originally intended for a local experiment but is now an Adams project under Doctor Hinds, Auburn, Ala., and this paper is presented with his permission.

MR. W. E. HINDS: I wish to bring out one point which I think is of interest. In the applications that have been made we found indications of a shedding due to the direct arsenical effects of the spray. Some of the fruit that was shed from treated trees had certain characteristics by which it could be distinguished from fruit shed from untreated trees. The question has been brought up in connection with these experiments as to the extent of this shedding due to arsenical application. The percentage varies considerably when the neutral and acid forms of arsenate of lead are used. As far as I know this point has not been considered heretofore. I would suggest at this time to those who have arsenate spraying projects under way that they see whether any way could be found to offset the shedding of unpunctured fruit.

MR. W. M. SCOTT: Was there any difference noted as to the effect of different forms of arsenate of lead on the foliage?

MR. W. E. HINDS: We had practically no injury. There were a few burned areas but not enough to be of economic importance.

PRESIDENT P. J. PARROTT: Mr. A. L. Melander will present the next paper entitled, "Can Insects become Immune to Spraying?"

CAN INSECTS BECOME RESISTANT TO SPRAYS?[1]

By A. L. MELANDER, *Entomologist, Washington Agricultural Experiment Station*

There is a prevalent feeling in some districts that sulphur-lime is less efficient now than formerly in controlling San José scale, or orchard aphides, or the brown mite. This has been largely ascribed to the general adoption of the factory-made clear solution which is popularly regarded as subject to a mysterious adulteration.

There seems to be no question but that some years and in some places sulphur-lime is a rapidly acting insecticide. In Piper's elaborate experiment at Wawawai, Washington, in 1902, he repeatedly found all the scales dead a week after the application. The same is true of some Wenatchee scales I examined two years ago. At the same time that these Wenatchee scales were counted, specimens from Clarkston, Washington, sprayed two weeks before, showed 90 per cent alive. Even with 26° sulphur-lime, ten times stronger than a normal application, 74 per cent of the scales were still alive.

In the experiment of 1902 Piper discovered that sulphur-lime was

[1] Contribution from the Entomological Laboratory of the Bussey Institution, Harvard University, No. 75.

equally effective whether applied one pound of sulphur to three gallons, or one pound to six gallons. I noted the same in some tests at Clarkston in 1908, but discovered that here and there on certain branches were individuals that were still alive a month after spraying, although as well covered by the spray as the others. This experiment was repeated in 1910 at Walla Walla, Washington, with the same results, except that a considerable number of the scales, averaging more than 10 per cent, was still alive.

For several years the San José scale has been increasingly prevalent in the Clarkston Valley. The growers have erected a local sulphur-lime factory in the effort to control faulty preparation of the spray; they have drenched their trees by power spraying in the endeavor to overcome faulty application, and yet the scale has uncontrollably spread. Some branches I examined in 1912, that had been given three applications, at intervals of about two weeks, using a hot sulphur-lime of the 30:40:100 formula, showed 50 per cent. of the scales still alive under the crust of dried spray.

This led us last spring at the Washington Station to try identical solutions in a number of localities, and then to make bi-weekly counts of the proportion of living and dead scales,—an experiment we were able to carry on through the help of the Adams Fund. Clarkston, Walla Walla, Kennewick, Prosser, Sunnyside, North Yakima and Wenatchee were the localities selected, comprising an air-line circuit of four hundred miles, and at each place materials from the same stock were used. In the course of the bi-weekly visits made to these places upwards of 350,000 scales were individually examined under the binocular microscopes, by my assistant, M. A. Yothers and myself.

PERCENTAGE OF LIVING SCALES

	No. Yakima				Sunnyside				Clarkston			
	When sprayed	2 weeks	4 weeks	6 weeks	When sprayed	2 weeks	4 weeks	6 weeks	When sprayed	2 weeks	4 weeks	6 weeks
1. Sulphur-lime 5°.....	92	57	30	0	95	60	6	0	95	90	77	8
2. Sulphur-lime 3°.....	92	80	51	0	95	78	3	0.5	95	92	81	13
3. Sulphur-lime 2°.....	92	75	40	0.5	95	76	4	0	95	90	76	17
4. Sulphur-lime, 1:½:5.....	92	88	35	0.1	95	93	2	0.2	95	93	75	4
5. Sulphur-lime, 1:2:5.....	92	50	22	0.2	95	58	4	0	95	77	52	8
6. Spramulsion.....	92	44	2	2	95	50	7	2.4	95	70	40	12
7. Orchard Brand Oil Spray	92	6	0	0	95	13	0	0	95	4	1	0
8. Fuel oil emulsion.....	92	60	0	0	95	91	0	0	95	62	0	0

For the sake of brevity the accompanying table shows the results obtained at but three of the places, North Yakima, Sunnyside and True's orchard, Clarkston, selected because the conditions for the

experiment were ideal in each of these cases. The trees were vigorous, the scales abundant, the applications thorough and bad weather did not interfere. The figures show the proportion of scales rated as alive at the successive bi-weekly counts. The first experiment represents 5° factory-made sulphur-lime, approximating one pound of sulphur to three gallons. The second, 3° sulphur-lime, or one pound to five gallons, the third 2°, or one pound to seven gallons. Then follow two sulphur-limes prepared just before the application, experiment four, 3°, corresponding to the second experiment, and number five, with the same amount of sulphur but with four times the chemical requirement of lime. The sixth test gives a carbolated emulsion, called Spramulsion, prepared on the Pacific Coast. The last two represent oil sprays made with a fish oil emulsifier: Thomsen's Orchard Brand and a fuel oil emulsified during the tests.

It will be observed that the normal action of the sulphur-lime is continuous, producing complete destruction of the scale in a little more than a month's time. In the Clarkston experiment, however, from 4 to 13 per cent, or more, of the scales were alive six weeks after spraying, at which time they had begun their spring growth and were probably but little susceptible to whatever weathered sulphur-lime remained.

Attention may be called to the similarity of the results obtained with the last two oil sprays at all three places, showing that Clarkston scales have no resistance to these sprays, and to the similarity of the action of sulphur-lime used at North Yakima and Sunnyside, as compared with Clarkston. It is evident from these figures that the San José scale at Clarkston manifests a decided resistance to the action of sulphur-lime.

Although sulphur-lime has come to be regarded quite as a panacea, because of its destructive action on fungi, lichens, insect eggs, scales, etc., yet it is specifically a scalecide, and particularly is used against the San José scale during its hibernating condition. Other scales are less susceptible, the naked Lecaniums not at all, and thick shelled or active insects emerge quite unharmed from a bath of sulphur-lime. Even the San José scale shows a variable susceptibility, for during the growing period sulphur-lime has proved to be much less effective. Furthermore, there is a sex-difference, for among the resistant individuals escaping the action of the spray, the majority are males. Sulphur-lime is not a universal poison; it does not assure certain destruction of all insects; and there is thus a chance for an immunity to manifest itself in increasing degree as the insects become acclimatized.

The physiological effect of sulphur-lime is believed to be due to

a chemical reduction of the insect, an action that is vigorous at first but after a few weeks or days gives place to a chemical deposit of sulphur. The effects are thus not altogether immediate, but prolonged, and the reactions grow weaker day by day. That the San José scale is able to resist the first shock of deoxygenation is evident from the abundance of living scales for several weeks after the application.

It is a difficult matter to determine just when a scale insect dies. A killed scale becomes dry in a few days, during which time its protoplasm changes from a pale yellow juicy condition, through a viscous sirupy stage, to a darker yellow oily meal. This reaction is not reversible, and thus differs from the first effects of dessication, from which insects may be revived. In making counts of the scales we rated as dead all insects that showed gelation of the protoplasm when crushed under the microscope.

That the San José scale should become acclimatized to a sulphur-lime environment is not altogether a strange thing. There are organisms living in sulphur springs, in thermal springs, in hypertonic salt and alkaline lakes, and even in petroleum wells,—all of them environments fatal to normal forms. An example of such abnormal species in the making can be readily observed in an estuarial tension life-zone, where the salt water forms are invading the fresh water region, and the fresh water species are becoming adapted to the recurring tides.

One of the strangest instances of acclimation is the case of arsenic eaters. By consuming repeated small amounts of arsenic the body becomes immune to many times the normal lethal dose. When arsenic spraying for leaf-eating insects is imperfectly done it is quite possible for the insects to get daily homeopathic doses of arsenic and to become progressively resistant. Indeed, Mr. R. W. Glaser of the Bussey Institution, has experimentally verified this supposition in his work with the gipsy moth. By successively administering more and more spray, he tells me that he has succeeded in rearing a series of moths from larvæ that finally were feeding on heavy dosages of arsenate of lead. Indeed, these larvæ were especially hardy, and developed as strong an immunity to disease as they did to the arsenic. This may be the underlying reason why spraying for half-grown caterpillars and grasshoppers is usually so ineffective.

While immunity to arsenic may be a greater factor in the control of insects than we at present know, yet it is an adaptation of the individual only. We do not know that such an acquired immunity affects subsequent generations, although it would not be inconceivable that arsenic antibodies are passed on by the mother into the egg to give the offspring some initial immunity.

The resistance of the San José scale, however, is of a different kind. Spraying affects every tenth generation or so, and it is quite unlikely that an acquired immunity should make its effects felt over so long a period. Sulphur-lime spraying in the orchard districts is compulsory by law and so practically every scale is subjected to its action. We have often noted an individual scale, or a group of scales, probably brothers and sisters, still alive in the midst of a mass of dead insects. Such vigorous individuals have been just as thoroughly wet with the sulphur-lime as their neighbors, yet have escaped its action. The sporadic occurrence of naturally immune individual scales finds a parallel in recent work on heredity of protozoa and bacteria. Mutants less or not susceptible to certain toxins have been repeatedly found in cultures and from them have been produced immune strains. Similarly, disease-resistant wheat has been produced through Mendelian segregation, the new strain acting as a pure recessive.

The data at present at hand do not permit us to determine whether resistance and susceptibility are differences of degree and not of kind, or whether they behave as allelomorphs. That the mortality curve of the Clarkston scales is less steeply inclined from the beginning might indicate a partial immunity already possessed by nearly all the scales, but which is pronounced enough to be an absolute immunity only in a relative few. Such a view is especially interesting when we recall the reported rapid action of sulphur-lime a few years ago.

What is the economic importance of the appearance in a locality of a resistant strain of the San José scale? An alarmist might say that a few such scales would soon result in a totally immune insect, brought about by annual spraying. But viewed from a Mendelian standpoint, the consequences are less direful. If only the resistant individuals survived to reproduce then a pure line might result after repeated sprayings. But always there are some scales missed by the spraying, and these, during the ten generations between sprayings, will produce a population in part, at least, non-resistant. If resistance were a dominant characteristic there would already be a larger proportion of immune individuals than the data show. If it is recessive the crossing with scales missed by the spray would, by the end of each year, produce a majority of susceptible individuals. Thus we may make the strange assertion that the more faulty the spraying this year the easier it will be to control the scale the next year.

Practically, a change from sulphur-lime to an oil spray is all that is necessary for effectual control. However, even in the case of the oils we have noted a very few individuals that have manifested a remarkable tenacity of life. Should these result in a resistant strain sometime in the future it would be necessary to use both insecticides,

and then if the same individuals were doubly resistant we might have to introduce a weak strain of the the San José scale to cross with the immunes and thus return to the normal susceptible population.

PRESIDENT P. J. PARROTT: This is a very unique paper and ought to provoke considerable discussion.

Question: Are the records on the chart the result of a single year's experiment or combined results of several years?

MR. A. L. MELANDER: The curves were built up from last year's work at three different places.

Question: Can you tell us why the Clarkston results were not as good as the others?

MR. A. L. MELANDER: I tried to explain in the paper that I believed that the Clarkston scales possessed a hereditary resistance to the lime-sulphur spray. This may possibly be due to the fact that they have been subjected to this spray longer than any other place, for the lime-sulphur has been used longer in that valley in Washington than anywhere else in the northwestern part of the country.

MR. W. C. O'KANE: I was interested in what the speaker had to say in regard to the immunity of caterpillars to arsenic. I would like to know whether, after the first or second spraying, the caterpillars were increasing in size, and resistance, and were consuming much more than a dose which would ordinarily kill them?

MR. A. L. MELANDER: He told me that they were feeding and consuming many times as much poison as should ordinarily kill them.

PRESIDENT P. J. PARROTT: Can Doctor Wheeler give us any figures on the experiments which were conducted by Mr. Glaser?

MR. W. M. WHEELER: Mr. Glaser did not advise me in regard to the results of these experiments. I think they were taken up in connection with other work.

MR. E. P. FELT: I would like to ask Mr. Burgess if it is not a fact that when the gipsy moth caterpillar becomes nearly grown it is very difficult to destroy it with poison.

MR. A. F. BURGESS: Yes, that is true. If spraying is done when gipsy moth caterpillars are nearly full-grown it is very difficult to kill them. I think Mr. Glaser must have secured these results in connection with other experiments which he was carrying on.

PRESIDENT P. J. PARROTT: In using the lime-sulphur wash we have found from past experience that spraying may not kill the parent, although the treatment is destructive to the progeny. Has this been your experience?

MR. A. L. MELANDER: Considering the results from a chemical

standpoint the effect is weaker day by day. In the cases mentioned the lime-suphur wash was effective within a week after its application.

PRESIDENT P. J. PARROTT: We have conducted some comparative experiments in New York with the polysulphides of barium, calcium, sodium and potassium. The percentage of scales killed by the different compounds ranged from about 94 to 100 per cent. The calcium and barium preparations were uniformly more effective than the other mixtures. With all of the polysulphides there was some breeding, which was more noticeable on the trees sprayed with the sodium and potassium mixtures. This difference in effectiveness we attributed to the greater solubilities of the latter compounds.

Question: What results did you have with the polysulphide of calcium?

PRESIDENT P. J. PARROTT: The barium polysulphide was the most efficient preparation, while calcium polysulphide ranked as a close second in effectiveness.

A member: I have noticed that we cannot get good results with lime-sulphur wash after the 1st of April, that is, after the trees begin to grow actively. For some unknown reason the scales are not killed after this time.

PRESIDENT P. J. PARROTT: The next paper will be read by Dr. E. P. Felt on "The Reactions of Sugar Maples to Miscible Oils."

THE REACTION OF SUGAR MAPLES TO MISCIBLE OILS

By E. P. FELT, *Albany, N. Y.*

(Withdrawn for publication elsewhere.)

MR. GLENN W. HERRICK: Have you noticed any effect as to the time of spraying and have you any data on the effect of miscible oils on other trees than maples?

MR. E. P. FELT: Most of the injury we observed in certain cases followed spraying in the fall. We have studied several apple orchards where a serious condition developed, the damage being closely restricted to trees or even parts of trees which had been treated with a miscible oil.

MR. Z. P. METCALF: Our experimental results have shown that miscible oils are not the only thing that cause injury. A few years ago at Charlotte, N. C., I found three trees in three widely separated localities showing practically the same injury to the lower branches. One was a sugar maple which was not infested by insects and had not been sprayed. Another a silver maple which had been sprayed the previous