made to introduce and establish it. Why some Clarkston scales can survive a strong bath of lime-sulphur, but all die when brought to an upland locality, is one of the strange happenings of Nature.

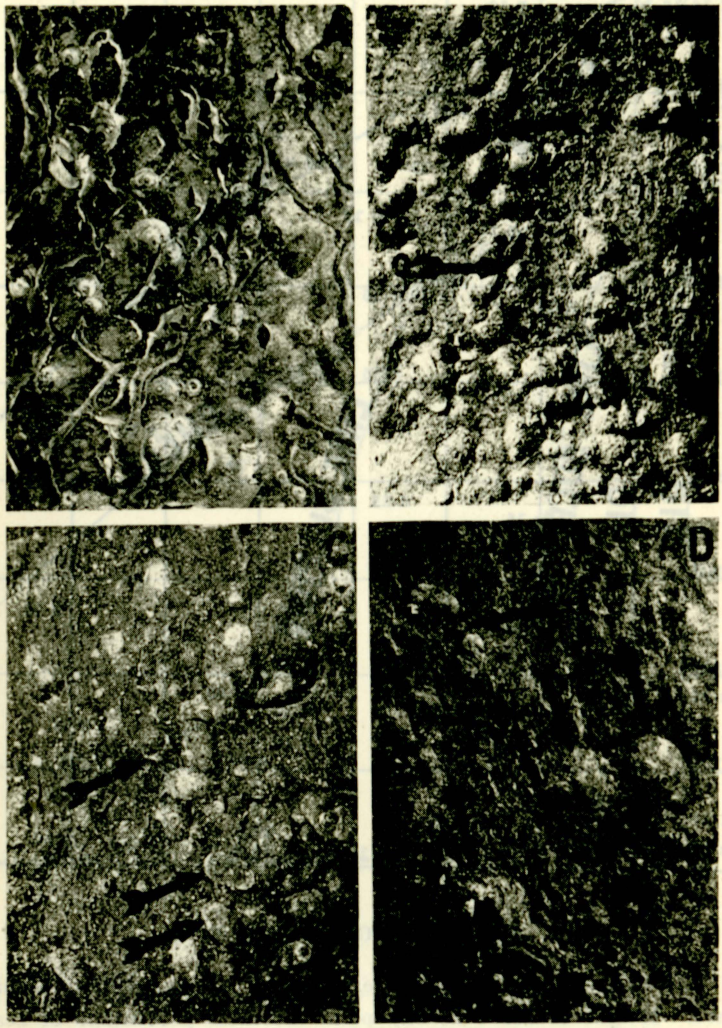
EXPLANATION OF PLATE

A. Oval male and circular female scales.
   Not Sprayed. Photographed April 19.

B. Clarkston scales photographed seven weeks after spraying with 10 degree lime-sulphur. The convex scales (x) have grown from the size indicated by the small killed wintering scales (o).

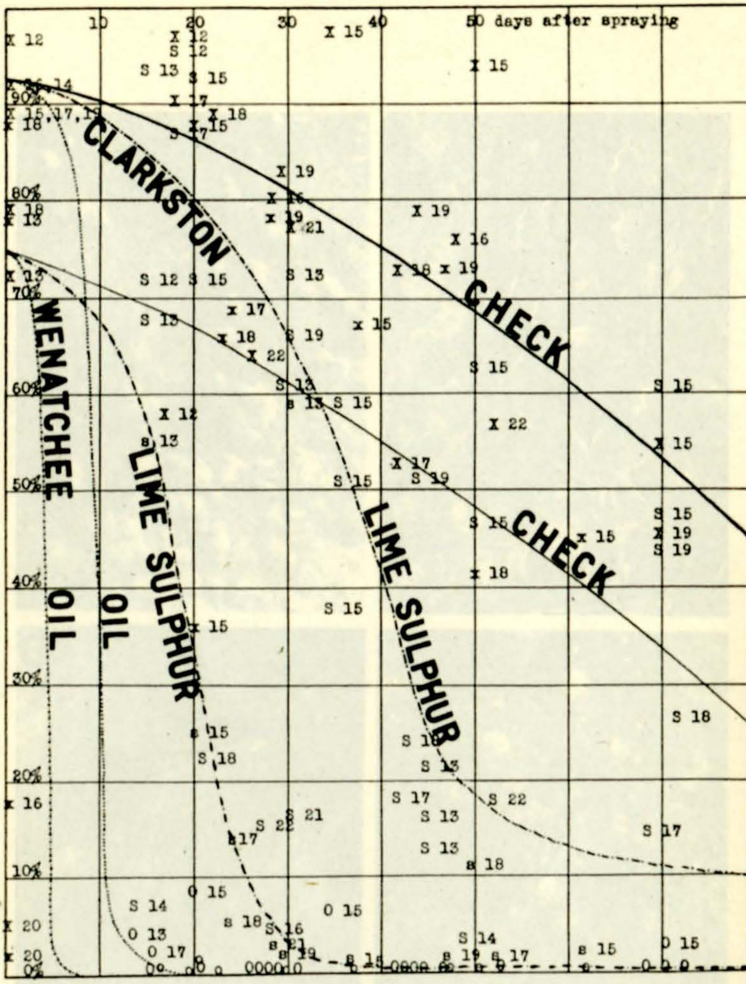
C. Yakima scales photographed 43 days after spraying with 1: ½ :5 lime-sulphur formula. Note that the marked individuals are still growing altho the scale covering is arrested.

D. Clarkston scales maturing though encrusted with lime-sulphur. Adult males have already emerged from the oval scales. The round scales are nearly full-grown females.



San Jose Scale on Apple Bark—Enlarged about eight diameters

(For explanation see page 48.)



EXPLANATION OF CHART

Mortality curves of San Jose scale at Clarkston and at Wenatchee. Height of curve at any point indicates percentage of scale alive. Distance to the right indicates days intervening since spraying. Unsprayed checks and treatments with 3 degree lime-sulphur and 5 per cent oil are indicated.

PAGE INDEX

TO INSECTICIDES TESTED ON SAN JOSE SCALE