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PRELIMINARY REPORT ON CONTROL OF SAN JOSE SCALE WITH LUBRICATING-OIL EMULSION.[1]

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CONTENTS.

RECENT INCREASE OF THE SAN JOSE SCALE IN NORTHWESTERN ARKANSAS.

The San Jose scale has increased in such alarming numbers during the last two years in several localities of the Ozark region of Arkansas as to threaten the destruction of the apple industry. During 1920 this pest was present in a large number of orchards and in the fall of that year much fruit was spotted with the scale, though only a few trees had been killed. Following the complete crop failure of 1921 the San Jose scale developed into the most serious problem fruit growers of this section had ever faced. Many acres of trees were dead by late summer and many orchards were so thoroughly infested with the scale that it became necessary to check the pest before the next growing season in order to save the orchards. Growers were extremely discouraged in view of many failures to control the scale with dormant sprays during the preceding two seasons.

[1] The writer wishes to acknowledge his indebtedness to Leslie Pierce, of the Bureau of Plant Industry, for his cooperation and assistance during the entire progress of this investigation, and to W. W. Yothers, of the Bureau of Entomology, for his many helpful suggestions on oil-emulsion sprays based on several years' experience in Florida.

Such being the critical situation, the laboratory of the Bureau of Entomology at Bentonville, Ark., began, as soon as practicable in the fall of 1921,[2] a series of experiments for the control of the San Jose scale. Of all the insecticides used in the experiments best results were obtained with the so-called paraffin-oil or lubricating-oil emulsion. The selection of oils of this type for experimental work against the San Jose scale was in consequence of the excellent results obtained with lubricating-oil sprays by W. W. Yothers, of the Bureau of Entomology, in the control of various citrus insects in Florida.

A preliminary announcement[3] of results in the use of lubricating oils for the San Jose scale was made as soon as sufficient evidence had been obtained to indicate strongly its suitability for this insect. This circular gives results obtained to date in the experiments with lubricating oils for the control of the San Jose scale, together with methods for the preparation of the emulsion and recommendations for the use of the insecticide. Investigation of this subject is being continued to obtain further information on the use of the emulsion in various parts of the country, and on various host plants, and to ascertain what injury, if any, will result to the various classes of deciduous fruits treated.

HISTORY OF INFESTATION.

During the season of 1918 the San Jose scale caused little or no damage to fruit or trees in northwestern Arkansas. At that time orchardists, as a rule, applied one dormant spray of liquid lime-sulphur solution in the spring just as late as possible before the fruit buds began to swell. At harvest time in 1919 several orchards showed fruit badly spotted with the scale, though practically no dead limbs or trees were evident. The beginning of the serious scale infestation in this region dates from the fall of 1919. In 1920 a large number of orchards were badly infested with the scale, much fruit was damaged, and limbs and trees were being killed. Even at that time, with the exception of an occasional orchardist, little anxiety was shown by the growers, as they were confident that the scale could be controlled with the dormant applications.

Orchards received little attention during the growing season of 1921, following the complete killing of the fruit crop by freezes in the spring of that year. By the fall of 1921 the San Jose scale had spread so rapidly that it could be found in practically every orchard of the region, and it had either killed entire orchards or portions of them in many instances. It was fully realized by this date that the scale must be controlled immediately or many of the growers would be driven out of the orchard business.

FACTORS INFLUENCING INCREASE OF THE SAN JOSE SCALE.

Several reasons can be assigned for the serious damage caused by the San Jose scale in this region. Foremost, without doubt, is un-

[2] The writer returned to the Bentonville laboratory of the Bureau of Entomology on November 1, 1921, after an absence of nine months, and Leslie Pierce, of the Bureau of Plant Industry, returned to this station about the middle of November.

[3] U. S. Department of Agriculture Clip Sheet 193, March 6, 1922. "A Promising New Treatment for the San Jose Scale," by A. L. Quaintance.

intentional carelessness in spray methods on the part of many growers. In the past one thorough dormant spray with liquid lime-sulphur solution has always controlled the scale satisfactorily, and practically all growers made the dormant application. When the scale first began to increase, some growers failed to apply the dormant spray and others were careless in their work. The tips of branches, especially in the tops of trees, were often missed, and scale infestations began at those points. There was carelessness, also, as to the amount of spray material used in the tank. Often mistakes were made in the size of measuring buckets or even in the size of spray tanks, so that the dilute spray solution was not strong enough. Many growers hurried their spraying operations to such an extent that the covering of spray material was insufficient to insure a thorough coating of all parts of the tree, which is very essential.

The first marked increase of the San Jose scale followed soon after the advent of the spray-gun. Many orchards in which spray-guns were used did not receive a thorough application. The coarse adjustment of the gun was used in trying to reach the tops of trees, with the result that the tips were not thoroughly coated with spray material. Several gun-sprayed orchards showed scale infestations which began in the tops of the trees.

Perhaps one of the most important factors in the scale increase has been unfavorable weather. At the time of the spring dormant spray, rainy weather and high winds often interfere with an application. This was especially true in the spring of 1920, when unfavorable weather delayed the spring application and warm weather opened the fruit buds before opportunity was afforded to apply the spray. With the buds opening as quickly as they did in 1920, some growers caused burning by spraying late and others were not able to go over their entire orchards. Thus, in trying to take advantage of the warm spring days when lime-sulphur solution is most effective against the scale, growers often did not find time enough to complete the spray application. The prevailing winds at this time of year blow strongly from the south, which makes it difficult to cover the north side of a tree thoroughly. It has often been noted that the young scale "crawlers" of the first generation are first observed in the spring on the north side of trees.

The lack of a sufficient number of parasites and the scarcity of predacious enemies of the San Jose scale has been another important reason for the rapid increase of the insect. This, together with a long, favorable breeding season, has tended to cause an unusually rapid increase in the scale infestation. Where a few scales escaped the dormant treatment, they increased to such numbers by late fall as to be scattered all over an orchard. The scale spread so quickly in 1921 that some orchards, which growers considered free from the scale in the spring, were either partially or almost entirely killed by late fall.

DISTRIBUTION OF INJURIOUS INFESTATIONS.

Speaking generally, the San Jose scale has become destructive during the past year throughout the southern limits of the apple belt in the Central Western States. Besides northwestern Arkansas,

severe infestations occur at several points in the Ozark region of Missouri, and in southern Illinois and Indiana. The Missouri River region in Nebraska, Kansas, and Missouri, centering about St. Joseph, Mo., at present is almost entirely free from the scale. Interior Kansas is also comparatively free from this insect.

In the Ozarks of Arkansas the most serious damage by the scale has been caused in the northwestern corner of the State. Orchards in the vicinity of Pea Ridge, Bentonville, and Centerton have been unusually hard hit. Orchards south of Bentonville and Rogers have not been so seriously damaged.

SERIOUSNESS OF INJURY IN ARKANSAS ORCHARDS.

The orchards which have been most seriously injured by the San Jose scale have been those which were the most productive and well cared for. Orchards in which the trees have made a vig-

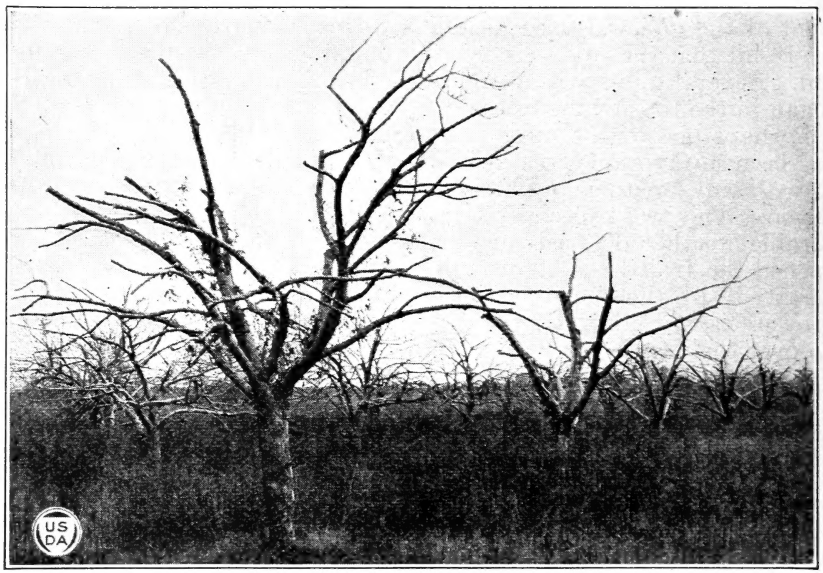

FIG. 1.—Trees attacked by the San Jose scale, dehorned, and ultimately killed.

orous growth are the ones where the scale has thrived. Figure 1 shows a block of trees in an orchard formerly one of the most productive in the Bentonville vicinity. These trees were cut back in the fall of 1921, and the following summer, when the photograph was taken, they failed to show any new growth. If the scale had been controlled by the spray application that was made during the dormant season of 1920–21, most of the trees in this orchard could have been saved. This orchard was so hard hit by the scale that 30 acres out of a total of 35 acres of trees were killed in two seasons.

Five hundred acres of bearing apple trees killed by the San Jose scale would be a conservative estimate of the damage caused in northwestern Arkansas.

COMPARATIVE SUSCEPTIBILITY OF APPLE VARIETIES.

The varieties of apples that have been most severely injured by the San Jose scale in Arkansas are Grimes, Ben Davis, Gano, Western Beauty, and Oliver. Some of the moderately susceptible varieties are Early Harvest, Mammoth Black Twig, Ingram, Jonathan, and Maiden Blush. Winesap, Arkansas Black, and Givens are rather resistant to scale attack.

Ben Davis is the leading commercial variety of the region. When large limbs of this variety are killed by the scale it is almost certain that blister canker will enter where the large pruning cuts have been made. For this reason Ben Davis trees, even when only partly killed by the scale, have small chance of surviving. Figure 2 shows a block of Ben Davis trees in which most of the scale-

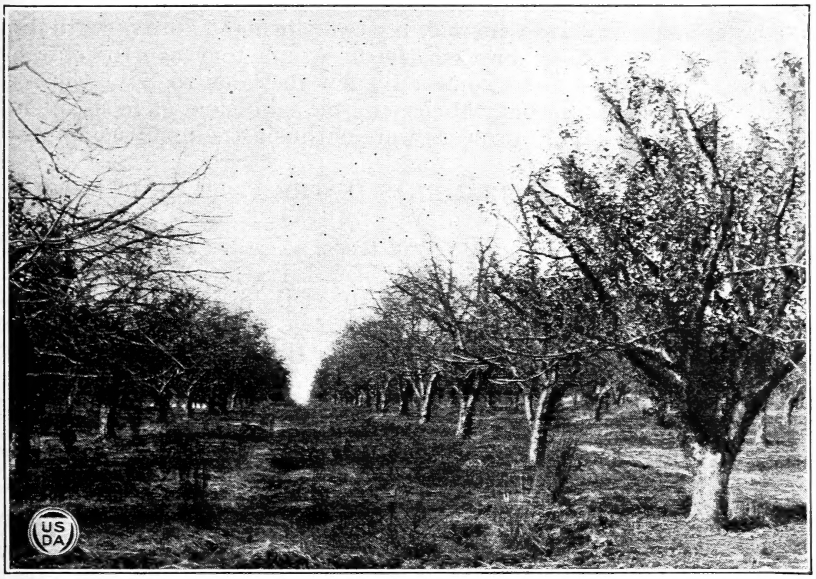

FIG. 2.—Ben Davis trees severely injured by the San Jose scale.

killed limbs have been pruned out. It is questionable whether many trees in this block can be saved, even after the scale has been controlled.

Vigorous-growing varieties like Mammoth Black Twig or Jonathan can be brought back after a severe pruning of limbs killed by the scale. Jonathan, which is probably the second variety in commercial importance in this region, is far more resistant to scale injury than Ben Davis or Gano. Nevertheless, it is not rare to find Jonathan trees incrusted with the scale.

CONTROL METHODS PRIOR TO 1922.

Before the San Jose scale became destructively abundant in northwestern Arkansas, the usual control procedure consisted of a single spring dormant spray applied as late as possible before the buds

opened, so as to take advantage of warm weather. Commercial liquid lime-sulphur solution was very generally used, although a few growers preferred miscible oil occasionally. When the scale began to increase, two dormant sprays were more frequently applied, one in the fall after the foliage was off and a second in the spring. At the same time many growers increased the strength of their spray mixture from the recommended 25 gallons of 33° Baumé lime-sulphur solution to as much as 35 or 40 gallons in a 200-gallon spray tank. In spite of this the majority of growers failed to obtain a satisfactory control of the scale. On incrusted trees enough scales escaped to provide breeding stock for the following season. A few growers, however, were able to control bad infestations of the scale with two thorough applications of lime-sulphur. In such instances all parts of the trees were thickly coated with spray, which required an unusually large amount of spray material on each tree.

The expense involved in making two dormant sprays with lime-sulphur solution, together with the unsatisfactory control obtained, led the orchardists to welcome any new methods to fight the scale. When it was found that lubricating-oil emulsion gave a splendid killing of the scale, the growers were enthusiastic about using it.

SPRAYING EXPERIMENTS IN THE FALL OF 1921.

A block of young Early Harvest trees, so badly incrusted with the scale that many limbs had already been killed, was obtained for the spraying experiments in the English & Boles orchard at Bentonville, Ark. The experiment consisted of 26 plats, and included tests of several different strengths of lubricating-oil emulsion, kerosene emulsion, a proprietary miscible oil, several brands of dry lime-sulphur, three brands of commercial liquid lime-sulphur, and home-made lime-sulphur solution. The spraying was done with a barrel spray rig which maintained a pressure of about 125 pounds for a single rod with one nozzle. The trees were small enough to avoid any difficulty in covering their entire surfaces by means of this outfit. The tests were made during the middle of December, 1921, after the trees were completely defoliated and before cold weather had begun. Each plat consisted of at least 4 trees, and examinations to determine the mortality of hibernating scales were made under a binocular microscope from twigs of 4 record trees.

All oil emulsions were made by the boiled process, and potash fish-oil soap was used as the emulsifying agent. No examination of twigs at the time of first-generation hatching or of the fruit at harvest time was made. Observations of the fruit on the oil-emulsion sprayed plats, however, showed scarcely any scale spotting at picking time.

Table 1 gives a summary of the experiment, showing the various insecticides and dosages used, with the percentage of dead scales in each plat at the time of examination. It requires about 30 days after spraying with oil emulsions before absolute determination of dead scales can be made. The killing power of lime-sulphur extended over a considerably longer period than that of oil sprays.

The results from the dry lime-sulphur plats are not included in this circular.

TABLE 1.—*Mortality of hibernating San Jose scales from spraying with oil emulsions, lime-sulphur, and a miscible oil, English & Boles orchard, Bentonville, Ark., 1921–22.*

Plat.	Insecticide.	Dosage.	Date of application.	Date of examination.	Number of scales dead.	Number of scales alive.	Per cent of dead scales.
			1921	1922			*P. ct.*
1	No. 1 oil emulsion	3 gallons in 100; 2 per cent	Dec. 14	Jan. 11	3,400	3	99.91
2	do	6 gallons in 100; 4 per cent	14	11	1,100	2	99.82
3	do	9 gallons in 100; 6 per cent	14	11	1,000	0	100
4	do	12 gallons in 100; 8 per cent.	14	11	1,000	0	100
5	No. 2 oil emulsion	6 gallons in 100; 4per cent	14	11	1,000	0	100
6	do	9 gallons in 100; 6per cent	14	11	1,000	0	100
7	do	12 gallons in 100; 8 per cent.	14	11	1,000	0	100
8	Kerosene emulsion	20 per cent	14	19	1,040	35	96.74
9	do	25 per cent	14	19	1,012	17	98.35
20	No. 1 commercial lime-sulphur.	32° B., 6½ gallons in 50	16	18	830	207	80.04
21	No. 2 commercial lime-sulphur.	do	16	21	803	224	78.19
22	No. 3 commercial lime-sulphur.	29° B., 10 gallons in 50	27	Feb. 5	1,015	125	89.03
23	Homemade lime-sulphur.	29° B., 9 gallons in 50	27	5	1,012	225	81.81
25	Miscible oil	3⅓ gallons in 50	27	5	1,200	29	97.64
26	Check (unsprayed)			Jan. 11	221	802	21.60

It will be noted that Plats 1 to 7, inclusive, comprising tests with various strengths of two different brands of lubricating oil, gave very encouraging results. When it was found that Plat 1, a 2 per cent lubricating-oil emulsion, was showing good killing, a large number of scales were examined to get an approximate estimate of the efficiency of this low-strength oil emulsion. Examination of a large number of scales in the higher-strength oil-emulsion tests was deemed unnecessary.

Plats 8 and 9, sprayed with a 20 per cent and 25 per cent kerosene emulsion, respectively, gave a fair kill of scales. Trees in these two plats looked oily for a period of perhaps 10 days or 2 weeks after the spray application, whereas trees in Plats 1 to 7, inclusive, had a very oily appearance for more than a month following the spray. Likewise the scale insects of the kerosene-emulsion plats, either dead or alive, showed no trace of oiliness on the date of examination, while the scales of the lubricating-oil emulsion plats still retained a thin oil film 30 days after they were sprayed. Apparently high dosages of kerosene emulsion with their corresponding high volatility were less effective at this time of year against the San Jose scale than the low-strength lubricating-oil emulsions with their low percentage of volatility.

Plats 20 and 21, sprayed with two different brands of commercial lime-sulphur, gave about equal kill. The concentrated lime-sulphurs used in Plats 22 and 23 tested so low that they were applied extra strong. All lime-sulphur plats, at the time of examination, showed poorer results than the oil-emulsion plats.

Plat 25, sprayed with a proprietary miscible oil, gave about the same kill of scales as the kerosene emulsions. This oil, like the kerosene emulsions, was far more volatile on the trees than the heavier grade lubricating-oil emulsions.

Under Plat 26 the percentage of dead scales on twigs of unsprayed trees is given.

TESTS WITH SEVERAL BRANDS OF LUBRICATING OIL.

Following the success with a 2 per cent lubricating-oil emulsion in the experiments of December, 1921, it was decided to test several different brands of oil sold in this district. For this experiment a block of large Ben Davis trees, entirely incrusted with scales, in the R. O. Pickens orchard at Bentonville, Ark., was available. A 200-gallon power sprayer with a pressure of 225 pounds, two rods, and double angle nozzles was employed for this work. One man sprayed from the ground and the other in the tower, spraying one side of a tree row at a time. One 200-gallon tank of spray material was used for each plat. The results of the experiment are given in Table 2.

Plats 1 and 2 were treated, respectively, with a 1 per cent and a 1½ per cent emulsion of the No. 1 lubricating oil used in Plats 1 to 4 of Table 1. Plat 3 received a 2 per cent emulsion of the same oil as that used in Plats 5 to 7 of Table 1. Plats 4 and 5 received 2 per cent emulsions of two other brands of oil which may be termed No. 3 and No. 4 lubricating oils. Thus, this experiment embodied a test of four different brands of heavy commercial lubricating oils the analyses of which differed only slightly one from another. The essential object of this experiment was to determine the comparative effectiveness of several different brands of lubricating oil. For this reason there was no need of an unsprayed plat for a check. Examination of the trees before spraying showed an abundance of live scales.

A very severe spell of cold weather occurred during the middle of January, just before Plats 1 and 2 were sprayed. Again, during the last of January and prior to the dates of spraying Plats 3, 4, and 5, very cold weather prevailed. On the dates of the applications rather mild winter weather was encountered. Table 2 shows the mortality of the scales resulting from the various oil emulsions.

TABLE 2.—*Mortality of hibernating San Jose scales from spraying with several brands of lubricating-oil emulsion, R. O. Pickens orchard, Bentonville, Ark., 1922.*

Plat.	Insecticide.	Dosage.	Date of application.	Date of examination.	Number of scales dead.	Number of scales alive.	Per cent of dead scales.
			1922	1922			*P. ct.*
1	No. 1 lubricating-oil emulsion.	1½ gallons in 100; 1 per cent.	Jan. 21	Mar. 7	3,265	35	98.94
2		2¼ gallons in 100; 1½ per cent.	21	7	3,000	6	99.80
3	No. 2 lubricating-oil emulsion.	3 gallons in 100; 2 per cent	Feb. 3	28	1,500	12	99.21
4	No. 3 lubricating-oil emulsion.	3 gallons in 100; 2 per cent	3	27	2,100	4	99.81
5	No. 4 lubricating-oil emulsion.	3 gallons in 100; 2 per cent	4	28	1,675	4	99.76

The weakened dosage of the No. 1 lubricating-oil emulsions in Plats 1 and 2, respectively, gave a very good kill of scales. A 2 per cent emulsion of this same oil under similar orchard conditions, as shown in Plat 1, Table 1, was very effective. Plats 3, 4, and 5 in Table 2 show a rather uniform killing of scales for 2 per cent emulsions of three different brands of oil.

WEAK DOSAGES OF LUBRICATING-OIL EMULSION.

The success attained with a 1 per cent and a 1½ per cent emulsion, Plats 1 and 2 of Table 2, suggested the possibility that weaker dosages than the 2 per cent emulsion might be effective against the scale in the dormant season. Tests with three brands of oil, each with dilutions of ¾ per cent, 1 per cent, and 1½ per cent, were made in the Pickens orchard at Bentonville on February 11. Conditions pertaining to degree of scale infestation and spraying equipment were similar to those outlined in the preceding experiment. Table 3 gives the results from the use of weakened oil-emulsion sprays.

TABLE 3.—*Mortality of hibernating San Jose scales from spraying with weak dosages of lubricating-oil emulsions, R. O. Pickens orchard, Bentonville, Ark., 1922.*

Plat.	Insecticide.	Dosage.	Date of application.	Date of examination.	Number of scales dead.	Number of scales alive.	Per cent of scales dead.
			1922	1922			*P. ct.*
1	No. 4 lubricating-oil emulsion.	1⅛ gallons in 100; ¾ per cent..	Feb. 11	Mar. 22	1,000	20	98.04
2		1½ gallons in 100; 1 per cent..	11	22	1,000	18	98.23
3		2¼ gallons in 100; 1½ per cent.	11	23	1,675	2	99.88
4	No. 1 lubricating-oil emulsion.	1⅛ gallons in 100; ¾ per cent..	11	23	1,046	20	98.12
5		1½ gallons in 100; 1 per cent..	11	25	1,075	24	97.82
6		2¼ gallons in 100; 1½ per cent.	11	25	1,625	4	99.75
7	No. 2 lubricating-oil emulsion.	1⅛ gallons in 100; ¾ per cent..	11	25	1,000	35	96.62
8		1½ gallons in 100; 1 per cent..	11	25	1,000	19	98.14
9		2¼ gallons in 100; 1½ per cent.	11	25	1,550	6	99.61

The three-fourths per cent emulsion of the three different oils apparently gave a fair kill of scales. The 1 per cent emulsions were practically no better than the slightly weaker three-fourths per cent emulsions. The 1½ per cent emulsions in all cases killed over 99 per cent of scales. It was evident from this experiment that a 2 per cent emulsion was not the minimum dosage at which a good kill of scales might be effected. For practical purposes, however, it is likely that the 2 per cent emulsion is the lowest dosage that could be used by growers to insure a successful control of the scale.

USE OF OIL EMULSION FOR DORMANT SPRAY IN COMMERCIAL ORCHARDS.

Soon after it became evident that lubricating-oil emulsion was giving good control of the San Jose scale in an experimental way during the dormant season, it was decided that the growers should be informed of the data already at hand. Accordingly, all the details of the experimental work that had been carried on were given to growers in the vicinity of Bentonville. Although the investigation was far from complete, many growers were interested to get any new suggestions on scale control. Nothing was known about the possibility of injury to trees following an application of this emulsion. With the knowledge that much information covering this subject was still lacking, a large number of growers voluntarily decided to use the emulsion for the spring dormant treatment.

A plant for the manufacture of oil emulsion was set up at Bentonville, and growers were first supplied with the product early in

February, 1922. Following this initial venture, plants at two other points in northwestern Arkansas began the manufacture of this insecticide. About 1,000 barrels of oil emulsion were used commercially, taking the place of approximately 4,000 barrels of concentrated lime-sulphur solution.

A 2 per cent emulsion, or 6 gallons of stock in a 200-gallon spray tank, was the strength used by practically all growers. The period during which oil emulsion was applied for the dormant spray in various orchards extended from the middle of February until after the buds had opened, some growers even using it as late as the pink spray. Growers who made the application late secured unusually good control of the green apple aphis in addition to killing the scale. In fact, many growers later used the oil spray against the green aphis when they found that this insect, usually of little economic importance in this section, was causing considerable damage.

A very satisfactory control of the scale in commercial orchards was obtained with the 2 per cent emulsion in practically all instances. The scale was brought under control in orchards in which it had been increasing gradually in previous years in spite of dormant spraying. While the scale was by no means eradicated, growers felt more optimistic of their ability to hold it in check than heretofore. Examinations of twigs from a large number of oil-sprayed orchards showed just as good kill of scales as was effected in the experimental spraying. Occasionally a few live scales were found in protected places, such as crevices on the fruit spurs or in deep depressions or cracks of old hail bruises. Of course, some trees were not covered completely with the spray, and missed spots showed live scales.

SUMMER TREATMENTS WITH OIL EMULSION.

Tests with lubricating-oil emulsion were made during the summer, from the time the young scale crawlers of the first generation appeared until the fruit was harvested. Only a partial control of the scale was accomplished at this season in any of the tests, although oil emulsion of the same strength was used as for the dormant spray. The high summer temperatures caused the spray solution to evaporate so quickly that only the most tender stages of the insect were killed. All the crawling scales that were hit by the spray were killed, as well as the newly settled young. Many of the young which had not emerged from under the scale covering of the adult female were also reached by the oil spray, and in such cases the young near the exit hole were killed, which prevented those that were not touched from escaping. Some half-grown scales and a few full-grown females were killed by the summer sprays. In the course of a week or 10 days following the spray, however, young crawlers would be found emerging and settling down.

Many growers used oil emulsion in the standard summer Bordeaux sprays, and there is no doubt that the scale was held in check to such an extent that much spotting of fruit and damage to limbs was prevented. Much of the scale was cleaned off the fruit by the summer sprays. Most of the live scales left on such fruit were found deep in the calyx or stem cavities, where the spray solution failed to reach them.

Complete eradication of the scale can not be expected with summer treatments with any insecticide. With trees in full foliage it is impossible to cover entirely all parts of the trees with a spray solution. The best results that can be hoped for with a summer application are to hold the scale in check until the dormant sprays can be applied. The only time when bad infestations of the scale can be completely cleaned off is during the dormant season.

As soon as continued cool weather occurred some tests with late summer sprays were conducted. These were applied on September 21 and 22 on trees thoroughly infested with the scale. The application was made on the Ben Davis variety about a month before the fruit was harvested. The weather remained generally cool after the tests were made. In Table 4 are given the data covering this experiment.

TABLE 4.—*Mortality of all stages of the San Jose scale from the use of late summer sprays, English & Boles orchard, Bentonville, Ark., 1922.*

Plat.	Insecticide.	Dosage.	Date of application.	Date of examination.	Number of scales dead.	Number of scales alive.	Per cent of scales dead.
			1922	1922			*P. ct.*
1	Lubricating-oil emulsion	3 gallons in 100; 2 per cent.	Sept. 21	Oct. 1	3,025	79	97.45
				20	2,350	49	97.96
2	Lubricating-oil emulsion. Bordeaux	3 gallons in 100; 2 per cent. ½–½–50	22	1	1,700	53	96.98
				20	1,550	51	96.81
3	Liquid lime-sulphur	1½ gallons in 50	22	1	1,000	87	92.00
				20	1,556	839	64.97
4	Liquid lime-sulphur. 40 per cent nicotine sulphate.	1½ gallons in 50. 1 to 800	22	1	1,000	31	96.99
				20	1,698	816	67.54
5	Check (unsprayed)			1	1,288	638	66.87
				20	1,566	839	65.11

Two examinations of scale-infested twigs from the various plats were made, the first 10 days after the spray application and the other about 20 days later. The reason for the first examination was to get an idea of the mortality of the scales, particularly the young crawlers, before the dead bodies were blown away. Plats 1 and 2, 2 per cent lubricating-oil emulsion plats (a weak Bordeaux being used with the lubricating-oil emulsion on Plat 2) showed a fair kill of the scales on the dates of both examinations. At the time of the last examination all the young stages of the scale were dead, only a few of the full grown females in protected crevices escaping. A kill of 96 to 97 per cent of the scales during the cool weather of late summer compares favorably with results from a dormant treatment with 2 per cent oil emulsion, especially since the foliage hinders thorough work in a summer treatment. Plats 3 and 4, summer-strength lime-sulphur solution plats, lime-sulphur used alone in one and 40 per cent nicotine sulphate added in the other, showed comparatively good killing at the first examination. When these plats were examined about a month after the application, however, they showed approximately the same percentage of dead scales as on Plat 5, the unsprayed check. On October 20, twigs from Plats 3, 4, and 5 were abundantly covered with crawling young, settled scales, and full-grown females.

Practically all scales on the fruit of Plats 1 and 2 were killed by the action of the oil emulsion, the only scales escaping being located deep in the calyces. Live scales on the fruit of the other three plats were plentiful.

The results of this late summer treatment demonstrate that a fair percentage of the scales can be killed with oil emulsion if cool weather prevails. Much damage from the scale has resulted in this section in former years during the period from the middle of September to the middle of November.

ADVANTAGES AND DISADVANTAGES OF OIL EMULSION.

The low cost of lubricating-oil emulsion appeals strongly to orchardists. Another advantage of oil emulsion is the fact that hired hands will do a better job of spraying with this solution than they would with more caustic insecticides. They are not so cautious about dodging the spray when it does not burn the face and eyes. Oil emulsion also leaves the spray-rig in much better condition after an application than is the case with many insecticides. Some growers even consider that a saving in spray material follows from the spreading power of the oil spray. It is not advisable, however, to attempt a saving of spray solution in fighting a bad infestation of the scale.

Some trouble has been encountered in the Ozark region because the stock emulsion would not mix readily with the water that was used for spraying. Oil is set free in some instances when hard water is used for spraying. Free oil in the spray tank appears as a thick greenish scum on the surface of the dilute solution. A weak Bordeaux mixture, used at the rate of 4–4–50, will overcome this difficulty. This weakened Bordeaux has never failed to make the hardest water of this section mix with the stock emulsion. Whenever available, soft water should be used with the oil emulsion.

The presence of lime-sulphur residue in the spray tank and spray pump has been responsible for some of the difficulty experienced in obtaining a proper emulsion. A small amount of lime-sulphur will set the oil free. Any lime-sulphur residue present in a spray-rig should be cleaned out by running a strong solution of caustic soda or lye through the pump and washing the inside of the spray tank before the oil emulsion is used. Even then it is advisable to use the weak Bordeaux mixture in the first tank or two.

Precaution should be taken to prevent the stock emulsion from freezing, which occurs at a temperature of about 15° F. If sufficient shelter is not available to protect barrels of oil emulsion during cold weather, they should be thoroughly covered with straw or other suitable material. When the stock has once been frozen the emulsion will break down and become unfit for later use.

SPRAY INJURY.

The possibility of injury was one of the unknown factors in the use of oil emulsion on apple trees. From experience with this insecticide in commercial citrus groves in Florida, where an emulsion containing 1 per cent of oil has been used on trees in foliage for a number of years, it was felt that an emulsion containing 2 per cent of oil would be safe on apple trees during the dormant season. The

chance of injury to trees, however, prevented a few growers, especially orchardists who had light infestations of the scale, from using this material.

Observations were made in many orchards following the general use of this oil spray during the dormant season, but no injury to the wood or the fruit buds could be detected. In some instances growers sprayed several tanks of material in which some free oil was present, due to hard water, but even in those cases no signs of injury could be found. Trees ranging in age from 1 year up received the dormant treatment with 2 per cent oil emulsion, yet there was no indication of damage to trees of any age. The only trees sprayed with heavier dosages of oil than 2 per cent were those in some of the experimental plats. One plat received an application with an emulsion containing 8 per cent of oil. Trees in the heavy dosage plats of the experimental spraying had a normal foliage and set a good crop of fruit.

Lubricating-oil emulsion in the summer sprays caused burning in some orchards at various times, but no very severe cases of injury were noted. When burning occurred it was doubtless produced by excessively hot weather. An emulsion containing 3 per cent of oil was used during very hot sunny weather in one orchard, and rather severe injury resulted to fruit and foliage on some trees. The injury in this orchard was "spotted," being noted in patches here and there. Injury on the fruit showed in the form of small dark spots, slightly sunken. Apparently the hot sun evaporates the water in the emulsion so quickly that tiny spots of oil are sometimes left scattered on the fruit and foliage. Three months after this one bad case of injury was noticed it was rather difficult to find any outward signs of injury. Close observation revealed slight stunting of growth and size of fruit on some trees. No case of injury has been observed on fruit sprayed with a 2 per cent emulsion during the summer. Some growers used a 2 per cent emulsion in several summer sprays without any injury.

In instances where burning resulted during the summer sprays, the damage was no more severe than would be caused by summer-strength lime-sulphur solution applied during hot weather. Any one contemplating the use of lubricating-oil emulsion for a summer spray should take care to avoid using it when the temperature is above 90° F. Some growers avoided injury from summer sprays by making the application during the cool part of the day, during the morning and late afternoon. Unless scale infestation is very bad, oil emulsion should not be used in the summer sprays, especially since only a partial control of scale can be obtained at that time.

METHOD OF PREPARATION.

Lubricating-oil emulsion, made by the boiled process, is prepared as follows:

Formula for stock emulsion.

Red engine oil	gallon	1
Water	do	½
Potash fish-oil soap	pound	1

The oil, water, and soap are placed in a tank and heated until the contents come to a boil. Just before boiling a brown scum ap-

pears on the surface of the mixture and as the boiling begins the brown scum will begin to disappear. At this stage the heat should be cut off and the entire mixture should be pumped twice under a pressure of about 60 pounds while still very hot. The first pumping may be made from the tank into a second container. The second pumping can then be made back into the original container or into barrels or other storage receptacles.

Heating the mixture is not sufficient to produce an emulsion. The mixture should be boiled, but it is not necessary that the boiling continue more than a few minutes. In pumping, the entire contents should pass through a pressure pump twice. A rotary pump should not be used for the pumping. Stirring will not produce a proper emulsion nor should the mixture be allowed to cool before it is pumped.

Figure 3 illustrates the outfit which was used for making stock

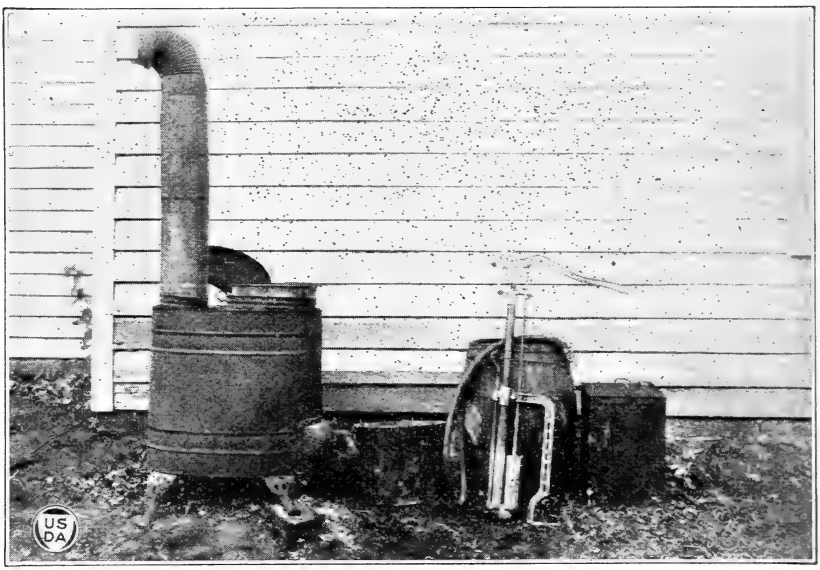

FIG. 3.—Equipment used for making stock emulsion for experimental spraying.

emulsion for the experimental spraying. The mixture was boiled on a wood stove and emulsified by the use of a hand pump. With this small outfit a barrel of stock emulsion could be made in half a day.

The method of preparing the stock emulsion is so simple that any grower with the proper equipment can make his own emulsion. By using a galvanized tank of about 200 gallons capacity a 50-gallon barrel of oil, 25 gallons of water, and 50 pounds of soap could be cooked. It is necessary that the tank be large enough to allow for the increase in volume that occurs during boiling. A power sprayer does very well for the pumping. With such an outfit the suction hose is placed in the boiling mixture and the material may then be pumped into the spray tank. From there it can then be pumped again into barrels. Old hose should be used, as the hot oil mixture

will in time destroy the rubber. The pump packing in most power sprayers will withstand the hot oil for a considerable time. A

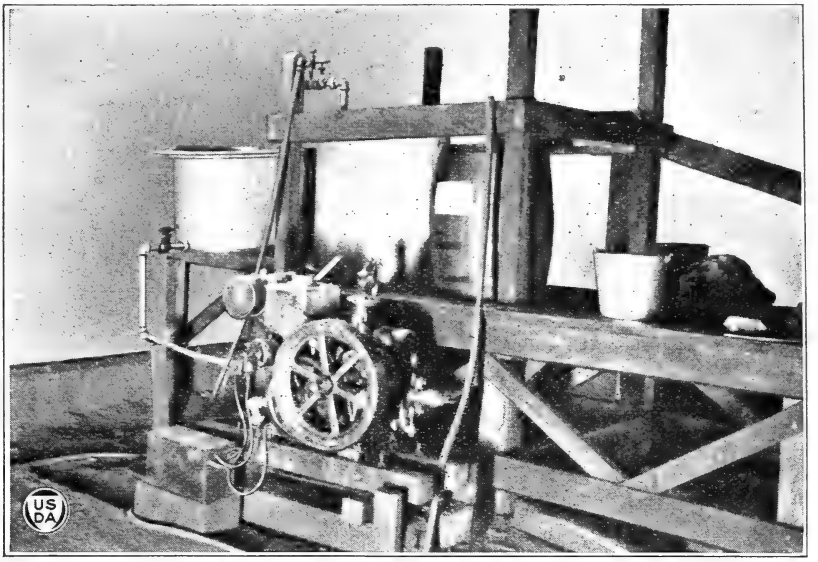

FIG. 4.—Small plant suitable for the production of oil emulsion on a commercial scale.

nozzle with the disk and cap removed is satisfactory for use in pumping the mixture.

A small plant capable of producing oil emulsion on a commercial scale is shown in Figure 4. The essential parts of this outfit are an

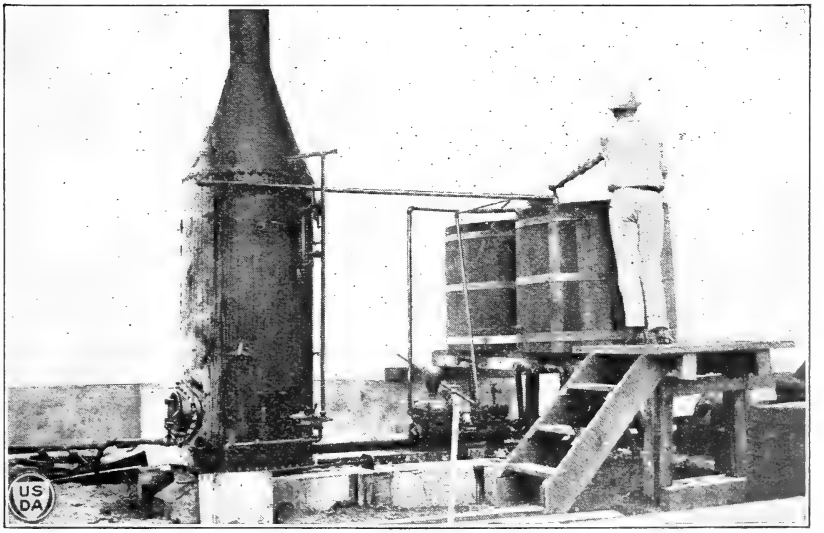

FIG. 5.—A convenient outfit for making oil emulsion.

engine and pump demounted from a power spray machine, two galvanized tanks, and a steam line from an outside boiler. The stock

emulsion mixture is boiled by steam in one of the galvanized tanks, from which it runs by gravity to the pump. It is pumped to the second galvanized tank, from which it again flows by gravity to the pump for the second pumping into barrels for storage.

Figure 5 shows a very convenient oil-emulsion plant. In this outfit the emulsion mixture is boiled by live steam from a boiler which also runs a steam pump to emulsify the mixture.

The most satisfactory method of preparing the emulsion on a large scale is to employ live steam for the cooking. In case steam is used, a 1-inch steam pipe can be run down into the boiling tank in the form of a double coil, placed a few inches above the bottom of the tank. Several holes should be bored in the lower side of the coil to allow the steam to escape into the mixture. The steam boiler should

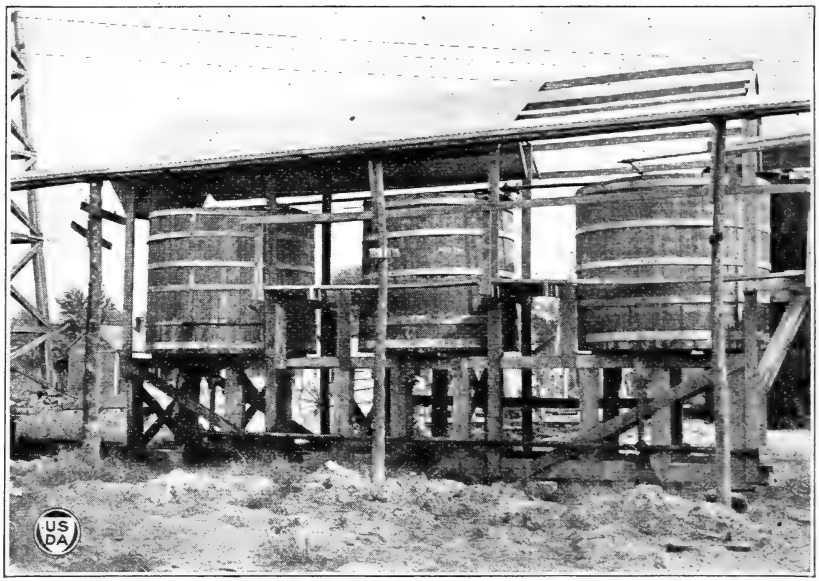

FIG. 6.—A plant capable of producing oil emulsion on a large scale.

furnish a head of steam large enough to boil the mixture quickly, so that the condensation of steam into water will be overcome by the evaporation that takes place. Where it is found that some water through condensation is added to the mixture during boiling, allowance can be made by deducting the amount of the increase from the original amount of water used. Plants which use steam for cooking in northwestern Arkansas plan to bring the mixture to a boil in from 5 to 10 minutes. A steam pump is best for operation on a large scale.

Figure 6 shows a plant which can manufacture oil emulsion on a large scale. Steam is supplied from a boiler in a factory near by into the 1,500-gallon tank at the right. After boiling, the mixture flows by gravity from the cooking tank to a steam pressure pump in the factory, where the mixture is pumped under pressure through a pipe overhead into the central tank. The operation is then repeated, the emulsion being discharged by gravity and pumped by

the steam pump into the third tank to complete the second pumping. From this third tank the finished emulsion is drawn off in barrels.

SOAPS AND OILS.

The best soap for emulsifying the mixture is potash fish-oil soap. W. W. Yothers, in his experience of more than 10 years with oil emulsions used to control scales on citrus trees in Florida, has found that potash fish-oil soap gives the most satisfactory emulsion.

The oils that have given good results in Arkansas are the "red engine" oils suitable for use in stationary gas engines. Practically all oil companies handle oils of this type. No oils of lighter grade than these have been used.

Analyses of several oil samples have been furnished by the Bureau of Chemistry of the United States Department of Agriculture. The analysis of the oil which was most widely used commercially follows:

Appearance: Red.		
Ash	per cent	0.028
Volatility (loss at 105–110° C. after 4 hours)	do	0.01
Flash-point (Pensky-Martin apparatus)	°C.	186
Fire-point (Pensky-Martin apparatus with open cup)	do	236
Viscosity (Engler number, water=1) at 20° C.		17.71
Specific gravity at 20° C. (Westphal)		0.894
Reaction to litmus: Neutral.		

RECOMMENDATIONS.

The San Jose scale can be controlled in the Ozark region of Arkansas by a spray application in the dormant season with a so-called paraffin-oil or lubricating-oil emulsion. Thorough spraying with an emulsion containing 2 per cent of oil should clean up bad infestations of the scale. The application may be made at any time during the dormant season when the weather is fit for spraying. It is advisable to make two dormant sprays in orchards that are incrusted with the scale. No indication of injury to trees from the use of lubricating-oil emulsion as a dormant spray has been observed following its use for one season in commercial orchards of Arkansas.

Soft water should be used with the stock emulsion for spraying whenever possible. Hard water in many instances will set free some of the oil in the emulsion. Lime-sulphur residue in the spray tank or spray pump will also produce some free oil. The sprayer should be thoroughly cleaned with a caustic soda solution before oil emulsion is used. If hard water must be used for spraying, a weakened Bordeaux, at the rate of $\frac{1}{4}$–$\frac{1}{4}$–50, can be added. This will make the hard waters of the Ozarks mix with the stock emulsion. Care should be taken to protect the stock emulsion from freezing, which occurs when it is exposed to temperatures of about 15° F.

The time to control the San Jose scale is during the dormant season. Summer treatments with lubricating-oil emulsion and with other insecticides have failed to clean up severe infestations of scale satisfactorily. The best results that can be hoped for with summer sprays of oil emulsion are a partial checking of the scale.

When this insecticide is used during the growing season, precaution should be taken to make the application during the cool part of the day. Injury to fruit and especially to foliage is likely to result from its use during extremely high temperatures.

Very thorough work should always be done in spraying to control the scale. To insure a complete coating of the trees with the spray solution, it is best to spray one side of a tree row at a time with rods, using one man in the tower and another on the ground. It is well to take advantage of the wind, spraying with the wind behind the mist of spray. It is almost impossible to wet the small tips when spraying against the wind. When the wind changes, the opposite sides of the tree rows should be sprayed. Most growers, when spraying according to this method, in reality spray two-thirds of a tree row from each side, thereby making sure that no spots are missed.

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