DIPPING OF NURSERY STOCK IN THE LIME-SULPHUR WASH.

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DIPPING OF NURSERY STOCK IN THE LIME-SULPHUR WASH

P. J. PARROTT, H. E. HODGKISS AND W. J. SCHOENE.

SUMMARY.

Dipping in the lime-sulphur wash is a method of treatment proposed for the disinfecting of nursery stock for such pests as the San José scale, woolly aphis and other destructive insects. Its utility for these purposes has not been thoroughly established, and more knowledge on the safeness and efficiency of this treatment has been desired. This bulletin is a contribution of additional data, which are based on experiments to determine: (1) The effectiveness of the lime-sulphur wash as a dip on the San José scale, and (2) the effects of dipping in this mixture upon the health of nursery trees.

Tests were made of the standard lime-sulphur wash at temperatures of 60°, 100°, 120°, and 212° F. For purposes of comparison, experiments were also made with kerosene emulsion, containing 10, 15, and 20 per ct. of oil; miscible oil diluted with 10, 15 and 20 parts of water; and hydrocyanic acid gas at the rate of 0.3 gram of potassium cyanide per cubic foot. The stock used for these tests was 180 3-year old Bartlett pears and 970 3-year old Ben Davis apples, all of which were infested with the San José scale; and 300 Mann apples, 470 Bartlett pears, 300 Satsuma plums and 300 Fitzgerald peaches, all of which were clean and healthy trees.

Immersion in the lime-sulphur wash at temperatures ranging from 60° to 120° F. and for time periods varying from instantaneous dipping to immersion for ten minutes gave uncertain results on the scales. When heated to 212° F. the wash killed the scales and caused severe injuries to buds and bark, which ruined the
trees. The wetting of the roots of fruit trees by this wash was generally accompanied with injuries. These were especially severe with Fitzgerald peaches and Ben Davis apples, of which 95 per ct. and 96 per ct., respectively, were killed. The treatment, by immersion of the tops of apples, pears, peaches and plums, for less than three minutes in the sulphur wash, at temperatures of 60° to 120° F., was usually unattended with appreciable injuries.

In the field experiments, the preparations of the oil emulsion and miscible oil caused no apparent harm to any of the trees, even when the roots were immersed. The emulsions containing 15 per ct. and 20 per ct. of kerosene, or miscible oil diluted with 10 and 15 parts of water, were more efficient as dips on the San José scale than the sulphur wash. In laboratory tests conducted later, trees were frequently severely injured by the immersion of their roots in emulsions containing 20 per ct. of kerosene. Fumigation with hydrocyanic acid gas completely destroyed the scales and the treatment was not harmful to the trees.

The results of these experiments indicate that dipping of nursery trees in the standard lime-sulphur wash for the purpose of destroying the San José scale is a doubtful practice. Nurserymen are advised to continue the use of fumigation with hydrocyanic acid gas, which is the more efficient means of freeing dug nursery stock of this pest.
Plate II.—Fitzgerald Peaches Dipped in the Lime-Sulphur Wash: (1) Tops only Immersed, (2) Entire Trees Immersed. Conditions Representative of all Lots Treated for Different Time Periods.
Plate I.—Ben Davis Apples Dipped in the Lime-Sulphur Wash: (1) Tops only Immersed, (2) Entire Trees Immersed. Conditions Representative of all Lots Treated for Different Time Periods.
INTRODUCTION.

With the introduction of the San José scale as a nursery and orchard pest, some system of official supervision of nurseries, which had in view control of this insect, became imperative. To this end, nursery inspection laws, designed principally to prevent the distribution of the scale by the trade and to protect innocent purchasers, were enacted in many states. The official inspection and certification of nurseries that followed, and the growing practice of intending purchasers of buying only of responsible firms, have awakened nurserymen generally to the necessity of affording suitable protection to their plantings and of selling only clean and reliable stock. To meet the demands of the trade for protection against the scale, fumigation of nursery stock before shipment with hydrocyanic acid gas was put into practice with the passage of the inspection laws, and has been generally recognized as the most efficient method for the general treatment of the common injurious insects of dug nursery trees.

DIPPING FOR THE TREATMENT OF NURSERY STOCK.

Within recent years, interest in the dipping of nursery stock in contact sprays has been revived as a means of insect destruction as an alternative treatment for fumigation as commonly practiced. The mixture generally suggested for the purposes of a dip is the lime-sulphur wash, because of its efficiency as a spraying mixture for the San José scale, and its valuable fungicidal qualities for various fruit diseases. The advantages claimed for this treatment by immersion, although they have not been well substantiated, are its convenience and general adaptibility for the purposes for which fumigation with hydrocyanic acid gas would be employed. This method of treating nursery stock has not been officially recognized, except by the Oregon State Board of Horticulture.¹

which, at the request of the nurserymen of that state, annulled on October 8, 1906, Rule 8 of the quarantine regulations, requiring nursery stock to be fumigated, and substituted in its place a provision which compelled dipping in a standard solution of the lime-sulphur wash. Present interest in the probable utility of this treatment in actual practice is largely the result of the adoption of this rule.

**PRESENT STATUS OF DIPPING AS A MEANS OF DISINFECTING NURSERY STOCK.**

Dipping of nursery stock in various contact sprays is not a new practice and has long been employed for various purposes by nurserymen, especially for the treatment of scions and budding sticks. With the appearance of the San José scale as a nursery pest, the immersion of infested trees in strong liquid insecticides was naturally, in view of existing practices, one of the first methods to be suggested and to be officially tested, to determine the value of the more promising sprays then in use, as disinfectants for this pest.

Upon the discovery of the San José scale in nurseries on Long Island in 1894, Mr. F. A. Sirrine of this Station directed some extensive experiments on the treatment of nursery stock, by immersion of trees in strong preparations of whale-oil soap, which was then regarded as the most efficient spraying insecticide for this insect. The results were not entirely successful and the failures were attributed to careless work in the dipping operations. Dipping of purchases of trees, before planting, in soap mixtures is still practiced by some fruit growers as a means of precaution, to prevent the introduction on their premises of destructive insects such as scales and root-inhabiting lice.

In recent years, with the growing interest in this treatment, a number of experiments have been undertaken to determine the utility of the newer and more efficient spraying mixtures for dipping purposes. Prof. C. P. Close of the Delaware Ex-

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(2) Ann. Rept. of this Station, 14: 612. 1895.
periment Station, has made some extensive tests to ascertain the effects of immersing fruit trees in oils, oil emulsions and the lime-sulphur wash. The results of these tests indicated the danger of wetting roots with contact sprays. The tops of the trees, especially of apples, proved much less sensitive to injury. In 1904, Mr. F. W. Faurot\textsuperscript{4} dipped a number of trees in the lime-sulphur wash with slight losses. A test was again made in the following year with twenty-five apples and twenty-five peaches. None of the apples sustained injuries while four of the peaches were killed. A portion of this loss was attributed to adverse conditions in planting.

Dipping of nursery trees in the lime-sulphur wash has been practiced quite extensively in Georgia, and the results have apparently been satisfactory. An experiment conducted by Prof. Wilmon Newell\textsuperscript{5} indicated, however, that injuries might follow this treatment; and on the basis of his results, warning was given to fruit-growers of the possible damages to young trees by this practice. Dr. G. F. Warren\textsuperscript{6} made a test with 100 Mountain Rose peaches, to determine the effects of dipping in the lime-sulphur wash on the health of the trees. One lot of trees was immersed in the lime-sulphur wash of double strength. No apparent injuries attended the treatment, even when the roots were immersed. In an experiment conducted by Prof. J. L. Phillips,\textsuperscript{7} of Virginia, apple trees allowed to remain in the standard lime-sulphur wash at temperatures of 60° to 120° F. for five minutes, sustained only slight injuries. The effects of the dipping on peaches were much less favorable, for many trees died as a result of the treatment. Immersion in this wash did not entirely rid the plants of the scales.

Dipping of nursery trees in liquid sprays is not generally practiced by nurserymen and fruit-growers, and its use seems to be largely experimental. There is very little definite knowledge of the real advantages to be derived from this practice and

\begin{itemize}
\item \textsuperscript{(*)} Mo. Fruit Sta., Bul. 14. 1906.
\end{itemize}
of the conditions under which immersion of plants can be safely employed.

EXPERIMENTS IN DIPPING MADE AT THIS STATION.

OBJECTS.

The experiments reported in this bulletin were undertaken for the purpose of contributing further data on the value of dipping in the lime-sulphur wash for the treatment of nursery stock infested with the San José scale. The principal factors to be considered in determining the utility of the mixture for this purpose are its efficiency and safeness. In this inquiry, efforts were largely directed toward ascertaining: (1) The effects of the treatment on the scale, and (2) the effects of the treatment on the trees.

The ultimate aim of this work is to determine the value of the more efficient spraying mixtures for the disinfection of nursery trees for the common injurious insects. This information is especially sought for by fruit-growers, who are gradually realizing the desirability of treating their own purchases of stock before planting, for woolly aphis, peach aphis, San José scale, etc. A safe and efficient dip for these purposes would encourage the fruit-grower to rely more on his own efforts to protect the trees and less on the nurserymen, and would aid in dispelling the present uncertainty and confusion that now attends the placing and filling of orders for nursery stock.

OUTLINE OF THE EXPERIMENTS.

For the experiments 970 Ben Davis apples, 300 Mann apples, 650 Bartlett pears, 300 Satsuma plums and 300 Fitzgerald peaches were used. The trees were three years old. The Ben Davis and Bartlett stocks were generally well infested with the scale while the remainder of the trees were clean. The standard lime-sulphur wash was used for the larger number of the experiments, but comparative tests were also made with kerosene emulsion, containing 10, 15 and 20 per ct. of oil, with
miscible oil diluted with 10, 15 and 20 parts of water, and with fumigation, using potassium cyanide at the rate of 0.3 gram per cubic foot. In the dipping operations the trees were immersed singly. For the main portion of the experiments, the temperature of the spraying mixtures was 60° F. To determine the effects of higher degrees of heat and prolonged immersion on both scales and trees, tests were made with these mixtures at temperatures varying from 60° to 212° F., and with time periods varying from instantaneous dipping to immersion for ten minutes. To ascertain the effect upon the health of the plants of wetting roots with the sprays, in most cases half the trees in each lot were dipped with the exception of the roots and the others were wholly immersed. In each experiment checks were reserved of each variety for purposes of comparison, to note the effects of the various treatments upon the scales and the health of the trees.

THE EFFECTS OF DIPPING ON THE SAN JOSÉ SCALE.

EXPERIMENT NO. 1.

INFESTED BEN DAVIS APPLES DIPPED IN SULPHUR WASH OF DIFFERENT TEMPERATURES.

The principal object of this experiment was to determine the effects of dipping trees in the lime-sulphur wash, heated to various temperatures, upon the San José scale. The trees used for this test were Ben Davis apples of three years of age, which were moderately encrusted with the scale. While the scale was in conspicuous numbers on them, the trees appeared to be vigorous and showed no appreciable signs of injury other than the usual discoloration of the cambium layer. The trees selected for treatment were dug from the nursery row on April 4, suitable protection being immediately given from the sun and the wind. They were dipped during the following day in the lime-sulphur mixture, prepared after the stand-
ard formula. The trees were dormant and showed no signs of growth other than a slight swelling of the buds.

For the dipping operations, four preparations of the standard lime-sulphur wash, with temperatures of 60°, 100°, 120° and 212° F. respectively, were made. Four lots, of thirty trees each, were quickly plunged into the respective preparations of the wash and instantly withdrawn. Immediately after they were dipped the trees were "heeled in;" and on May 6 were planted 18 inches apart in rows 4 feet apart. They were afterward cultivated according to nursery practice.

Results on scale.—On July 5, active lice were discovered for the first time for the season. All the lots, exclusive of those dipped in the wash at 212° F., had a few trees on which there was an occasional active scale. The majority of the trees showed no signs of larval activity. On August 14 the lice were more numerous and there was quite a little sprinkling of scales on the trees that were originally much more encrusted. A few trees in each lot were free of scale. As a result of the treatment, a large percentage of the old infestation had weathered off, and the bark of the trees was quite clean, and in marked contrast to the checks, which were much encrusted. An examination of the trees on September 8 showed that about one-third of them, not including the lot dipped in the wash at 212° F., were clean, while the remaining two-thirds showed an infestation which varied from 2 per ct. to 35 per ct. of that previous to the treatment. The lot dipped in wash heated to 212° F. were entirely cleaned of scales but were much injured. The injury was especially apparent on the younger growth.

EXPERIMENT NO. II.

INFESTED BEN DAVIS APPLES DIPPED FOR DIFFERENT TIME PERIODS IN A SULPHUR WASH.

The purpose of this experiment was to determine the effects of immersion for different periods of time upon the San José scale. Six lots of trees, each comprising 30 well-infested Ben
Davis apples, were used. One lot was simply plunged into the wash and immediately withdrawn, while the others were immersed respectively for one, two, three, five and ten minutes. The temperature of the sulphur wash was 60° F.

Results on scale.—The trees were examined at regular intervals to determine the effects of the treatment on the San José scale. On July 5 a few larvae were found on a number of trees in all of the lots. During August there was a slight increase in the numbers of the scales, but in no instance was the new infestation conspicuous. As compared with the condition of the trees before dipping there was a marked reduction in the numbers of the scales. The moderately infested trees were as a rule quite clean, and larval activity was usually most prominent on the trees that were originally the most infested. Taking the trees as a whole, there was very little difference in the amounts of scale destroyed by dipping for the various time periods. In all of the lots there were some trees that were clean and others that showed varying degrees of infestation, which was sometimes as much as 35 per ct. of that at the time of the treatment.

EXPERIMENT NO. III.

INFESTED BARTLETT PEARS DIPPED IN SULPHUR WASH FOR DIFFERENT TIME PERIODS.

The details of this experiment are the same as the one just preceding, differing only in that 180 Bartletts were used in place of the apples. All the trees were well infested with the scale.

Results on scale.—In all of the lots there were trees which showed on July 5 more or less breeding of the scale. By September 8 there was no apparent difference in the conditions of the trees in the various lots. Some trees were clean and the others, although the numbers of the scales were much reduced, showed varying degrees of infestation.
EXPERIMENT NO. IV.

INFESTED BEN·DAVIS APPLES DIPPED IN VARIOUS SPRAYS.

This experiment was a comparative test of various sprays to determine their merits for the treatment of nursery stock by dipping. The mixtures employed were the standard lime-sulphur wash; kerosene emulsion containing 10, 15, or 20 per cent. of oil, and miscible oil at the rate of 5, 6½ or 10 per cent. Hydrocyanic acid gas was used for the purpose of comparing its effectiveness with the liquid sprays. For the fumigation, 0.3 gram of potassium cyanide per cubic foot was used. The temperature of the mixtures was 60° F. Seven lots of trees were dipped in the respective preparations, and one lot of thirty trees was fumigated.

Results on scale.—The effects of the different treatments on the scale, as shown by observations on July 5, August 14 and September 8, are briefly summarized in the accompanying table.
<table>
<thead>
<tr>
<th>Remedies</th>
<th>No. of trees</th>
<th>July 5</th>
<th>August 14</th>
<th>September 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur wash</td>
<td>120</td>
<td>Few active scales</td>
<td>Sprinkling of scales, some trees clean</td>
<td>Some trees clean. Others with quite a few scales</td>
</tr>
<tr>
<td>Kerosene emulsion, (10% oil)</td>
<td>16</td>
<td>No active scales</td>
<td>Few active scales</td>
<td>Some trees clean; others with a few scales</td>
</tr>
<tr>
<td>Kerosene emulsion, (15% oil)</td>
<td>16</td>
<td>An occasional scale</td>
<td>An occasional scale.</td>
<td>Trees usually clean. Very few scales</td>
</tr>
<tr>
<td>Kerosene emulsion, (20% oil)</td>
<td>66</td>
<td>No active scales</td>
<td>Rarely a young scale</td>
<td>Two trees showing few scales. Other trees clean</td>
</tr>
<tr>
<td>Miscible oil (1-10)</td>
<td>10</td>
<td>Except on one tree, no signs of active scales</td>
<td>Rarely an active scale</td>
<td>Three trees with few scales. Other trees clean</td>
</tr>
<tr>
<td>Miscible oil (1-15)</td>
<td>40</td>
<td>No active scales</td>
<td>Few young scales</td>
<td>Several trees clean, others with few scales</td>
</tr>
<tr>
<td>Miscible oil (1-20)</td>
<td>10</td>
<td>Few active scales</td>
<td>Quite a few active scales</td>
<td>Some trees clean. Others with sprinkling of scales</td>
</tr>
<tr>
<td>Hydrocyanic acid gas</td>
<td>18</td>
<td>No active scales</td>
<td>Scales apparently all dead</td>
<td>No signs of living scales</td>
</tr>
<tr>
<td>Checks</td>
<td>30</td>
<td>Quite a few active scales</td>
<td>Many active scales</td>
<td>Trees well encrusted</td>
</tr>
</tbody>
</table>
None of the liquid treatments entirely destroyed the scales and there was more or less breeding, which varied according to the spray and the dilution employed. The most efficient of this class of remedies were the kerosene emulsion containing either 15 or 20 per cent. of oil, and miscible oil, diluted with either ten or fifteen parts of water. The stronger preparations of these two mixtures gave almost perfect results, as there were only two trees treated by the former and three trees treated by the latter, which showed any larval activity, and that was very slight. Of the trees dipped in the sulphur wash some were free of scales and others were more or less infested. Of the treatments to which the trees were subjected, fumigation with hydrocyanic acid gas was the only one that effectively checked the breeding of the scales.

THE EFFECTS OF DIPPING ON FRUIT TREES.

EXPERIMENT NO. V.

BEN DAVIS APPLES DIPPED IN SULPHUR WASH AT DIFFERENT TEMPERATURES.

The purpose of this experiment was to determine the effects of dipping in the lime-sulphur wash upon fruit trees. The variety used was the Ben Davis apple, of which there were 120 trees, divided into 4 lots of 30 trees each. Four preparations of the standard lime-sulphur wash were made, which were maintained at temperatures of 60°, 100°, 120° and 212° F. respectively, during the dipping operations. In the treatment of the trees, each lot was first equally divided, and one-half the trees were entirely dipped in the mixture, while the others were immersed with the exception of the roots. Dipping was instantaneous.

Results on trees.—The effects of dipping upon the trees and the behavior of the trees following the treatment are plainly indicated by the following brief notes, which are based on observations made on the dates given.
LOT 1. TEMPERATURE 60° F.
ONLY TOPS DIPPED.
May 22. Trees leafing. Some buds retarded on all of the trees and a number of trees are much more backward than others.
June 5. Foliage fair. Trees backward, because of a late spring.
July 5. Trees normal, with abundant foliage, and making good growth.

TOPS AND ROOTS DIPPED.
May 22. Trees leafing. General conditions as above on same date.
June 5. Foliage about same as above but not quite so abundant. Some leaves are wilting.
July 5. Three trees are alive and twelve trees are dead.

LOT 2. TEMPERATURE 100° F.
ONLY TOPS DIPPED.
May 22. Conditions as above.
June 5. Conditions as above.
July 5. Trees normal.

TOPS AND ROOTS DIPPED.
May 22. Condition of trees generally as above.
June 5. Every tree shows signs of decline.
July 5. All trees dead.

LOT 3. TEMPERATURE 120° F.
ONLY TOPS DIPPED.
May 22. Same as preceding.
June 5. Same as preceding.
July 5. Trees normal.

TOPS AND ROOTS DIPPED.
May 22. All trees show retardation of buds.
June 5. Trees show evidences of decline, leaves wilting and falling.
July 5. All trees dead.

LOT IV. TEMPERATURE 212° F.
ONLY TOPS DIPPED.
May 22. Many buds killed. Leaves are very few in number.
June 5. Tips of branches are dead. Amount of foliage reduced.
July 5. All trees show evidences of injury by much cracking of bark, small growth and less abundant foliage.

TOPS AND ROOTS DIPPED.
May 22. Four trees are apparently dead. Many buds have been killed.
June 5. Foliage is scanty. Bark is much cracked.
July 5. All trees in rapid decline.
July 5. All trees dead.

Summary of results.—Instantaneous dipping of the tops of trees in the sulphur wash at temperatures of 60°, 100° and 120° F. caused no appreciable injuries. Complete immersion of the trees, including their roots, was in nearly every case attended with the decline of the plants within three weeks of leafing. Of sixty trees that were entirely dipped, 57, or 95
per ct. of the number treated, died as a result of the roots being wetted by the mixture. The dipping of the tops of the trees in boiling preparations destroyed many buds and caused much cracking of the bark. Trees wholly immersed in the boiling wash were killed. All of the checks, thirty in number, lived and made a satisfactory growth.

EXPERIMENT NO. VI.

BEN DAVIS APPLES DIPPED FOR DIFFERENT TIME PERIODS IN A LIME-SULPHUR WASH.

This experiment was to ascertain the effects upon nursery fruit trees of immersion for different time periods in the lime-sulphur wash. Apples of the Ben Davis variety were used. There were 180 trees, divided into six lots of 30 trees each. For dipping, each lot was first equally divided, and 15 trees were wholly immersed and the remaining 15 trees were dipped, leaving the roots untreated. The temperature of the wash was 60° F. The time periods were instantaneous immersion and dipping for one, two, three, five and ten minutes respectively.

Results on trees.—The effects of the treatments are briefly as follows:

LOT I. IMMERSION.

TOPS ONLY.

May 22. Trees leafing.
June 5. Foliage fairly abundant.
July 5. Trees normal, with healthy foliage and vigorous growth.

TOPS AND ROOTS.

May 22. Trees leafing as above.
June 5. General condition of trees same as above, only some leaves are wilting.
July 5. Three trees are alive and 12 trees are dead.

LOT II. DIPPED ONE MINUTE.

TOPS ONLY.

May 22. Trees leafing.
June 5. Trees in foliage, showing small losses of leaf buds and slight twig injuries.
July 5. Trees in excellent condition.

TOPS AND ROOTS.

May 22. Trees normal.
June 5. Trees are dying.
July 5. All trees are dead.
Lot III. Dipped Two Minutes.

Tops only.

May 22. 6 trees are normal and 9 trees are very backward.
June 5. 14 trees are in full foliage and 1 tree dead.
July 5. 14 trees are normal and 1 tree is dead.

Tops and roots.

May 22. Trees are more backward than the above. Retardation of buds is very marked.
June 5. All trees are declining.
July 5. 15 trees are dead.

Lot IV. Dipped Three Minutes.

Tops only.

May 22. 4 trees show normal foliage and 11 trees have leaves reduced in size. There are some dead twigs. Small losses of buds.
June 5. Trees are making good growth.
July 5. Trees are normal.

Tops and roots.

May 22. 4 trees with slightly smaller leaves than the above. Remainder of trees show considerable retardation and injuries to bark and buds.
June 5. All trees are declining.
July 5. 13 trees are dead and 2 are barely alive.

Lot V. Dipped Five Minutes.

Tops only.

May 22. 6 trees are normal and 9 trees show retardation and small losses of buds, and a few dead twigs.
June 5. With exception of small amount of dead twigs and slight reduction in number of leaves, the trees are normal.
July 5. All trees are in a thrifty condition.

Tops and roots.

May 22. 8 trees are normal and 7 trees are backward, with losses of buds and twig injury.
June 5. All trees are declining.
July 5. All trees are dead.

Lot VI. Dipped Ten Minutes.

Tops only.

May 22. Trees are in leaf and are making a uniform growth. The leaves average smaller than those on trees in the lots dipped for short time periods.
June 5. Trees are normal, with only slight injuries to buds and bark.
July 5. Growth of trees is normal, but foliage is not quite so abundant as that of the preceding lots when tops only were dipped.

Tops and roots.

May 22. 3 trees are normal. Remainder of trees with uneven growth and buds are barely bursting. Slight losses in buds and some injury to twigs.
June 5. All trees are declining.
July 5. All trees are dead.
Summary of results.—As in experiment V, the immersion of the roots of Ben Davis apples in the lime-sulphur wash invariably resulted in the death of a large number of the plants. Of ninety that were wholly dipped, 85 trees, or 94 per ct. of the number treated in this manner, were killed. Dipping of the tops of the trees was unaccompanied by important injuries. Immersion of the tops of the trees for periods of five to ten minutes seemed to cause a slight retardation of the buds, and in some instances to destroy a few buds and to injure the tips of pruned branches. All of the thirty checks lived, without showing appreciable injuries by transplanting.

EXPERIMENT NO. VII.

BEN DAVIS APPLES DIPPED IN DIFFERENT SPRAYS.

The sprays employed were the standard lime-sulphur wash, kerosene emulsion, containing 10, 15 and 20 per ct. of oil, and miscible oil in the proportions of one part to ten, fifteen and twenty parts of water. For purposes of comparison 18 trees were fumigated with hydrocyanic acid gas, using potassium cyanide at the rate of 0.3 gram per cubic foot. Each lot of trees intended for treatment by a mixture at a desired strength was divided equally, and half the trees were wholly immersed and half were dipped with the exception of the roots. The temperature of the liquids was 60° F. For the experiment 430 Ben Davis apples were dipped. In the treatment, the trees were plunged into the mixtures and instantly withdrawn.

Results on trees.—The effects of the different treatments on the trees are shown in the accompanying table:—
### Table II.—Effects on Ben Davis Apple Trees of Dipping in Various Sprays.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>No. of trees</th>
<th>Results on trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphur wash, tops only</td>
<td>135</td>
<td>No injury.</td>
</tr>
<tr>
<td>Sulphur wash, tops and roots</td>
<td>135</td>
<td>133 trees killed and two trees with slight injuries.</td>
</tr>
<tr>
<td>Kerosene emulsion (10-20% oil), tops only</td>
<td>30</td>
<td>No injury.</td>
</tr>
<tr>
<td>Kerosene emulsion (10-20% oil), tops and roots</td>
<td>30</td>
<td>No injury.</td>
</tr>
<tr>
<td>Miscible oil (10-20% oil), tops only</td>
<td>50</td>
<td>No injury.</td>
</tr>
<tr>
<td>Miscible oil (10-20% oil), tops and roots</td>
<td>50</td>
<td>No injury.</td>
</tr>
<tr>
<td>Fumigation with hydrocyanic acid gas</td>
<td>18</td>
<td>Trees normal.</td>
</tr>
<tr>
<td>Checks, no treatment</td>
<td>30</td>
<td>Trees normal.</td>
</tr>
</tbody>
</table>

**Summary of results.**—From the above table it will be seen that no injuries attended the dipping of the trees in kerosene emulsion or miscible oil in the proportions as given. The trees having their tops only immersed in the lime-sulphur wash likewise sustained no harm, while of the trees which were completely wetted with this spray, 133 were killed outright and 2 lived to make a very poor growth. The trees that were fumigated showed no appreciable injuries and made a normal growth. All of the thirty checks grew satisfactorily, without evidences of injuries by the handling and transplanting.

**Experiment VIII.**

Bartlett Pears Dipped in Sulphur Wash for Different Time Periods.

In this experiment there were 120 2-year-old Bartlett pears divided into six lots of 20 trees. Each lot was equally divided, and half the trees were wholly immersed and the remaining ones were dipped, with the exception of the roots. The time periods were as follows:—

Lot I, instantaneous immersion, Lot II, dipped for one minute, Lot III, two minutes, Lot IV, three minutes, Lot V,
five minutes, Lot VI, ten minutes. The standard lime-sulphur wash, with a temperature of 60° F., was used.

Results on trees.—With few slight exceptions, no injuries were sustained by any of the trees preceding Lot V. In Lot V, six trees that were completely immersed, died; and in Lot VI two trees similarly treated were killed. There were no losses among the checks.

EXPERIMENT IX.

MANN APPLES DIPPED IN SULPHUR WASH FOR DIFFERENT TIME PERIODS.

For this experiment 290 3-year-old Mann apples were used. The trees had been kept through the winter in cold storage and were not removed until April 27, when they were dipped. At the time of treatment the trees were dormant, with the bark and roots dry. For dipping, the trees were divided into six lots as follows: Lot I, 140 trees, instantaneous immersion, Lot II, 30 trees, immersion for one minute, Lot III, 30 trees, two minutes, Lot IV, 30 trees, four minutes, Lot V, 30 trees, five minutes, and Lot VI, 30 trees, ten minutes. Each of the above lots was divided into three parts; and for the treatment the trees in part I had the tops only dipped; in part II had the roots only dipped; while those in part III were wholly immersed. The temperature of the sulphur wash was 60° F.

Results on trees.—The effects of these different treatments upon the trees are given briefly in detail as follows:—

Lot I. Instantaneous Immersion.

Tops only.

May 22. Trees are leafing out.
June 4. Trees are making good growth.
July 5. Trees are normal.

Roots only.

May 22. Leaves are making their appearance.
June 4. As above.
July 5. Trees are making normal growth.
ENTIRE TREES.

May 22. Trees are as above.
June 4. 10 trees are very backward. Remainder as above but some show signs of wilting.
July 5. 14 trees are dead. 32 trees are normal.

Lot II. DIPPED ONE MINUTE.

TOPS ONLY.

May 22. Buds are opening. Some trees are retarded.
June 4. 8 trees are in leaf. 2 trees with buds just opening.
June 5. Trees are making normal growth.

ROOTS ONLY.

May 22. As above.
June 4. 4 trees are in leaf. 6 trees with buds just opening.
July 5. 4 trees are dead. 6 trees are normal.

ENTIRE TREES.

May 22. 6 trees are in leaf. 4 trees are much retarded.
June 4. 7 trees are making good growth. 3 trees with buds unopened.
July 5. 7 trees are dead. 3 trees with poor growth.

Lot III. DIPPED TWO MINUTES.

TOPS ONLY.

May 22. 1 tree in leaf and 9 trees with unopened buds.
June 4. 7 trees are making good growth. 3 trees with buds just breaking open.
July 5. All trees are in normal condition.

ROOTS ONLY.

May 22. Same as above.
June 4. 2 trees are making good growth. 8 trees with unopened buds.
July 5. 5 trees are dead. 5 trees are making fair growth.

ENTIRE TREES.

May 22. 5 trees are in leaf. 5 trees are dormant.
June 4. 8 trees are making good growth. 2 trees are backward.
July 5. All trees are making fair growth.

Lot IV. DIPPED THREE MINUTES.

TOPS ONLY.

May 22. All buds are retarded, barely showing green at tips.
June 4. 4 trees in leaf. 6 trees with many buds unopened.
July 5. Trees are making good growth.

ROOTS ONLY.

May 22. Same as above.
June 4. 2 trees are in leaf. 8 trees with buds unopened.
July 5. 2 trees are dead and 8 trees are normal.

ENTIRE TREES.

May 22. Same as above.
June 4. About same as above.
July 5. 5 trees are dead and 5 trees are making fair growth.

Lot V. DIPPED FIVE MINUTES.

TOPS ONLY.

May 22. 5 trees are in leaf and 5 trees with unopened buds.
June 4. 7 trees are making good growth and 3 trees are much retarded.
July 5. All trees are in fair condition.
ROOTS ONLY.

May 22.  2 trees are in leaf.  8 trees are dormant.
June 4.  Trees same as above.
July 5.  Trees are as above.

ENTIRE TREES.

May 22.  Trees are as above.
June 4.  General condition same as preceding.
July 5.  4 trees are dead and 6 trees are making poor growth.

LOT VI.  DIPPED TEN MINUTES.

TOPS ONLY.

May 22.  All trees very much retarded.
June 4.  All trees are retarded and many buds are unopened.
July 5.  Trees with fair quantity of leaves and showing dead stubs.

ROOTS ONLY.

May 22.  3 trees in leaf.  Remainder are much retarded.
June 4.  All trees are showing small leaves and dead stubs.
July 5.  3 trees are dead and 7 trees show fair growth.

ENTIRE TREES.

May 22.  2 trees in leaf.  Remainder are much retarded.
June 4.  All leaves are small and some are wilting.
July 5.  4 trees are dead and 6 trees show fair growth.

Summary of results.—The Mann apples, which were taken from cold storage, did not sustain quite as severe injuries as Ben Davis apples, removed directly from the field, as described in preceding experiments. Of 188 trees that had the roots treated with the sulphur wash, 48 trees, or 26 per ct. of the trees dipped, were killed. The trees that had their tops only treated showed no appreciable injuries by instantaneous immersion or dipping from one to three minutes. The trees that were dipped for ten minutes showed retardation of buds and small losses in foliage. The checks made a good growth and there were no apparent injuries to any of the trees.

EXPERIMENT X.

BARTLETT PEARS DIPPED IN SULPHUR WASH FOR DIFFERENT TIME PERIODS.

This experiment was conducted in the same manner as the one preceding. The stock consisted of 290 3-year-old Bartletts taken from cold storage. The details of the dipping operations are the same as in experiment No. IX.
Results on trees.—In Lot VI, of which the tops of the trees were immersed for ten minutes, slight injuries to the buds were apparent. On June 7, the number of the leaves appeared to be reduced. Quite a number of sprouts were growing out from the sides of the trunk, just below the treated area, at the bases of the lower branches. These trees showed very little improvement by July 5. Ten trees with the roots only dipped in the sulphur wash were also injured and made very little growth. Many of the pruned branches appeared as dead stubs. The trees in the remaining lots were not affected by the treatments and with some exceptions all made normal growth. On the whole, pears sustained very little injury as compared with apples similarly treated.

EXPERIMENT XI.

SATSUMA PLUMS DIPPED IN SULPHUR WASH FOR DIFFERENT TIME PERIODS.

This was conducted in the same manner as Experiment IX. The nursery stock was taken from cold storage and consisted of 290 3-year-old Satsuma plums. All details of the dipping operations are the same as previously described.

Results on trees.—No important differences were noted in the trees of lots I to III inclusive. The effects of the treatments upon the remainder of the trees are as follows: —

LOT IV. DIPPED THREE MINUTES.

TOPS ONLY.

May 22. Trees are in leaf.
June 7. Leaves are very small and growth is poor.
July 5. Growth is good. Many tips of branches are dead and considerable sprouting shows below base of lower branches.

ROOTS ONLY.

May 22. Same as above.
June 7. Tips of branches are dead and sprouts show on trunk. 3 trees are dead.
July 5. 4 trees are dead. Remainder of trees have made a poor growth.

ENTIRE TREES.

May 22. Trees are in leaf.
June 7. Leaves are very small. Tips of branches are dead. Few sprouts show on trunk.
July 5. Growth is small and much dead wood appears in tops of trees.
LOT V. DIPPED FIVE MINUTES.
TOPS ONLY.
May 22. Growth is much retarded and few leaf clusters are apparent.
June 7. Considerable sprouting shows on sides of trees and bases of branches.
July 5. Growth is poor. Much dead wood is apparent. Considerable sprouting shows on trunks.

ROOTS ONLY.
May 22. As above.
June 7. Leaves are larger and more abundant than above. Injuries to wood are not so extensive.
July 5. Growth is good. 1 tree is dead and 3 trees are backward.

ENTIRE TREES.
May 22. Trees are more retarded than above.
June 7. 6 trees are declining. 4 trees are in fair condition.
July 5. All trees are in very poor condition. Tops are dead. Few sprouts show on trunks.

LOT VI. DIPPED TEN MINUTES.
TOPS ONLY.
May 22. All trees are much retarded.
June 7. Tops practically killed. More or less sprouting on trunks.
July 5. Tops of trees consist entirely of dead stubs. Sprouting on trunks below branches.

ROOTS ONLY.
May 22. All trees in leaf.
June 7. Leaves in full number but are small.
July 5. Tops of trees are small and growth is poor. No apparent injuries to branches.

ENTIRE TREES.
May 22. 6 trees much retarded and showing considerable injuries.
June 7. Tops dead. Much sprouting on sides of trunks.
July 5. Trees are nearly dead. Sprouts on sides of trunk are making feeble growth.

Summary of results.—The trees in lots I to III inclusive showed very little difference in their conditions as a result of the treatment. The trees generally made a satisfactory growth. Plants immersed for three or more minutes usually sustained severe injuries. Trees with their tops only immersed had many buds and some of the wood killed. Injuries to the branches were followed by considerable sprouting on the trunks below the areas treated. The effects of immersion of plum roots in the sulphur wash for the longer time periods were somewhat variable, but as a rule such treatment was followed by a poor growth, resulting in many instances in the death of the trees. No injuries were apparent among the checks, of which there were thirty.
EXPERIMENT XII.

FITZGERALD PEACHES DIPPED IN SULPHUR WASH FOR DIFFERENT TIME PERIODS.

The details of this experiment are the same as described for experiment IX. For the treatment, 300 3-year-old Fitzgerald peaches, taken from cold storage, were used. The details of the dipping operations are as described in preceding experiments.

Results on trees.—The injurious effects of the treatments were generally more pronounced on the peaches than on other kinds of fruit. The results in detail are briefly as follows:

Lot I. Instantaneous Immersion.

Tops only.

May 22. All trees are dormant.
June 7. Growth is good.
July 5. Trees in excellent condition.

Roots only.

May 22. All trees are dormant.
June 7. 53 trees are dead. 10 trees are apparently alive.
July 5. 58 trees are killed. 5 trees show poor growth.

Entire trees.

May 22. Trees are dormant.
June 7. Trees show little life.
July 5. All trees, 30 in number, are dead.

Lot II. Immersed One Minute.

Tops only.

May 22. Trees are dormant.
June 7. Trees are as good as checks.
July 5. All trees show good growth.

Roots only.

May 22. Trees are dormant.
June 7. All trees are as good as checks.
July 5. All trees, 10 in number, are dead.

Entire trees.

May 22. Trees dormant.
June 7. All tops are dead. Trees are sprouting near ground.
July 5. All trees, 10 in number, are dead.

Lot III. Immersed Two Minutes.

Tops only.

May 22. Trees are dormant.
June 7. Good growth but little inferior to checks.
July 5. Trees are in excellent condition.

Roots only.

May 22. Trees are dormant.
June 7. Tops are dead. 4 trees show young sprouts on trunks.
July 7. 7 trees are dead. 3 trees show live sprouts on trunk.
ENTIRE TREES.

May 22. Trees are dormant.
June 7. Tops are killed. 9 trees show sprouts on trunk.
July 5. All tops are dead. A few sprouts near the ground appear on all of the trees.

LOT IV. IMMERSED THREE MINUTES.
TOPS ONLY.

May 22. Trees are dormant.
June 7. Some buds are killed. Leaves are few. Many sprouts appear on trunks.
July 5. New growth is heavy. Old branches are dead. Many sprouts show on trunks.

ROOTS ONLY.

May 22. Trees are dormant.
June 7. 3 trees are dead. 7 trees show a few leaves and sprouts appear on trunks.
July 5. 4 trees are dead. 6 trees have small tops and poor growth.

ENTIRE TREES.

May 22. Trees are dormant.
June 7. All trees are alive. Tips of branches are dead. Many sprouts show on trunks.
July 7. Growth is small. Old branches are dead.

LOT V. IMMERSED FIVE MINUTES.
TOPS ONLY.

May 22. Trees are dormant.
June 7. 6 trees show dead tops. 3 trees have few leaves and sprouts on trunks.
July 5. All tops, 10 in number, are dead. Considerable growth of sprouts appears on trunks.

ROOTS ONLY.

May 22. Trees are dormant.
June 7. All tops are dead. 5 trees with sprouts on sides of trunk.
July 5. All trees, 10 in number, are dead.

ENTIRE TREES.

May 22. Trees are dormant.
June 7. 9 trees are dead. 1 tree is barely alive.
July 5. All trees, 10 in number, are dead.

LOT VI. IMMERSED TEN MINUTES.
TOPS ONLY.

May 22. Trees are apparently dormant.
June 7. All tops are killed. Much sprouting appears on sides of trunks.
July 5. Tops of trees are dead. Long growth of sprouts near surface of ground.

ROOTS ONLY.

May 22. Trees are apparently dormant.
June 7. All trees are apparently killed.
July 5. All trees, 10 in number, are dead.

ENTIRE TREES.

May 22. Trees are apparently dormant.
June 7. All trees are apparently killed,
July 5. All trees, 10 in number, are dead.
Summary of results.—The peaches generally proved very much more susceptible to injuries by complete or partial immersion in the lime-sulphur wash than any of the other kinds of fruits that were tested. Injuries to the buds were caused by the dipping of the tops in the mixture for periods of three or more minutes, and the tops of the trees were killed by immersion for ten minutes. Trees with their roots immersed in the lime-sulphur wash were seriously injured or killed by the treatment. Of 188 trees that were dipped with the roots, 179, or 95 per ct. of the number treated, were killed. All of the checks, thirty in number, made a normal growth.

ROOT INJURIES BY IMMERSION IN SPRAYING MIXTURES.

The trees with roots immersed in the sulphur wash frequently sustained injuries. The effects of this treatment upon the health of the plants were most plainly apparent about fourteen days after the trees were in leaf. The first indications of the injuries were by the wilting and curling of a few leaves, which during a succession of hot days gradually extended to the entire foliage. The trees that were extremely affected soon became defoliated, from which they did not revive. The growth that was made appeared to be entirely at the expense of the reserve food materials, which had been stored up in the main axis of the plants.

An examination of the underground portions of a number of trees dipped in the wash showed that the root system may be seriously damaged by this treatment. The extent of the injuries was not constant and varied with individual plants of the same variety. Cross sections of immersed roots, which externally exhibited no evidences of injuries, showed frequently a discolored cambium. Large portions of the tips of the older roots and often entire smaller roots were killed. In some instances the cambium was killed in spots which gave rise to more or less extensive dead areas. Wounded areas made by the cutting of a large root sometimes did not callous and failed to produce adventitious roots.
In the field experiments with oil emulsions, there were no evidences of injuries to the trees, but in some laboratory tests, conducted later, on the immersion of roots in an emulsion, containing 20 per ct. of oil, damages resulted. The injuries were even more severe than with the sulphur wash, and were apparent about the collar as well as the roots of the plants.

**GENERAL SUMMARY.**

Immersion of moderately infested apple and pear stocks in the standard lime-sulphur wash was attended with variable results on the scales. None of the four lots, representing 600 affected trees, that were dipped showed complete destruction of this pest. In each lot there were individual trees on which the scale was efficiently combated, but the remainder of the stock, while deriving some benefit from the treatment, showed an infestation which varied from two per ct. to thirty-five per ct. of that previous to dipping. Preparations of washes at temperatures of 60°, 100° and 120° F. exhibited similar variations in their effectiveness on the scale, while immersion of infested trees in the wash at a temperature of 212° F. entirely killed the scales and severely injured the trees. Dipping of roots in the sulphur wash was usually accompanied by injuries which varied in extent with the kinds of stock, apples and peaches sustaining the most damage. Ben Davis apples showed a loss of 96 per ct. of the number of trees wholly dipped, Mann apples, 26 per ct., and Fitzgerald peaches, 95 per ct. The treatment of the tops of apples and pears by instantaneous dipping or immersion from one to five minutes in the wash at temperatures of 60° to 120° F., generally caused no important injuries. Mann apples and Bartlett pears apparently sustained slight damages to buds by immersion for ten minutes. The dipping of the tops of peaches and plums in a sulphur wash at temperatures of 60° to 120° F., for less than three minutes, was unattended with appreciable injuries, while immersion for longer periods of time seemed
in some instances to destroy many buds. The tops of peaches were killed by immersion for ten minutes in the lime-sulphur wash at a temperature of 60° F.

In the field tests with kerosene emulsion, containing 10, 15 and 20 per ct. of oil, and miscible oil, diluted with 10, 15 and 20 parts of water, to determine their value as dips, no injuries were apparent to any of the trees, even when the roots were immersed in the liquids. These proved not only safer but the stronger preparations were also much more effective on the scales than the sulphur wash. Kerosene emulsion, containing either 15 or 20 per ct. of oil, and miscible oil, diluted with either 10 or 15 parts of water, were generally very efficient. With the exception of a few trees on which there was a little breeding, the stock was cleaned of the scales. Fumigation with hydrocyanic acid gas at the rate of 0.3 gram of cyanide per cubic foot caused no appreciable harm to the trees and completely destroyed the scales.

DISCUSSION OF RESULTS AND CONCLUSIONS.

The purpose of these experiments was to determine the merits of the standard lime-sulphur wash as a dip for the treatment of nursery trees. In this endeavor, efforts were principally directed to determine the safeness of dipping trees in this mixture and the probable effects of this operation in field practice accomplishing the real object of the work, i. e., to clean the stock of San José scale. The experiments have yielded data bearing on both of these points, which show plainly that the immersion of the roots of fruit trees in a sulphur wash may be accompanied with serious injuries to the stock, and that this treatment does not entirely destroy the scales. In view of these limitations, it is believed that this method of disinfecting nursery trees is a doubtful practice for both nurserymen and fruit-growers, neither of whom can afford to take chances on the reliability of their purchases and shipments. In the light of these experiments, uncertain and disappointing results could hardly fail to follow the employ-
ment of this kind of treatment for nursery stock. Until more knowledge is obtained of the strength of the sulphur wash that will effectively control the scale, dipping of the tops of trees in this mixture for purposes of disinfection should be regarded as wholly experimental. As immersion of the tops of the trees in the standard sulphur wash at temperatures of from 60° to 120° F. for short time periods is unattended with important injuries, it is possible that stronger preparations of the sulphur wash can be employed for the treatment of stock, excluding the roots, which will give efficient results on the scales and will not prove harmful to the plants.

The results obtained with the oil emulsions and miscible oils indicate that they are more efficient for dipping purposes than is the sulphur wash. Their actual value for this purpose and the conditions under which they may be safely employed are problems for future experimentation.

The fact that fumigation with hydrocyanic acid gas, in addition to proving safe to the plants, was the only one of the remedies employed that completely destroyed the scales, deserves special emphasis. This process is the most efficient means of disinfecting nursery stock and its utility for this purpose has been abundantly established by many experiments and by the experience of careful nurserymen. While it is not an absolute guarantee of the immunity of the trees from destructive insects, it is without question the most effective method of accomplishing their destruction. Its efficiency and safeness are proportionate to the care that is exercised in carrying out the details of the operation. For dug dormant stock, infested with the San José scale, fumigation is the more reliable treatment.