The effect of petroleum oil sprays on insects and plants

Milton Dyer Farrar

Iowa State College

Follow this and additional works at: https://lib.dr.iastate.edu/rtd

Part of the Ecology and Evolutionary Biology Commons, Entomology Commons, and the Environmental Sciences Commons

Recommended Citation


This Dissertation is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
THE EFFECT OF PETROLEUM OIL SPRAYS ON INSECTS AND PLANTS

BY

MILTON DYER FARRAR

A Thesis Submitted to the Graduate Faculty
for the Degree

DOCTOR OF PHILOSOPHY

Major Subject: Entomology

Approved:

[Signature was redacted for privacy.]

In charge of Major work

[Signature was redacted for privacy.]

Head of Major Department

[Signature was redacted for privacy.]

Dean of Graduate College

Iowa State College
1933
INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I.  INTRODUCTION</td>
<td>6</td>
</tr>
<tr>
<td>II. DEFINITION OF TERMS</td>
<td>10</td>
</tr>
<tr>
<td>III. PETROLEUM OIL AS AN INSECTICIDE</td>
<td>12</td>
</tr>
<tr>
<td>IV. HISTORY OF OIL SPRAYS</td>
<td>14</td>
</tr>
<tr>
<td>V.  PREPARATION OF THE EMULSIONS</td>
<td>17</td>
</tr>
<tr>
<td>VI. PROPERTIES OF OILS</td>
<td>20</td>
</tr>
<tr>
<td>VII. EFFECT OF PETROLEUM OILS ON PLANTS</td>
<td>23</td>
</tr>
<tr>
<td>VIII. INJURY OF OIL SPRAYS TO FOLIAGE</td>
<td>27</td>
</tr>
<tr>
<td>IX. INSECTICIDE TESTS WITH THE EMULSIONS</td>
<td>39</td>
</tr>
<tr>
<td>A. Codling Moth</td>
<td></td>
</tr>
<tr>
<td>1. The addition of petroleum oils to lead arsenate spray</td>
<td>40</td>
</tr>
<tr>
<td>2. White oil emulsions as a substitute for lead arsenate</td>
<td>41</td>
</tr>
<tr>
<td>3. Field tests on the control of the codling moth</td>
<td>43</td>
</tr>
<tr>
<td>a. White oil emulsions as a substitute for lead arsenate</td>
<td>44</td>
</tr>
<tr>
<td>b. White oil emulsions with pyrethrum and derris</td>
<td>45</td>
</tr>
<tr>
<td>c. White oil emulsions with nicotine</td>
<td>46</td>
</tr>
<tr>
<td>d. Arsenical residues</td>
<td>50</td>
</tr>
</tbody>
</table>

\[ T \text{ 4475} \]
-3-

4. Laboratory tests on the codling moth
   a. Technique
   b. White oil emulsions
   c. White oil emulsions plus pyrethrum
   d. White oil emulsions plus nicotine
   e. White oil emulsions plus derris
   f. White oil emulsions plus other insecticides
   g. Laboratory tests with lead arsenate

B. Red Spider
   1. Field tests on conifers
   2. Field tests on raspberries

C. San Jose Scale

D. Aphids

E. Oyster Shell Scale

F. European Elm Scale

G. Fruit Tree Leaf Roller

F. Fleas

X. DORMANT OILS WITH FUNGICIDES

XI. DELAYED DORMANT APPLICATIONS OF OIL SPRAYS

XII. SUMMER OILS WITH FUNGICIDES

XIII. THE DISTRIBUTION OF A UNIT VOLUME OF SPRAY MATERIAL

XIV. SUMMARY AND CONCLUSIONS
XV. PRESENT TRENDS OF OIL SPRAYS  
XVI. LITERATURE CITED  
XVII. ACKNOWLEDGEMENTS  
XVIII. VITA  
XIX. ILLUSTRATIONS  

Fig. 1 Field tests with codling moth larvae  
Fig. 2 Laboratory tests with codling moth larvae  
Fig. 3 Injury from oil emulsions and lime sulphur  
Fig. 4 Injury from delayed dormant oil sprays  
Fig. 5-9 Photomicrographs of some experimental emulsions  

XX. TABLES  
1. Experimental oils, properties of  
2. Foliage injury, tests of emulsions  
3. Foliage injury, tests of emulsions  
4. Codling moth, summary of field tests  
5. Arsenical residues, experimental plots  
6. Codling moth, summary of laboratory tests  
7. Red spider, conifers and raspberries  
8. San Jose scale, tests of miscible oils  
9. San Jose scale, tests of commercial oils  
10. Aphids, tests of miscible oils
11. Aphids, tests of commercial oils  
12. Aphids, tests of white oil emulsions  
13. Oyster shell scale, control in egg stage  
14. Oyster shell scale, control at time of hatch  
15. Fruit tree leaf roller, laboratory tests  
16. Volume of spray and area covered
INTRODUCTION

The data presented in this thesis were compiled from a research project carried on since 1925 at Urbana, Illinois, under the supervision of the Crop Protection Institute. In 1925 the officials of the Standard Oil Company of Indiana felt that an investigation of the petroleum oils as tree sprays might be productive of emulsions superior to the products then being marketed. They established a research fellowship with the Crop Protection Institute for the investigation of petroleum oils suitable for tree sprays.

Dr. L.L. English, a graduate student at Iowa State College, was employed as Research Fellow to carry on the active program of the investigation. The project was located at Urbana, Illinois, under the auspices of the Illinois Natural History Survey.

Professor W.P. Flint, Survey Entomologist, was placed in charge of the investigation. For several years, he and his staff had been actively investigating the problem of oil sprays for the control of San Jose scale. The equipment and facilities of the Natural History Survey were ample for the project. In addition to office facilities, laboratory
equipment, and greenhouse space of the Survey, the investigators have always enjoyed the cooperation of the Department of Horticulture whose extensive orchards were invaluable for conducting field tests, particularly the injury tests on apple trees. Many of the field tests were conducted in private orchards located in western, central, and southern Illinois. Some of the field experiments were cooperative with the Natural History Survey, the Department of Horticulture, and the Crop Protection Institute. As the work progressed, the investigation was expanded beyond its original scope to include new lines of research that have kept the fellowship active.

In 1928 Dr. L. L. English published a part of the findings of the investigation under the title of "Some Properties of Oil Emulsions Influencing Insecticidal Efficiency". A summary of the unpublished findings from January, 1928, to January, 1932, forms the major portion of this thesis, although some of the earlier data have been included in the tables for comparison.

The relatively long period of the investigation and the gradual changes in technique have made it impractical to compare directly data collected from year to year. In organizing the results into comprehensive tables, it is unfortunate that many interesting developments must be omitted.
The author, in presenting this paper, has attempted to bring together in tabular form such experiments as appeared to illustrate progress in our knowledge of oil sprays. For purposes of discussion and comparison of the various emulsions, the information is grouped under the general headings referring to the specific insects and plants used in the experiments.

The experiments have included tests on about three-hundred and ten oil or oil emulsion formulae of which about 16 percent were soluble oils and 34 percent stock emulsions. In addition to these, various chemicals were included in many of the formulae.

A very limited number of emulsion formulae were tested under field conditions for more than one season. The greater portion of them were tested under field conditions for only one year. Laboratory studies were made upon all of the formulae to determine their physical properties and toxicity to bean foliage. A limited number of tests were performed on insects to evaluate the insecticidal properties of each emulsion. Such formulae as offered promise as a result of information gained in the laboratory were tested under field conditions the following season.

As tangible results of the investigation, a miscible oil and a white oil stock emulsion have been developed. In the investigation of these products and the study of their
related formulae, a fund of constructive information has been compiled that has been of great assistance in the interpretation of results. This information has added greatly to our understanding of some of the factors affecting the reactions of petroleum oils on insects and plants.
DEFINITION OF TERMS

Technical White Oil is one from which the preponderance of unsaturated hydrocarbons has been removed, but it is not of medicinal grade. A Technical White Oil or Saturated Oil is practically inert chemically. Paraffine Oil or Unsaturated Oil is not as highly refined as is the technical white oil and contains unsaturated hydrocarbons in varying amounts depending on the degree of refinement. The degree of saturation is expressed as unsulfonated residue and is determined by a standard procedure. Unsulfonated residue, or degree of saturation, may be determined by various procedures all giving different values. All values given in this paper were determined by the "Whiting Method".

Viscosity as measured by the Saybolt test, is the resistance to flow of a given volume of oil through a given orifice at 100°F., and is expressed in units of seconds.

Stock Emulsions are oil emulsions of a paste-like consistency. They generally contain water as a separate phase. Oil 200, and boiled fish oil soap emulsion are examples of this type of emulsion.
Miscible or Soluble Oils are clear oil-like emulsions containing very little water. In these a soap emulsifier is dissolved into the oil. On the addition of water the miscible oils disperse to form a milky white emulsion of very small oil droplet size. The commercial oils, Dendrol and Sunoco, are examples of this type of emulsion.

Lead Arsenate, as used in this paper, refers to acid lead arsenate; the powdered commercial product marketed for insecticidal purposes.

Concentration of emulsions refers, in this paper, to measurements by volume.
PETROLEUM OIL AS AN INSECTICIDE

The first use of oil to destroy insects is not known. It was first recommended for use on plants in 1763. Oil has been employed in many ways: directly against insect pests; as a carrier of other insecticides or poisons; as an emulsion; or mixed with flocculent insecticides.

Forms of Use:

1. Petroleum oil is used without further change in the control of mosquitoes, animal parasites, and household pests; as a carrier of other insecticides, or as a sticker in many sprays and dusts.

2. Emulsions containing petroleum oils are not sharply divided but can be classified into three general groups.

A. Miscible or Soluble Oils are oils in which a soap emulsifier has been dispersed into the oil. Their clear oil-like nature makes them convenient to store, handle or dilute. The use of miscible oils is generally restricted to the dormant stage of plant growth by the soap emulsifier and the relatively small size of the oil droplets. Miscible oils vary widely in their physical properties.
Stock Emulsions are creamy paste-like emulsions. They can be made with either inert or chemically active emulsifiers and usually contain about one-third of their volume of water. The water content is often sufficient to make them unstable at temperatures that cause the water phase to freeze and thaw. The properties of this type of emulsion will vary with its previous history, that is, the formula used, the method and temperature of preparation, the oil droplet size of the prepared emulsion, etc.

Quick-Breaking Emulsions are made in the spray tank with or without the addition of some emulsifying agent. The emulsion depends upon the agitation to break up the oil into droplets. The oil droplets are very large and loosely emulsified, and the oil phase will separate either on standing or soon after application. For certain insects such as leaf rollers and case bearers, they are superior to the more stable emulsions.
THE HISTORY OF OIL SPRAYS

According to Lodeman (1898), Goeze was the first to recommend the use of oils on plants. In 1763, J.A.E. Goeze wrote, "petroleum, turpentine and other oils are also recommended; but care must be taken in their use, since they act upon the plants, making them sick or even killing them." He also credits William Forsyth as the first to call attention to the use of train-(whale) oil against coccus or scale insects on plants in 1800.

The first record of petroleum oil as an insecticide in America is a recommendation in 1865 to use kerosene undiluted. The oil was to be applied by means of a feather on citrus trees for the control of citrus scale. Kerosene was first employed as a spray in 1868 by Henry Bird, Newark, New Jersey. He used a mixture of kerosene, soap and water for the control of the currant worm. It was not generally used as an emulsion until recommended by A.J. Cook in 1878.

By 1882, H.G. Hubbard had developed a satisfactory formula for kerosene emulsion using soap as an emulsifier. Kerosene and other light petroleum oils were used quite generally either as emulsions or as mechanical mixtures previous to 1900. Distillate emulsions appeared in 1900,
followed by distillate-water mechanical mixtures in 1902 and by miscible oils in 1904, according to Mason (1928) and Essig (1931).

The injury often resulting from the use of the earlier types of emulsions encouraged the use of lime sulphur for the control of San Jose scale. For a number of years lime sulphur almost supplanted the use of oils for scale control. Following 1919, a series of favorable years for scale proved that lime sulphur was not satisfactory as a scale spray. A new interest developed in oil sprays about this time, and since that period the field of uses for oil sprays has been intensively investigated.

Early emulsions were usually prepared by machinery that was inadequately powered to reduce the oil phase of the emulsion to a droplet size suitable for spray purposes. Such emulsions were very unstable and often separated before the emulsion could be applied.

With the development of miscible or soluble oils, extremely stable oil emulsions were prepared. In an attempt to market oil sprays that would mix or dilute with all types of hard water, the ratio of the emulsifier to the oil phase was increased, resulting in extremely stable emulsions that contained very small oil droplets. Emulsions of this type are not as efficient insecticides as are those emulsions whose
size of oil droplets approaches that of the less stable
emulsions, according to deOng (1926), Griffin, et al (1927)
and English (1928). The recent work done with the so-called
"quick breaking" emulsions has resulted in the development
of preparations that will mix with the majority of hard
waters and yet possess the quick breaking property that gives
to them high insecticidal efficiency.
PREPARATION OF THE EMULSIONS

The experimental emulsions discussed in this paper were prepared in the laboratories of the Standard Oil Company of Indiana. The commercial oils used for comparison in many experiments were furnished by their respective manufacturers* for that purpose. Certain emulsions were prepared by the author or his assistants and are listed as boiled fish oil soap emulsions.

The physical and chemical properties of the experimental oils used are shown in Table I. The analyses are furnished by the Standard Oil Company of Indiana. All miscible oils were prepared by a standard technique worked out in the Standard Oil Laboratories at Whiting, Indiana. Stock emulsions incorporating inert emulsifiers were emulsified by colloid mills, capable of producing emulsions of uniform dispersion of oil droplets in the technical white oil emulsions. The addition of various chemicals to either the oil, water, or emulsifier phases of these emulsions often changed the degree of dispersion. The difficulty of classification made

*Manufacturers of commercial oils used in these tests: Sun Oil Co.; B.G. Pratt & Co.; Sherwin-Williams Co.; California Spray Chemical Co.; Shell Oil Co.; Schaeffer Bros. & Powell, St. Louis, Mo., and Standard Oil Co. of Indiana.
impractical the consideration of particle size in the experimental white oil emulsions. It is generally recognized that the less dispersed oil emulsions separate faster and are more toxic to insects.
### Table I
Properties of Experimental Oils*

<table>
<thead>
<tr>
<th>Oil</th>
<th>No.</th>
<th>Specific Gravity at 60°F</th>
<th>Flash Point °F</th>
<th>Fire Point °F</th>
<th>Viscosity (Saybolt) Seconds</th>
<th>Evaporation at 100°F</th>
<th>Evaporation at 212°F</th>
<th>Unsulfonated Residue Percent</th>
<th>Unsulfonated Residue Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technical White Oil</td>
<td>32</td>
<td>0.801</td>
<td>174</td>
<td>206</td>
<td>32</td>
<td>35.1</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>0.857</td>
<td>345</td>
<td>395</td>
<td>83</td>
<td>0.0</td>
<td>99.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>95</td>
<td>-</td>
<td>366</td>
<td>410</td>
<td>95-100</td>
<td>6.6</td>
<td>99.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>190</td>
<td>0.878</td>
<td>375</td>
<td>430</td>
<td>190</td>
<td>0.2</td>
<td>93.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paraffin oil</td>
<td>32</td>
<td>0.82</td>
<td>164</td>
<td>196</td>
<td>32</td>
<td>54.3</td>
<td>92.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>83</td>
<td>0.883</td>
<td>335</td>
<td>385</td>
<td>83</td>
<td>1.7</td>
<td>91.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>104</td>
<td>0.889</td>
<td>355</td>
<td>405</td>
<td>104</td>
<td>1.2</td>
<td>93.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Technical white oils of viscosities other than those listed correspond to technical white oil 83 in unsulfonated residue. Paraffin oils correspond to paraffin oils 83 and 104 in unsulfonated residues. The data given above were submitted from the laboratory of the Standard Oil Company of Indiana, Whiting, Indiana. Unsulfonated residue, or degree of saturation, values given in this paper were determined by the "Whiting Method". These values are higher than those given by some other methods.
PROPERTIES OF OILS

Saturation, or ratio between saturated and unsaturated hydrocarbons, has sharply divided the usage of oil sprays into two distinct fields. The works of Gray and deOng (1926), deOng, et al (1927), English (1928) and others show that the oils containing the larger quantities of unsaturated hydrocarbons are the more likely to cause plant injury under comparable conditions. Extensive experiments indicate that the less highly refined oils are safe to apply on dormant trees if they are properly emulsified. Because of the lower cost of this grade of oil, its use in dormant sprays has become general.

The viscosity of oils used in tree sprays must be kept within the limits of plant tolerance. Oils of less than 40 to 50 seconds of viscosity are very difficult to combine into a stable emulsion. Although somewhat safer to use on plants, these light viscosity oils disappear too rapidly to have a good insecticidal value. Knight, et al (1929) feel that a 60 second viscosity oil represents about the upper limit of plant tolerance and that oils of higher viscosities must be used with caution if serious ultimate injury is to be avoided. Most authors agree that the lighter oils are safer.
on plants and generally recommend the lightest oil that will give the proper control of the insect involved. The temperature under which an oil is used in the field should determine the proper viscosity, according to deOng (1931), although Green (1927) did not find viscosity a factor for toxicity in dormant spraying. Oils from 60 to 125 seconds are now being used in the manufacture of the greater part of the commercial brands of oil emulsions.

Volatility is a property that some authors have considered important in petroleum oils for use in tree sprays. Although perhaps of some importance, its significance has not been fully accepted by all workers. The property of volatility is by no means identical with that of viscosity; nevertheless it is closely associated with viscosity. According to the findings of Knight, et al (1929) the effect of volatility "due to the enclosure of the oil in the intercellular spaces (it) is unquestionably negligible in comparison with translocation." In this paper, the author has not considered volatility an independent property of the oils used in the emulsions tested.

The emulsifier plays a very important role in the performance of oil emulsions as is shown by the work of deOng and Knight (1925), deOng (1926), deOng, et al (1927) and others. Oil emulsions that incorporate excessive amounts of
emulsifier are very easily emulsified but are not as efficient for the control of scale as are less stable emulsions. English (1928) working with aphids, San Jose scale and oyster shell scale clearly demonstrated that high mortality was associated with emulsions exhibiting the quicker breaking properties.

By combining the proper grades of oils and emulsifiers in certain proportions it is possible to produce an emulsion that is stable under ordinary conditions of storage and handling and will give a high kill of insects when it has been properly diluted.
By the penetration of the oil applied, into the intercellular spaces of the vegetable to vegetable tissues, the loop about insecticides. In this paper he concluded that, "By the use of the sheet of petroleum oil when used on plants as an erpers, cockle moth and Oriental fruit moth, etc., constitutes a very important weapon for the control of many dangerous pests such as sooty, white aphids, etc., consters, now recognized that oil expels serve the proper preparation and application of compositions for these were rapid development in the use of petroleum oils. During this same period the more suitable oils and emulsion types that could be used became more general and in combination became available to form new petroleum oil. About 1906 the use of petroleum oils in the use of petroleum oils to not substitute the use of insecticide oil. In to 1906 from the experience of plant with petroleum oils the many cases of plant injury were reported previous

THE EFFECT OF PETROLEUM OILS ON PLANTS

-27-
the plant." He also found the lighter oils less injurious than heavy oils and that the degree of injury depended upon certain physical factors. Some of the factors listed by Volck are— the condition of the plant, type of oil, amount of spray used, whether the spray is applied to the upper or lower leaf surface, and temperature and humidity at the time of spraying. He demonstrated a physical injury from oil that he attributed to "insulation" or sealing over of the parts of the plant; this insulation interfered with both respiration and transpiration of the plant. The chemical effects caused by the petroleum oils used by Volck can now be largely corrected by employing the highly refined white oils containing a minimum of the unsaturated hydrocarbons.

Volck (1903) found that the important injuries to citrus leaves by oil are general and not local. This observation has been substantiated in the more recent work by the determination of rather definite plant tolerances to oil sprays. No rules can be established relative to the tolerance of plant species to oils, but it is known within limits the amount of certain petroleum oils that can be applied with relative safety to the more important trees and plants. It is now well established that a dormant tree will withstand higher dosages of lesser refined oils than the growing tree. The type of oil that may be used with safety to the plant will depend to
In repeated development experiments and studies between February and March, and between February and April, some trees were subjected to little effect, damage, and severe effect, December. Some trees were subjected in November before the December effect on pruning. In the experiments, pruning extended over two years, effects applied in November, before the trees entered the season of 1926 (1927) and the following year when the trees were exposed with the soil. The mature and food eaten portions of the soil and the season of the wood were examined. The effects of exposure to the degree of association with the heavy types of evergreen plant materials associated with the heavy types of evergreen plant materials, Watson with pruning, found the effect of the soil may be returned to.

"..." (1927) stated that "from the theoretical viewpoint, the effect appears to disappear as the plant approaches dormancy, and which time the process appears during the active growth of the plant, and becomes pronounced during the active growth of the plant, and becomes pronounced by Votey (1927), and others. It is the accumulation effect of all effects that has been a large extent on the season of the year when it is applied. "

-25-
Knight, et al (1929) determined histologically the distribution of the petroleum oil in the plant tissue following an oil spray. They found that the saturated white oils were absorbed by the tissues and not volatilized as considered by some authors. The translocation of the absorbed oil was traced from the leaf surface to its final deposition in the large storage cells of the pith and the old wood fiber of the xylem. During the period of oil penetration and initial translocation, transpiration was sharply decreased and respiration enormously increased. Knight and his co-workers attributed the metabolic disturbances to physical rather than chemical handicaps imposed by the intrusion of the saturated petroleum oils into the plant tissue. Ginsburg (1929) found that apple foliage sprayed four times between July 12 and August 24 increased in chlorophyll content from 28 to 47 percent in the two apple varieties tested. This secondary effect of oil sprays of increasing the green appearance of the oil sprayed foliage has been reported by numerous workers with oil emulsions. Working with excised twigs, Kelley (1930.a.) found that, "Saturation of the heavier oils, comparable to those used in commercial spraying, was not important in either the dormant or delayed dormant periods. It was relatively unimportant in foliage applications."
INJURY OF OIL SPRAYS TO FOLIAGE

The works of Volck (1903), Yothers (1913), deOng (1926, 1928.b., 1931), English (1928), Knight et al (1929), Kelley (1926, 1930.a., b.), Ginsburg (1929, 1931.a., b.) and others demonstrate that oils applied to foliage produce certain physiological effects on the trees. As yet no one has advanced a good criterion as to just what physiological effects can be classified as injury resulting from an oil spray. Woodworth (1930) proposes certain terms which may be useful in classifying these effects. It is true that certain oils will injure or burn more than other oils under a comparable set of conditions, but it has never been possible to show that a certain property of an oil, if present in an emulsion, will result in foliage injury. In this paper, injury is considered as visible changes in the normal leaf tissue following the application of an oil spray. This type of injury usually is evident on the margins or tips of the more terminal leaves.

A part of the difficulty in dealing with emulsions lies in the fact that every emulsion prepared is an individual colloidal system possessing properties distinctive from every other emulsion. Although this condition is
literally true, the emulsions tested in this work were
approximately the same since they are prepared in the same
manner and from very similar materials. It was found possible
to duplicate quite closely formulas that were used in previous
tests.

In addition, wide variations in individual trees,
localities, weather conditions, etc., exist in most orchard
experiments. These variations have led to the publication
of a vast amount of data covering experiments with the use of
oil emulsions. In many of the experiments the results can
not be duplicated by the workers themselves. This has
filled the literature with numerous discussions of individual
experiments most of which prove little one way or the other
relative to the toxicity of oils to plants.

The consistent annual spraying of deciduous fruit
trees in the dormant stage with good oil emulsions has pro-
duced apparent injury to them, according to Yothers (1918),
Burroughs (1923), Newcomer and Yothers (1927) and Swingle
and Snapp (1931). This fact is well established even though
many individual cases of injury have been reported during
certain experiments, particularly with non-dormant trees.
Vigorous trees are very tolerant to oil sprays and are seldom
injured by them if the emulsions are properly prepared and
applied. When oils or other spray materials are applied
under abnormal conditions, numerous foliage reactions may set in according to Overley and Spuler (1923) and Dutton (1932). The accumulative effect of petroleum oils applied to foliage has been observed by Yothers (1913) and others. Overholser and Overley (1930) found that more than three applications of medium to heavy viscosity oils applied to apple trees carrying a heavy crop resulted in a decrease in the size of fruit and a poor set of buds and fruit the following year. These effects usually follow the too frequent application of emulsions to foliage early in the growth of new tissue. The delay of such sprays until growth has about stopped and the tissues hardened greatly reduces the abnormal physiological changes such as destruction of tissue, yellowing, premature leaf drop and change in chlorophyll content.

The lower viscosity oils have from the first been considered less toxic to foliage than the heavier oils. The usual explanation is based on the fact that the heavier oils are less volatile and persist in the plant over a longer period of time than do the lighter oils. The detection by Gray and deOng in 1915, Gray and deOng (1926), that the unsaturated hydrocarbons present in untreated oils are largely responsible for the injury to plants has contributed more toward the development of emulsions for use on growing plants than any other discovery.
Additional factors associated with plant injury of less importance are: the use of inert emulsifiers; the limits of the size of the oil droplets; and the effect of oil droplet size on quick breaking. All of these properties have a bearing on the emulsions and predetermine to a limited extent the physical properties of an emulsion suitable for tree spray purposes.

The stage of growth in the plant, weather conditions at the time and following a spray application, time and method of application, and a host of other factors are so influential in the final results from an oil spray, that an emulsion incorporating all the desirable properties of a summer oil will not insure uniform performance of an insecticide without injury to the host plant.

With these conditions in mind one is in position to attempt to judge foliage injury following the use of an oil spray. Table 2 presents data summarizing most of the results obtained from the use of oil sprays on foliage over a five year period. Particular attention should be given to Item 1 covering the work with a summer oil possessing all of the physical properties seemed necessary for safety to foliage. This oil emulsion in 75 field tests gave 1 case of severe injury, 2 of moderate, 3 of slight injury, and 69 cases where no injury was observed. When given adverse
conditions this oil emulsion, although relatively safe, produced severe injury or burn to apple foliage. A very similar result was obtained with the emulsions under Item 5. If given a sufficient number of trials under varying conditions, there is no doubt that the other emulsions listed in the table would have shown a similar number of cases where injury occurred.

Emulsions listed in Items 3 and 4 are similar to those in Item 1 with the exception that extracts of tobacco or derris have been added to the emulsions for the purpose of increasing their insecticidal efficiency. The incorporation of these materials into an inert white oil emulsion did not materially increase foliage injury.

The injury shown in Items 6, 7, and 8 was probably caused by the copper, sulphur, or sodium fluosilicate mixed with the white oil emulsions. The formulae containing copper injured in 51 percent of the cases and those with sulphur in 70 percent of the cases where they were tested.

Technical white oils, Item 9, made up as a stock emulsion with a soap emulsifier did not injure in the limited number of trials given. The same oils, when combined as a miscible oil, injured in 14 percent of the tests.

Petroleum oils containing as much as 9 percent of unsaturated hydrocarbons will cause injury in most cases if
they are combined with soap emulsifiers. The soap emulsifier, Item 14, is no doubt responsible for some of the injury obtained with emulsions containing soap. The miscible or soluble oils, Items 11 and 12, give relatively more injury than do the stock emulsions, Item 13. The smaller oil droplet size and greater stability of the miscible oils are responsible to some extent for the injury that follows the use of miscible oil emulsions. It is evident that, other factors being equal, the emulsions with the smaller oil droplets are the more likely to cause injury to foliage.

In Table 2, a large number of cases are reported where no injury was observed with any of the sprays listed in Items I to 14. These occurrences are significant because they explain to some extent the confusion resulting from reports of injury occurring in the individual experiments of all workers.
# Table 2

**RELATION BETWEEN THE PROPERTIES OF EMULSIONS AND THEIR RELATIVE SAFETY WHEN APPLIED ON APPLE FOLIAGE AT A CONCENTRATION OF TWO PERCENT**

<table>
<thead>
<tr>
<th>Item</th>
<th>Type of Emulsion</th>
<th>Oil</th>
<th>Emulsifier</th>
<th>Additional Material</th>
<th>No. of Tests</th>
<th>Total</th>
<th>Cases of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stock</td>
<td>Technical White Oil</td>
<td>99</td>
<td>Inert</td>
<td>None</td>
<td>7</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>69</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Misc.*</td>
<td>8</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Nicotine</td>
<td>5</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Derris</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Pyrethrum</td>
<td>8</td>
<td>41</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Copper</td>
<td>7</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Sulphur</td>
<td>10</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Inert</td>
<td>Sodiumgluconate</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Stock</td>
<td>&quot;</td>
<td>99</td>
<td>Soap</td>
<td>None</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Miscible</td>
<td>&quot;</td>
<td>99</td>
<td>Soap</td>
<td>None</td>
<td>7</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Miscible</td>
<td>Paraffin</td>
<td>90</td>
<td>Soap</td>
<td>None</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>

*Petroleum compounds with nitrogen or oxygen, furfuramid, chinchona alkaloids.*
Table 2, cont'd.

<table>
<thead>
<tr>
<th>Item</th>
<th>Type of Emulsion</th>
<th>Composition</th>
<th>No. Formulae Tested</th>
<th>Cases of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oil</td>
<td>Unsulfonated Residue</td>
<td>Emulsifier</td>
</tr>
<tr>
<td>12</td>
<td>Experimental Miscible</td>
<td>Paraffin</td>
<td>91</td>
<td>Soap</td>
</tr>
<tr>
<td>13</td>
<td>Experimental Stocks</td>
<td>Paraffin</td>
<td>91</td>
<td>Soap</td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td>Soap</td>
</tr>
<tr>
<td>15</td>
<td>Water Control</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some of the recent work of deOng (1926), deOng, et al (1927), and Smith (1929, 1930 and 1931) has again raised the problem of applying oils to plants without the aid of an emulsifier or with only sufficient emulsifier to permit dispersion by agitation in the spray mixture. Such a method of application has several advantages over emulsions containing emulsifiers, as expressed by deOng and Knight (1925). It has been demonstrated that it is possible, with the proper machinery, to use oils without emulsifiers, but the construction of spray machinery now in operation will not warrant the general adoption of this method of applying oils to deciduous trees.

Some further evidence on the relation of saturation, the amount of emulsifier present in an oil, and oil droplet size is shown in Table 3. In Items 1 and 2, a technical white oil and a less saturated oil were applied without the aid of an emulsifier. The stability of such an emulsion was almost negative and the oil droplets so irregular and unstable that they were difficult to measure. The oil drops were very large and coalesced rapidly. Neither of these oils injured foliage at 1% percent concentration but the less saturated oil spotted the fruit of apple.

In Items 3, 4 and 5 a technical white oil was used that contained a product known as "butylacetyl resinoleate", 
which has been shown to impart to an oil the property of
dispersion in water with limited agitation. This material
was added to the oil at 2, 4 and 6 percent respectively, to
study the effect of this emulsifier on droplet size and
foliage injury. The range in oil droplet size does not
present a true picture of the condition existing in the
dilute sprays of these oils. Oil No.13740, Item 5, contains
many more small oil droplets than Oil No.13540, Item 3.
With each increase of this emulsifier there is a corresponding
reduction in the average oil droplet size. This reduction
in oil droplet size produced increased injury as is shown
in Items 3 to 5. None of these emulsions caused injury to
the fruit.

Stock emulsion No.200 was used in this experiment
as a comparison with the other emulsions. It contains a
technical white oil with an inert emulsifier, quick breaking
properties, and is relatively safe on apple foliage.

Soluble oils No.8300 and 8790 contain the same
ratio of emulsifier as soluble oil No.17 but are prepared
with 60 and 33 second viscosity white oils respectively. In
Items 7, 8 and 9 there was no marked difference between the
technical white oils and the less saturated oil in their
injury either to fruit or foliage when they were emulsified
with certain soaps.
Considering the graduation in the oil droplet size and stability, Items 1, 3, 5, and 8, all containing technical white oils, it is evident that the emulsions with the smaller oil droplets and greater stability are the more injurious to apple foliage. Similar differences are exhibited between Items 2 and 9, both of which contain oils with a lower sulfonation test.
Table 3

THE RELATION BETWEEN THE EMULSIFIER, DROPLET SIZE, SATURATION AND FOLIAGE INJURY TO APPLE. Sprays applied to foliage at one and one half percent concentration of oil in the water phase.

<table>
<thead>
<tr>
<th>Item</th>
<th>Oil Formulae</th>
<th>Oil Composition</th>
<th>Oil Sat.</th>
<th>Emulsifier</th>
<th>Stabilizer</th>
<th>Droplet Size</th>
<th>Injury to Foliage</th>
<th>and Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technical White Oil</td>
<td>Technical White Oil</td>
<td>83 99</td>
<td>None</td>
<td>None</td>
<td>4-24</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>2</td>
<td>Paraffin Oil</td>
<td>Paraffin Oil</td>
<td>104 91</td>
<td>None</td>
<td>None</td>
<td>4-24</td>
<td>None</td>
<td>Trace</td>
</tr>
<tr>
<td>3</td>
<td>13550 Technical White Oil</td>
<td>Technical White Oil</td>
<td>83 99</td>
<td>&quot;Bar&quot;</td>
<td>Very quick breaking</td>
<td>1-12</td>
<td>Trace</td>
<td>None</td>
</tr>
<tr>
<td>4</td>
<td>13720</td>
<td>83 99</td>
<td>&quot;Bar&quot;</td>
<td>1-12</td>
<td>Light</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>13740</td>
<td>83 99</td>
<td>&quot;Bar&quot;</td>
<td>1-12</td>
<td>Moderate</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Stock 200</td>
<td>83 99</td>
<td>Gum quick breaking</td>
<td>2-6</td>
<td>None</td>
<td>None</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Soluble oil 8800</td>
<td>60 99</td>
<td>Soap 15</td>
<td>1-8</td>
<td>Severe</td>
<td>Severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Soluble oil 8790</td>
<td>83 99</td>
<td>Soap 15</td>
<td>1-8</td>
<td>Severe</td>
<td>Severe</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Soluble oil 17</td>
<td>Paraffin Oil</td>
<td>83 91</td>
<td>Soap 15</td>
<td>1-6</td>
<td>Severe</td>
<td>Severe</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.0</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

"Bar", a material which, when added to an oil, permits dispersion of the oil into water by agitation.
INSECTICIDE TESTS WITH THE EMULSIONS

The Codling Moth, *Carpocapsa pomonella* Linn.

The codling moth is by far the most destructive insect encountered in the production of apples. The annual abundance of codling moth and the difficulty of securing an adequate control by the use of poison sprays have given this pest a role as limiting apple production, particularly in the sections where apples are grown commercially. In seasons of abundance the late brood larvae will destroy from 10 to 40 percent of the marketable fruit. This condition persists in orchards receiving six to twelve sprays of lead arsenate.

Arsenical sprays were first introduced against codling moth in recommendations by Cook (1880) and have continued to be the most satisfactory method of control provided a sufficient coating of spray is maintained on the fruit. The number of arsenical sprays applied has increased in many apple growing sections and as a result the harvested fruit carries residues of arsenic in excess of the legal tolerance.

This condition has forced either the development of more efficient arsenical sprays or the use of non-arsenical sprays that can be substituted as sprays for lead arsenate.
one percent. It should not be added to more than three or

sufficient test applied in a proportionately less than

having a saliva test of 65 to 75 seconds and a high

Response and results (1925) suggest the use of a peroxide test or double method of

amount will give 80 to 95 percent and in the tests there was

that of lead arsenate alone. In the tests a 7 to 8 percent

equal to that of all alone and a larger than twice value of

with lead arsenate the results are the same and arsenate

spalter and dean (1920) state that "when our results are compared

interests to the extent of 0.0024 percent with lead arsenate.

architects are in position to take advantage of the

With the development of adequate washing machinery.

The addition of potassium nitrite to lead arsenate experts.

spalter and dean (1920) found that with the nitrite and lead

of the arsenate experts for the first time in

1925, and reported results as applicable to the use of all

arsenate experts in the latest experiments for the first time in

Rouse and Denonport (1920) need an all emulsion and lead

sparyes of the first introduction with the lead arsenate experts

emulsions either as direct substitutes for lead arsenate.

The most prominent development has been the use of summer

-40-
four of the lead arsenate sprays and in those sprays that occur when the highest percentage of eggs are on the trees and fruit. This statement is in accord with the "Report of the Western Cooperative Oil Spray Project for 1932", Better Fruit (1932), and the Washington Experiment Station recommendations for 1932.

**White oil emulsions as a substitute for lead arsenate**

The development of highly saturated white oils emulsified with inert emulsifiers, offered the first oil sprays that could be used on foliage during the growing season. The safety of emulsions of this type has been demonstrated by deCnng (1926), English (1928), and Headlee, et al (1930). Results of Headlee, et al (1930), Flint (1930-1931), and Newcomer and Yothers (1932) have shown that emulsions for the full season, without the use of lead arsenate, cannot be used to control codling moth. There are several reasons for this situation:

1. Oil emulsions are primarily contact sprays and can not be applied sufficiently often to kill all hatched larvae without disturbing the physiological development of the fruit and tree.

2. The ovicidal effect of oils can be utilized only occasionally.
3. Summer oil sprays can not be used with the necessary fungicides early in the season.

4. Summer oils are too expensive when compared with lead arsenate sprays.

The larvicidal effect of an oil deposit is inferior to that given by lead arsenate, as is shown in the results of Flint and Farrar (1931), Lathrop and Sazama (1932) and Newcomer and Yothers (1932). Nevertheless, field tests conducted in many states where oil and lead arsenate sprays have been compared, all favor the limited use of oil sprays in the control of late brood codling moth larvae. In most cases the lead sprayed fruit has had less codling moth entrances than the oil sprayed fruit but without sufficient difference in the control to justify the use of lead arsenate in the late sprays in those orchards that are not equipped to wash the fruit. In this regard oil emulsions have served as a valuable aid to codling moth control during the period when growers have been reorganizing their methods of harvesting and packing of fruit.

The results of Spuler and Dean (1930), Headlee, et al (1930), Flint and Farrar (1931) and Tolbert and Swartwout (1931) indicate that oil emulsions can be substituted for lead arsenate in the late brood sprays. Oil sprays applied at this season do not produce the injurious effects on tree growth that is brought about when the same sprays are used earlier in the season.
Two to four applications of two percent oil emulsions have given protection in the late summer sprays.

The spray recommendations for most sections suggest the direct substitution of oil sprays in the place of the usual lead arsenate sprays. This has been done without regard for the most efficient use of oil sprays as ovicides on the codling moth eggs. Newcomer and Yothers (1932) found that from 80.0 to 97.6 percent of the eggs failed to hatch if sprayed with a two percent heavy oil emulsion and that 64.5 percent of the eggs did not hatch if laid within seven days after the application of an oil spray. The ovidical effect obtained from oil sprays will explain in many cases why the same oil spray has given variable results in succeeding years and in different orchards.

Field tests on the control of codling moth

Since 1927 orchard tests have been conducted to compare the efficiency of oil emulsion sprays with that of the lead arsenate sprays. The schedule followed for dates of spraying was that schedule recommended for the respective years 1928 to 1932 by the Illinois Agricultural Experiment Station. Close supervision of the application of the sprays insured a uniform covering in all of the experimental orchards. Experimental blocks of apples were made up of mature trees
from twenty-five to forty years of age. Each block contained twenty-five to thirty trees of the varieties Jonathan, Crimenes Golden, Staymen Winesap, or Ben Davis. The spray plots were conducted in duplicate or triplicate in each orchard.

When the fruit was ready for harvesting the performance of the individual sprays was graded by members of the entomology and horticulture staffs. These men, at the time they scored each plot, were unfamiliar with the spray treatment the plot had received. The four center trees of the plot furnished the fruit used in scoring spray performance. Apple pickers gathered the fruit from the inside quarters of these trees. A one-thousand apple sample was taken from this fruit as the sample to be graded in scoring the plot.

**White oil emulsions as a substitute for lead arsenate.**
The population of codling moth varied in the test orchards from light to extremely heavy, including in the five years of records representative orchards in the commercial apple growing sections of the state. A summary of five years of data is given in Table 4 and Figure 1. Item 1 can be used as a basis of comparison since this treatment conforms with the recommendations for the control of second and third brood codling moth larvae. Lead arsenate was applied at 2 pounds per 100 gallons in 1927, 1928, 1929, 1930, and at 4 pounds per 100 gallons in 1931. This change in 1931 gave lead arsenate an
advantage in 1931 as no change was made in the oil spray schedule. In Items 1 and 2 a direct comparison is shown between lead arsenate plus hydrated lime (1 pound of lead arsenate to 2 pounds of lime) and oil emulsion at 2 percent concentration. The results in 1927 were decidedly unfavorable to the oil sprayed plot. The years 1928 and 1930 showed 5 percent and 16 percent less entrances in the oil sprayed fruit. In 1929, 55 percent and in 1931, 18 percent more larvae entered the oil sprayed fruit. For the five year average, 19.5 percent more larvae entered the oil sprayed than the lead arsenate sprayed fruit.

Items 2 and 3 show the performance of two commercial white oil emulsions. The droplet size of these two oils is illustrated by photomicrographs, Figure 9, C and D. The oil droplet size in stock 200 is much larger. The emulsion contains 15.6 percent less oil, has a relatively low wetting property, and gives a very spotted type of covering. Commercial oil stock No. 5 has small oil droplets, high wetting, and leaves a smooth, even oil covering. If the protection given fruit from codling moth larvae and the safety to fruit and foliage be considered, the oil stock 200 is superior to the other oil emulsion for second brood codling moth control.

**White oil emulsions with pyrethrum and derris.** Poison plant extracts from pyrethrum flowers, tobacco, or derris root
combined or mixed with stock emulsion 200 have been given many field trials. Data covering the work with codling moth are given in Table 4, Items 4, 5 and 6. Emulsions containing extracts of derris and pyrethrum were found to be less toxic to codling moth larvae under field conditions than the non-impregnated emulsions. The exposure of either of the plant products to the action of sunlight and oxygen destroyed their activity toward insects, as is clearly demonstrated by laboratory tests. These same oil emulsions, when tested in the laboratory after a relatively short exposure to the air, consistently gave superior performance to non-impregnated emulsions when tested against codling moth larvae, Figure 2, Items 5 and 6.

**White oil emulsions with nicotine.** The use of nicotine with oil emulsions is finding a place in the oil spray program for second brood codling moth according to Herbert (1931). The field results with nicotine and oil sprays, Table 4, Item 5, show it to be equal or superior to lead arsenate. This is in line with the results of Herbert and Leonard (1929), Regan (1929, 1930), Leonard (1930), Spuler and Dean (1930) and Webster (1931).

The most favorable mixture of oil and nicotine has been that of summer oil emulsion at 1 percent concentration with nicotine sulphate in dilutions from 1-300 to 1-1600
parts. Free nicotine used in place of nicotine sulphate will give a somewhat quicker kill but is not as effective a mixture as is the oil with nicotine sulphate. The relative persistence of the two nicotine products has not been tested in the field under Illinois conditions. The 1932 report of the Western Cooperative Codling Moth Conference recommends oil and nicotine sprays as the most practical sprays for late brood codling moth larvae where lead arsenate cannot be used.

Figure 1 illustrates graphically the data given in Table 4. The relative control given by all of the sprays as compared with no spraying is striking, especially in the second and third brood. Certainly in seasons when the fruit is plentiful and prices are low the cost of second brood sprays must be low in order to justify their application.

All of the spray mixtures tested show a seasonal variation in their relative efficiency. When codling moth is abundant and the season favors its development, the number of larvae entering the fruit will increase in spite of consistent and careful spraying. This has led to the general conclusion as put forth by Headlee (1932) that spray materials and spraying alone will never give adequate control of this insect unless the population of moths can be kept within reasonable limits by the use of supplementary measures of control such as orchard sanitation and tree banding.
Table 4

CODLING MOTH CONTROL IN THE ORCHARD OVER A FIVE-YEAR PERIOD

Orchard tests were conducted in commercial orchards of western, central and southern Illinois. A test was a count made on 1,000 apples taken from the four center trees of a test block. The early season spray schedule for Items 1 to 7 was lead arsenate 3 to 4 pounds and hydrated lime 6 to 8 pounds per 100 gallons of spray, in the calyx and two or three cover sprays. In 1931, Item 1, the lead arsenate was increased to 4 pounds per hundred gallons in the late brood treatments. Nicotine, Item 5, was nicotine sulphate at 1/2 pint per hundred gallons.

<table>
<thead>
<tr>
<th>Item</th>
<th>Spray Treatment (for Second and Third Brood Larvae)</th>
<th>Total No. Field Tests</th>
<th>Average Percent</th>
<th>5 Yr. Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lead arsenate + lime 2-4-100</td>
<td>1271 2201 2901 3001 3101 1270 2201 2901 3001 3101 Tests</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2 percent oil emul. Stock 200</td>
<td>3 10 6 6 3 1.8 3.8 3.7 18.4 5.1 28 6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2 percent oil emul. Stock 5</td>
<td>1 5 3 6 10 14.0 3.2 6.0 15.9 6.2 25 8.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>2% oil emul. Stock 200 with pyrethrum</td>
<td>2 5 2 - - 15.9 3.3 17.2 - - 9 9.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>2% oil emul. Stock 200 with nicotine</td>
<td>- 1 2 6 7 - 0.3 3.3 10.5 5.1 16 6.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>2% oil emul. Stock 200 with derris</td>
<td>- 2 2 7 1 - 3.3 7.0 15.1 25.3 12 12.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Unsprayed second and third brood</td>
<td>- - - 1 4 0 - - 25.8 33.7 5 27.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Unsprayed all season</td>
<td>2 4 3 4 2 56.7 46.1 62.8 42.5 36.4 15 49.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A five-year (1927-1931) comparison of oil sprays for the control of second and third brood codling moth larvae under orchard conditions.
**Arsenical residues.** The Food and Drug Administration of the United States Department of Agriculture has devoted considerable attention to the residues remaining on fresh fruits and vegetable products offered for market. To conform with the residue standards of other nations purchasing American products, the Federal Government established for 1932 the arsenical residue tolerance of 0.01 grains of arsenic trioxide per pound of fruit that was offered for interstate shipment.

The fruit industry has recognized for some time the fact that fruit sprayed throughout the season, following the modern spray schedules for lead arsenate sprays, would not meet the residue requirements without cleaning. Machinery for cleaning fruit has been developed for the washing or brushing of the excess residues from the fruit. Washing machinery now in use will almost completely remove ordinary residues of arsenic. The added cost of the cleaning of fruit has stimulated the search for a suitable material that can be used as a substitute for lead arsenate.

The white oil emulsions or the emulsion used with nicotine in the late brood codling moth sprays have proven themselves to be the most satisfactory substitute for lead arsenate. In only a few unusual cases has fruit treated with either of these sprays for the late broods of codling moth
larvae, exceeded the present world tolerance of 0.01 grains. In the majority of the cases the residues have been well below this figure.

Table 5 illustrates some of the results obtained from the analysis of sprayed fruit taken from the experimental plots. In all cases, for the years 1928 to 1932, the fruit sprayed with oil emulsion has not exceeded the world tolerance. In all cases (excepting one in 1928) the fruit sprayed with lead arsenate has exceeded the tolerance of 0.01 grains per pound of fruit.
Table 5. The analyses of harvested fruit for arsenical residue from plots treated in the late brood codling moth sprays with two percent white oil emulsions or the recommended strengths of lead arsenate and hydrated lime. The legal tolerance for 1932 was 0.01 grains of arsenic trioxide per pound of fruit.

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Analyses*</th>
<th>Grains of arsenic trioxide per pound of fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Oil (Lead Arsenate)</td>
<td>Oil (Lead Arsenate)</td>
</tr>
<tr>
<td>1928</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>1929</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1930</td>
<td>19</td>
<td>4</td>
</tr>
<tr>
<td>1931</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>1932</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>14</td>
</tr>
<tr>
<td>Average Residues</td>
<td></td>
<td>0.0058</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0199</td>
</tr>
</tbody>
</table>

*Analyses by the United States Department of Agriculture, Food and Drug Administration, St. Louis, Mo.
Laboratory tests on the codling moth.

Standardized laboratory tests were used in making close comparisons between oil emulsions. Many combinations of insecticides were tried in the search for the improvement in the killing power of oil sprays. The white oil stock emulsion 200 served as a basis of comparison for oil emulsions. This formula contains 64.4 percent of a technical white oil of 83 seconds of viscosity with an inert emulsifier. Such ingredients were varied in this formula as were thought might possibly influence its toxicity. In the series of emulsions tested the oil droplet size varied from one to twelve microns in diameter. Where the oil droplet size was not disturbed by changes within the emulsion or by the addition of chemicals to the emulsion, the size remained relatively constant between one and six microns, averaging about four microns, Figure 9, C. The greater number of emulsions tested did not depart far in oil droplet size or in other physical properties from those exhibited by oil emulsion stock 200. The emulsions were all diluted with tap water to a two percent concentration by volume and applied at once to test apples by the standardized methods described below.

Laboratory technique. The method used in rearing codling moth larvae for larvicidal tests was described by Farrar and Flint (1930). Refinements of technique for handling the
apples and the larvae are here briefly discussed. The method of applying the spray to the fruit was standardized as to distribution, time and pressure. Twenty-four hours after spraying each apple was infested with ten newly hatched larvae and then placed in a control chamber maintaining a temperature of 80°F. and a relative humidity of 65-70 percent. This set of conditions was found to be optimal for the entrance of codling moth larvae into untreated fruit. The infested fruit was kept under controlled conditions for twenty-four hours and then placed under laboratory conditions until it was checked for larval entrances. Three apples with a total of thirty larvae were considered a series and a check apple with ten larvae was included with every two series.

Seven series of tests were always conducted with a single emulsion. In the total test a material thus received twenty-one or more trials in which two hundred and ten codling moth larvae were given opportunity to enter the sprayed fruit. Because of the natural variation of larval vitality, it was found advisable to conduct on a material the seven smaller tests of three apples each over a period of days before evaluating its relative efficiency, rather than to make a large single test.
Scoring of treated and untreated fruit was done five days after infestation. All data obtained were calculated against the number of larvae entering untreated fruit. The relative efficiency for each emulsion has been calculated on the basis of the control given by the untreated fruit.

For the purpose of discussion the emulsions that are related in certain ingredients are grouped together, as shown in Table 6. Each group is arranged in the order of its respective efficiency against codling moth larvae. Figure 2 is a graphical illustration of the exact performance of each material tested. A point in this graph represents the results of a laboratory test on a respective emulsion. The outer extremes of the related formulae are connected with a heavy line to bring out the extent of variation in the control given by this group of emulsions. For clearness, Table 6 and Figure 2 will be discussed together.

**White oil emulsions.** The property of an emulsion can be altered by changing the viscosity of the oil. The average efficiency given by 15 changes in viscosity was 34.2 percent. The changes included cover the entire range in oil viscosities suitable for tree spray oils. This control is only 2.2 percent greater than that given by the 53 second oil which is the same as commercial oil stock 200. The total range in the results by changes of viscosities alone is not much greater
than that exhibited by the commercial white oil emulsions. Laboratory data, Figure 2, Item 2, would indicate that oil viscosities under 33 seconds are not as satisfactory as the higher viscosity oils for the killing of codling moth larvae.

The most efficient white oil emulsions were obtained by varying the concentration or type of emulsifier. The most efficient emulsion contained the emulsifier "Goulac", lignin pitch, a by-product of the paper industry, according to Hurt (1931). Physically this emulsion has undesirable properties. It is relatively unstable, has large irregular oil droplets and the concentrate tends to jell on standing.

The amount of emulsifier included in an emulsion will determine within certain limits the type of emulsion that will be formed. When the percent of emulsifier to the oil and water phases is reduced the size of the oil droplets tends to become larger. In the cases of the emulsions shown in Figure 2, Item 3, where the gum emulsifier was greatly reduced, the emulsion formed was stiff, had larger oil droplets and was more difficult to dilute than was the oil emulsion No. 200, Item 1. Although the physical change brought about by the reduction of emulsifier resulted in a somewhat higher kill of codling moth larvae, the physical characteristics of the emulsion made it impractical.
In general, under laboratory conditions the only
Superscripted by examining and testing the components of the
experiments, the component of the
were calculated. Ten separate experiments were
performed with the most exposed component with the
tissue of the testion of the Z pounds per
experiments, 1-7 pounds per
section of the testion of the

The results obtained with the components of the testion showed
that they were
properties, including the poor condition of the
drops. The results obtained with the components of the testion showed
that they were
The results obtained with the components of the testion showed
that they were
Item 5.

The addition of fungicides to pyrethrum emulsions reduced their average efficiency 21 percent. Furfural and beta naphthol did not reduce the kill as greatly as did copper soap, furfuramide, copper Bordeaux or sulphur, Table 6, Item 4; Figure 2, Item 6.

**White oil emulsions plus nicotine.** Oil emulsions with nicotine produced the second most efficient codling moth spray, Table 6, Item 2, Figure 2, Item 7. The seven formulae tested averaged ten percent less efficient than the pyrethrum sprays, although the range in control shown by the oil nicotine sprays is greater than for pyrethrum sprays. All sprays of oil emulsion with nicotine were more efficient than white oil emulsions alone. The use of oil emulsion-nicotine sprays in the field has shown the residue to be as toxic and nearly as persistent for codling moth larvae under field conditions as that of lead arsenate. Oil emulsions containing nicotine are the only mixtures of oil and a plant poison that have withstood exposure to weather approximate to lead arsenate.

**White oil emulsions plus derris.** The derris extracts act more slowly and are more stable to oxidation than are the pyrethrum extracts. It was with the hope of finding a more stable insecticide than pyrethrum that derris was tried
Figure 5. Each material is plotted separately in the order of relative absorbance which makes the Grünberg arrangement. In the materials measured, there are not all the components introduced in the most sensitive ones, so the study. The materials studied under the most sensitive groups 2 and 3 do not show a test under the most sensitive groups as an intense test with all the other materials offered. The intensity order than the expected of the plant positions within between 120 and 200 degrees Fahrenheit. The is the only nitrogenous base used in the tests have a boiling range. The tests a substance called pertronon nitrogenous base. The intensity under the most sensitive groups 1, Table 6, Item 7, is.

MATERIAL: Table 6, Item 7, Figure 2, Item 9.
Understandable properties which do not make them practical.
Leaves that can white out the test were put on the combination and are more possible to the most sensitive with all the materials and the the leaves all sensitive that are offer intense test.

The results obtained with the materials measured are not a dependent group when compared.
Analyze the very test of the test by the Grünberg arrangement; the very test is shown to be wide by the Grünberg arrangement; the very test according to the lower to the other components and the test test of the test. The results of the test were determined to those components present in the laboratory and test test. The results of the test.
its relative efficiency.

Laboratory tests with lead arsenate. Two pounds of lead arsenate plus four pounds of hydrated lime killed codling moth larvae in the laboratory as efficiently as it did in the field. It is of interest to note that with the most uniform coating obtainable with lead arsenate on apples, the efficiency of this spray over unsprayed apples was only 36.3 percent. This means that relatively 63.7 percent of the larvae penetrated a coating of lead arsenate and gained entrance to the fruit. The highest control with lead arsenate was 88 percent or identical in control with the average efficiency for the pyrethrum impregnated emulsions, Table 6, Item 10, Figure 2, Item 11.
Table 6
THE LARVICIDAL EFFICIENCY OF OIL SPRAYS TESTED IN THE LABORATORY AGAINST NEWLY HATCHED COOLING MOSH LARVAE

<table>
<thead>
<tr>
<th>Item</th>
<th>Type of Spray Tested</th>
<th>Formulae Variations. Materials added to oil stock or dilute spray</th>
<th>No.of Formulae Tested</th>
<th>Average Relative Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>White oil formula</td>
<td>Pyrethrum products. Viscosities 40 to 150 seconds</td>
<td>10</td>
<td>87.8</td>
</tr>
<tr>
<td>2</td>
<td>White oil formula</td>
<td>Nicotine products</td>
<td>7</td>
<td>77.6</td>
</tr>
<tr>
<td>3</td>
<td>White oil formula</td>
<td>Miscellaneous Group I*</td>
<td>4</td>
<td>68.7</td>
</tr>
<tr>
<td>4</td>
<td>White oil formula</td>
<td>A pyrethrum product plus 6 types of fungicides</td>
<td>10</td>
<td>66.6</td>
</tr>
<tr>
<td>5</td>
<td>White oil formula</td>
<td>Derris products</td>
<td>14</td>
<td>58.8</td>
</tr>
<tr>
<td>6</td>
<td>White oil formula</td>
<td>Four inert emulsifier combinations</td>
<td>4</td>
<td>58.5</td>
</tr>
<tr>
<td>7</td>
<td>White oil formula</td>
<td>10 percent fluosilicates</td>
<td>3</td>
<td>47.0</td>
</tr>
<tr>
<td>8</td>
<td>White oil formula</td>
<td>Miscellaneous Group II**</td>
<td>6</td>
<td>45.7</td>
</tr>
<tr>
<td>9</td>
<td>Commercial white oil stock</td>
<td></td>
<td></td>
<td>36.3</td>
</tr>
<tr>
<td>10</td>
<td>Arsenate of lead</td>
<td>Hydrated lime 4-100</td>
<td>3</td>
<td>36.3</td>
</tr>
<tr>
<td>11</td>
<td>White oil formula</td>
<td>Viscosity variations from 40 to 200 seconds</td>
<td>15</td>
<td>34.2</td>
</tr>
<tr>
<td>12</td>
<td>White oil formula</td>
<td>Five types of fungicides</td>
<td>8</td>
<td>33.6</td>
</tr>
<tr>
<td>13</td>
<td>White oil formula</td>
<td>Miscellaneous Group III***</td>
<td>6</td>
<td>25.0</td>
</tr>
<tr>
<td>14</td>
<td>Control</td>
<td>Water</td>
<td>1</td>
<td>0.0</td>
</tr>
</tbody>
</table>

(Table continued on page 63)
Footnote:

*Miscellaneous Group I—1% low boiling nitrogenous bases,
5% cresylic acid
1% high boiling nitrogenous bases
1% high and low (composite)
        nitrogenous bases.

**Miscellaneous Group II—1% dark cresylic acid
5% straw cresylic acid
1% "Penetrol"
5% Salol
1% tar acid oil
5% Alcetate
5% Soluble pine oil

***Miscellaneous Group III—An oxidized oil base,
1% cresylic acid
1% Salol
10% Waste sulphite liquor
4% Lethane
5% soluble pine oil

(The above groups are for convenience in evaluation
and do not necessarily contain chemically related
formulae.)
Figure 2. The relative efficiency of technical white oil sprays as tested against newly hatched codling moth larvae. Each point on the graph represents the average efficiency of a formula for a laboratory series.
Red Spider, *Tetranychus* sp.

**Field tests of white oil emulsions on conifers.**

Conifers are often attacked by red spiders to such an extent that the younger trees are killed. Where the mites are not sufficiently abundant to actually kill the trees, they so destroy the chlorophyll in the tissues that the trees appear brown. Many of the needles become dry and drop off leaving the tree very unsightly.

In general, it has not been considered safe to apply oil sprays to the foliage of conifers in the summer months or after growth has started. Conifer foliage is more sensitive to oil than deciduous foliage. This does not mean that oil sprays can not be prepared that will be relatively safe on conifers, particularly the more resistant varieties such as juniper, pine, arbor-vitae and some forms of spruce. In the course of this project field tests were carried on each year to determine the effect of certain oils on conifer foliage. In Table 7 a summary of these tests is given wherein several facts are brought out regarding foliage tolerance and red spider control. Oil stock 200 gave the best control of red spider of any of the materials tested. This control can be largely attributed to the type of coating given by this oil as stock 200 does not wet conifer foliage but adheres in the
form of drops. When this type of emulsion dries the oil is deposited in tiny spots over the surface rather than in a film, as is deposited by commercial oil stock No. 5. This irregular type of coating reduces the danger of injury of foliage and leaves the oil spots scattered over the surface to entangle the red spiders as they crawl about the needles. The immediate kill of the red spider by oil stock 200 is not apparent, but its residual effect gives the most satisfactory control of any emulsion tested. The addition of a material to this oil emulsion to give it higher wetting properties did not cause foliage injury but did reduce the protection afforded against red spider.

In two cases oil stock 6990 gave very severe injury, possibly because of its low viscosity and rapid penetration. Oil stock emulsions 5220 and 5230 were not as persistent as oil stock 200 and did not control red spider. This relation between persistence and control of red spider is in accord with the findings of deOng (1930). Neither oil 5220 or 5230 caused injury to conifer foliage.

The tolerance of conifers to oils depends on the species of the trees, the season of the year, concentration, saturation and viscosity of the oil, and the wetting power of the dilute spray. Sprays with high wetting power are more toxic to foliage than sprays without this property. This
excludes the use of oils with soap emulsifiers, such as miscible oils and inert emulsified oils with high wetting power. All oils should be of technical white grade and have a viscosity greater than 60 seconds and less than 100 seconds Saybolt. The concentration of the spray should be as low as will control the pest involved. The technical white oils, properly emulsified, may be applied with relative safety at any time of the year except in extremely hot weather. Care should be taken in applying oil sprays to blue spruce, compact arbor-vitae and all new plantings. The drenching of conifer foliage with oil sprays should be avoided. Pines and junipers will tolerate one or more applications of 1 to 2 percent oil emulsion, spruce, arbor-vitae, and similar tender species from 0.5 to 1.0 percent oil emulsion. One, or at most two applications of the proper oil emulsion have given excellent protection for the season against the common red spiders attacking evergreens.

Field tests of white oil emulsions on raspberries.

Oil emulsions have been tested on raspberries for two seasons. In these tests one to three applications of stock oil No.200 at one percent concentration gave excellent control of red spider without injury to the foliage. The sprays were applied with a power sprayer at a pressure of
two-hundred pounds. It was necessary to use care to
wet thoroughly all of the leaves on their under-surfaces for
satisfactory results. For this purpose a short rod carrying
three fine nozzles turned upward permitted excellent spraying
from the under side. Stock oils 5220 and 5230 did not injure
the foliage but failed to control the mites. The low viscosity
of these oils, 40 and 60 seconds respectively, would suggest
that they penetrated the tissues readily and did not leave a
persistent oil film to entangle the crawling spiders.

Favorable results with oils on red spider are
reported by Vinal (1917) on cucumbers, Newcomer and Yothers
(1927) on fruit trees, Whitcomb and Guba (1928) on cucumbers,
and Compton (1931) on greenhouse crops. Yothers and Mason
(1930) had unfavorable results in controlling the egg stage
of the citrus rust mite, Phyllocopites oleivorus Ashm. by the
use of oil sprays.
Table 7  
DEGREE OF SAFETY AND RED SPIDER CONTROL FOR OIL EMULSIONS ON THE FOLIAGE OF CONIFERS

<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae Oil No.</th>
<th>Properties</th>
<th>Oil Droplet Size Microns</th>
<th>Degree of red spider concentration to foliage at percent conc.</th>
<th>No. of tests*</th>
<th>Experimental degree safety to foliage at percent conc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6990</td>
<td>32 Gum</td>
<td>Low</td>
<td>1-5 Low</td>
<td>5</td>
<td>60 100</td>
</tr>
<tr>
<td>2</td>
<td>5220</td>
<td>40 Gum</td>
<td>Low</td>
<td>1-5 Low</td>
<td>1 4 1</td>
<td>100 100 100</td>
</tr>
<tr>
<td>3</td>
<td>5230</td>
<td>60 Gum</td>
<td>Low</td>
<td>1-5 Low</td>
<td>1 4 1</td>
<td>100 100 100</td>
</tr>
<tr>
<td>4</td>
<td>200</td>
<td>83 Gum</td>
<td>Low</td>
<td>1-5 High</td>
<td>1 17 5</td>
<td>100 94 80</td>
</tr>
<tr>
<td>5</td>
<td>200 + Blood**</td>
<td>83 Gum</td>
<td>High</td>
<td>1-5 Low</td>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>Commercial</td>
<td>- Inert</td>
<td>High</td>
<td>1-3 Medium</td>
<td>18 3</td>
<td>100 75 0</td>
</tr>
<tr>
<td>7</td>
<td>Control</td>
<td>- Water</td>
<td>-</td>
<td>None</td>
<td>17 17 17</td>
<td>100 100 100</td>
</tr>
</tbody>
</table>

*Field test blocks contained several species of conifers and 50 to 3,000 individual trees.

**Blood is a powdered residue sold as blood albumen, a by-product of the meat industry. It has about four times the wetting power of sodium oleate.
The data were
The proper concentration will depend on the properties
according to Ackerman (1927) and others, of at least 1926, 1957.
Agents will be required to give a satisfactorily complete or complete
according to most workers, at least 2 percent
exposure adequate to a number of insects other than those.
Chemical treatments necessary in an emulsion for the
control of this insect have demonstrated the physical and
emulsion a visible state of control. The work done in the
form fumes or contact that are toxic to these had made on
access to the existence. The ability of all supplies to
necessary that any insecticide, to be effective, must gain
the mutual protection afforded by the scale.

(1926)

according to Ackerman (1927) and others, of at
destruction of many crops by this scale from 1925 to 1927
all emulsions for this insect forming the compound
of control measures. Great importance was then to the study of
control of scale if has received much attention in the development of
about 1927. Because of the wide distribution of can be done
emulsions have been used extensively since

Avard-Petrunoff, Com.
San Jose Scale, Compsedaphis perniciosus

-70-
calculated according to the formula of Abbott (1925). Abbott (1926) found that mortality counts on San Jose scale made thirty days after the treatment by sprays gave accurate indices of performances. In these tests, the mortality counts were made from four to six weeks after the oil spray treatments were applied.

Soluble oils Nos. 16 and 90 contain the same amount of emulsifier, but oil No. 16 contains a highly saturated white oil. This emulsion is less stable than the emulsion containing the unsaturated oil, Figure 6, B and C. The effect of saturation on the stability of soluble Oil No. 16 is reflected in the difference between these two emulsions in the mortality of scale. The less stable soluble oil 16 is the more toxic.

Emulsions containing oils of 32 seconds of viscosity are not sufficiently persistent to give a satisfactory control of San Jose scale. The effect of the ratio of emulsifier to the oil phase is demonstrated in this series of low viscosity oils. Soluble oil No. 49 contains a high ratio of emulsifier to the oil and is less toxic than soluble oil No. 48 in which the amount of emulsifier is reduced. Soluble Oil No. 47 is intermediate between the other two emulsions in the ratio of emulsifier and the toxicity to scale, Figure 5, C and D.
A comparison of Items 1 to 3 with Items 4 to 7 shows decided superiority for the 33 second viscosity emulsions. Viscosity and not stability is the dominant factor in this comparison between soluble oils Nos. 47, 48 and 49 are all less stable than the 33 second viscosity emulsions even though the lighter emulsions contain the same emulsifier in greater quantity.

DeOng and Knight (1925) found as they decreased the amount of soap emulsifier used in relation to the volume of oil, "the results showed a progressive increase of kill as the amount of soap was decreased, but with the least amount of soap used, namely one percent, there was not a complete kill of the scales." DeOng (1926) gave additional data substantiating this principle. Soluble oils Nos. 90, 22 and 17, Items 5, 6 and 7 demonstrate the effect of the ratio of the emulsifier and oil on droplet size, breaking, and toxicity to San Jose scale. Soluble Oil No. 90 contains the most emulsifier, has smaller oil droplets and lower efficiency than either of the oils Nos. 22 and 17. Soluble oil No. 17 possesses the correct balance between oil and emulsifier. It is an emulsion with relatively large oil droplets, quick breaking, and a superior kill of San Jose scale.

Soluble oils Nos. 16 and 17 have a similar stability and compare favorably with one another in toxicity to San
Jose scale. It is evident from these data that efficiency is influenced by viscosity, saturation, and oil droplet size. These variations give to an emulsion certain properties that in turn influence the degree of control which the emulsion will give against San Jose scale.
### Table 8

THE RELATION BETWEEN VISCOSITY, SATURATION, RATIO OF EMULSIFIER, AND DROPLET SIZE, FOR MISCELLABLE OIL SPRAYS TESTED ON SAN JOSE SCALE

<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae Oil No.</th>
<th>Composition*</th>
<th>Oil Ratio of Emulsifier</th>
<th>Emulsifier Size to Oil (Microns)</th>
<th>No. Tests** at Percent Concentration</th>
<th>Relative Efficiency at Percent Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soluble oil 49</td>
<td>32 100 Na. oleate 1-1.5 1-5</td>
<td>1 1</td>
<td>37.6 45.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Soluble oil 47</td>
<td>32 100 Na. oleate 1-4.0 1-11</td>
<td>1 1</td>
<td>46.5 63.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Soluble oil 48</td>
<td>32 100 Na. oleate 1-5.6 1-20</td>
<td>1 1</td>
<td>44.7 83.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Soluble oil 16</td>
<td>33 100 Na.Pet. Soap 1-6.7 1-6</td>
<td>1 1</td>
<td>93.1 100.0 99.7 99.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Soluble oil 17</td>
<td>33 91 Na.Pet. Soap 1-6.7 1-3</td>
<td>1 1 4 1</td>
<td>57.1 87.5 91.8 99.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Soluble oil 22</td>
<td>33 91 Na.Pet. Soap 1-8.0 1-5</td>
<td>1 7</td>
<td>82.6 96.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Soluble oil 17</td>
<td>33 91 Na.Pet. Soap 1-9.0 1-6</td>
<td>1 3 7 4 2</td>
<td>91.2 94.0 97.4 98.8 97.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Control (Water) Scale 33.3 percent alive</td>
<td>5 5 5 5 5</td>
<td>0 0 0 0 0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Items 1 to 4 contain technical white oil; Items 5 to 7 contain paraffin oils.

**A test is a field series in which 1,000 to 4,000 overwintering scales were counted. Data includes six years' results.
The physical properties of proprietary emulsions tested against San Jose scale with their respective controls are shown in Table 9. Certain relationships are lacking but those most influential in control of scale are included. Soluble oils Nos. 1, 2, 17, Items 1, 2 and 3, are typical of soluble oils marketed in Illinois for dormant spraying of fruit trees.

Soluble oil No. 2 with an oil of 47 seconds of viscosity is inferior to soluble oil No. 1 containing a 350 second oil. The oil droplet size is not greatly different in these two emulsions. Soluble oil No. 17 has a lower ratio of emulsifier to the oil than the other soluble oils and is a quicker breaking emulsion. This oil is consistently superior to the others in its control of scale.

Boiled fish oil soap emulsions were as efficient against San Jose scale as was soluble Oil No. 17. Both of the boiled emulsions, Items 4 and 5, have larger oil droplets and somewhat quicker breaking qualities than soluble oil No. 17, Figure 8-A; Figure 5-B. Emulsions prepared on the "Government Formula"* contain one-half as much soap emulsifier and considerably more water than does the "Illinois formula".**

*Government formula: Potash-fish-oil soap-1 pound
Water-----------------2 quarts
Light grade lubricating oil-1 gallon

**Illinois formula: Potash-fish-oil soap-1-2 pounds
Water-----------------1 quart
Light grade lubricating oil-1 gallon
This condition imparts to the "Government Formula" a slightly larger oil droplet size and quicker breaking qualities.

There are certain sections in Illinois orchard areas where the extremely hard water will prevent this formula from emulsifying properly. For this reason the "Illinois Formula" is recommended and used. This emulsion contains sufficient soap to permit emulsification in most Illinois waters. Both of these emulsions contain about one-third of their volume in water and soap and are therefore recommended for use at a concentration of 3 percent which places them on about a comparable oil basis with a soluble oil at 2 percent concentration. When boiled soap emulsions are tested and compared with miscible oils on their oil basis they are as effective in their kill of scale as the soluble oils. This is in accord with the findings of Ackerman (1923), Davis (1924), Chandler et al (1926), English (1928) and Swingle and Snapp (1931).

Stock emulsions Nos. 5 and 8, Items 6 and 7, are emulsions containing inert emulsifiers. In both, the ratio of emulsifier to the oil is sufficiently low to impart quick breaking properties as shown by their respective oil droplet size. The control of San Jose scale exhibited by these emulsions is comparable with the quick breaking soluble oils and boiled fish oil soap emulsions.
Factors other than insecticidal efficiency have entered into the public acceptance of the several commercial emulsions. Many of those who have made and used the boiled fish oil soap emulsions will continue to do so, but there is an increasing trend toward the commercially prepared quick breaking soluble oils. This has come about from the relatively low cost of soluble oils, the ease with which they can be stored and diluted, and the uniform performance given by such oils as soluble oil No.17 in the control of San Jose scale.
### Table 9

**THE RELATION BETWEEN VISCOSITY, SATURATION, RATIO OF EMULSIFIER AND OIL DROplet SIZE FOR COMMERCIAL OIL SPRAYS TESTED AGAINST SAN JOSE SCALE**

<table>
<thead>
<tr>
<th>Item</th>
<th>Commercial Oil No.</th>
<th>Composition*</th>
<th>Ave.Range Oil Droplet Size in Microns</th>
<th>No. Tests** at</th>
<th>Relative Efficiency at Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soluble Oil 2</td>
<td>47 Soap</td>
<td>High 1-3</td>
<td>1</td>
<td>52.6 94.5 88.5</td>
</tr>
<tr>
<td>2</td>
<td>Soluble Oil 1</td>
<td>350 Soap</td>
<td>High 1-3</td>
<td>2</td>
<td>99.0 89.2 99.0 93.7</td>
</tr>
<tr>
<td>3</td>
<td>Soluble Oil 17</td>
<td>83 Soap</td>
<td>Low 2.5-3.5</td>
<td>1</td>
<td>91.2 94.0 97.4 98.6 97.0</td>
</tr>
<tr>
<td>4</td>
<td>Gov. Fo. BFOS</td>
<td>104 K. Fish</td>
<td>Low 3-4</td>
<td>1</td>
<td>91.1 98.4 95.9 100.0 98.5</td>
</tr>
<tr>
<td>5</td>
<td>Ill. Fo. BFOS</td>
<td>104 Soap</td>
<td>Low 2-3</td>
<td>1</td>
<td>95.4</td>
</tr>
<tr>
<td>6</td>
<td>Stock No. 59</td>
<td>80 Inert</td>
<td>Low 2.5-4.5</td>
<td>1</td>
<td>88.9 97.0 95.5 99.9 99.0</td>
</tr>
<tr>
<td>7</td>
<td>Stock No. 8</td>
<td>- Gum</td>
<td>Low 1.0-6.0</td>
<td>2</td>
<td>98.9 98.2</td>
</tr>
<tr>
<td>8</td>
<td>Control (Water)</td>
<td>Live scale 33.3 percent</td>
<td>5 5 5 5 0 0 0 0</td>
<td>0 0 0 0 0 0 0 0 0 0</td>
<td></td>
</tr>
</tbody>
</table>

*Item 6 contains a technical white oil.
Items 1 to 5 and Item 7 are paraffin oils.

**A test is a field series in which 1,000 overwintering scales are counted. Data includes six years' results.
Aphids, *Hysteroneura setariae* Thos., *Aphis pomi* De G. and *Aphis spiriacola* Patch

English (1928) found that "an emulsion in order to be effective against aphids must have 'high wetting' ability coupled with instability. Either of these factors may vary so as to be dominant. A relatively 'poor wetting' unstable emulsion may be more effective on aphids than a 'good wetting' stable emulsion. If the stability of two emulsions is about the same, then the one with the greater wetting ability is the more effective on aphids."

Griffin, et al (1927) found that "under conditions of comparable concentrations and type of oil, miscible oils are probably less toxic to insects than the ordinary soap emulsions, because they contain smaller oil droplets and the oil therefore adheres to the plant and (no doubt to the insect) less effectively."

Data given in Table 10 include the factors of wetting, quick breaking and droplet size. The miscible oils in Items 1, 2 and 3 contain the same oil and emulsifier as in Item 4, but are combined with their emulsifier in concentrations that give them entirely different physical properties. Soluble oil No.18, Figure 6-A is heavily emulsified and the oil droplets are so small that they are hardly visible under high
magnification. This emulsion has as high wetting properties as does the emulsifier in Item 4. The emulsion is extremely stable and gives a mortality of aphids comparable with the emulsifier. In soluble oil No.90, Figure 6-B the emulsifier has been reduced to give a quick breaking emulsion and a higher mortality of aphids. In soluble oil No.17, Figure 5-B the emulsifier has been reduced over that of soluble oil No. 90 with a still greater efficiency against aphids. This oil exemplifies about the maximum killing power obtainable with a miscible oil that is sufficiently stable to be marketed commercially. In all of the tests the toxicity to aphids is greater at the lower concentrations of the emulsions or the emulsifier. This condition illustrates the principle that excess wetting causes a "runoff" of the spray material and a reduction in the kill of some contact insecticides.
Table 10

RELATION BETWEEN OIL DROPLET SIZE OF A MISCELLAGE OIL AND ITS INSECTICIDAL EFFICIENCY AS TESTED AGAINST APHIDS

<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae</th>
<th>Oil</th>
<th>Visc.</th>
<th>Emulsi-</th>
<th>Ratio</th>
<th>Oil Droplet (1000 aphids)</th>
<th>Efficiency at percent</th>
<th>No. of tests</th>
<th>Relation of Percent Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Microns concentration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Sol. oil 18 Paraffin 83</td>
<td>Soap 15</td>
<td>1-2.6</td>
<td>&lt;1-3</td>
<td></td>
<td>0.5 1.0 2.0</td>
<td>96.5 89.4 80.6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Sol. oil 90 Paraffin 83</td>
<td>Soap 15</td>
<td>1-6.7</td>
<td>1-3</td>
<td></td>
<td>0.5 1.0 2.0</td>
<td>96.0 80.3 95.5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Sol. oil 17 Paraffin 83</td>
<td>Soap 15</td>
<td>1-9.0</td>
<td>1-6</td>
<td></td>
<td>0.5 1.0 2.0</td>
<td>98.0 90.0 98.0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Soap 15</td>
<td>-</td>
<td>Ma.Pet.</td>
<td>Soap</td>
<td>-</td>
<td></td>
<td>98.0 82.3 81.7</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Control (Water)</td>
<td>50</td>
<td>50</td>
<td>9.3</td>
<td>9.3</td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*H. setariae, A. pomi, A. spiracola.*
Table 11 includes the results obtained with five commercial emulsions that have a wide range of physical properties. The killing power of these emulsions at concentrations of 1/2, 1 and 2 percent is in line with Table 10, where the mortality was highest at a one-half percent concentration, lowest at 1 percent, increasing again at 2 percent. This effect is produced by the volume and concentration of spray material adhering to the bodies of the insects. The physical properties of wetting and stability of each emulsion determine to a large extent these factors. The effect of the wetting properties of emulsions on their efficiency can be illustrated by comparing Stock Oils Nos. 5 and 4. Stock Oil No.5, Item 1, Figure 9-D, contains an inert emulsifier and has quick breaking properties. It is less effective than Stock Oil No.4, Figure 8-A, which contains a soap emulsifier and has higher wetting and quicker breaking properties.

Soluble Oil No.17, Figure 5-B combines the property of higher wetting than the former emulsions with almost as good breaking properties. This emulsion gives the maximum kill of the commercial emulsions. "Illinois formulae" of boiled fish oil soap emulsion contains an excess of soap necessary for emulsification in hard waters. This excess soap gives to this emulsion very high wetting which offsets its advantages of larger droplet size and quicker breaking
properties. Soluble oil No.1, Figure 3-B is both high wetting and slow breaking, a combination of properties which would seldom give a satisfactory control of aphids at comparable concentrations.
Table 11

RELATION BETWEEN DROPLET SIZE AND INSECTICIDAL EFFICIENCY
OF COMMERCIAL OILS TESTED AGAINST APHIDS*

About 1000 aphids were used in each test.

<table>
<thead>
<tr>
<th>Commercial Oil No.</th>
<th>Composition</th>
<th>Wettability</th>
<th>Oil Drop Size</th>
<th>No. of Tests</th>
<th>Relative Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>At Percent</td>
<td></td>
<td>at Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Size in Microns</td>
<td></td>
<td>Concentration</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.5</td>
<td>1.0</td>
<td>2.0</td>
</tr>
<tr>
<td>1 Stock 5</td>
<td>Petroleum</td>
<td>60</td>
<td>Inert</td>
<td>Low</td>
<td>1-6</td>
</tr>
<tr>
<td>2 Stock 4</td>
<td>Paraffin</td>
<td>-</td>
<td>Soap</td>
<td>Low</td>
<td>1-21</td>
</tr>
<tr>
<td>3 Soluble Oil No.17</td>
<td>Paraffin</td>
<td>83</td>
<td>Soap</td>
<td>Medium</td>
<td>1-6</td>
</tr>
<tr>
<td>4 Illinois Formula</td>
<td>Paraffin</td>
<td>104</td>
<td>Soap</td>
<td>High</td>
<td>3-8</td>
</tr>
<tr>
<td>5 Soluble Oil No.1</td>
<td>Paraffin</td>
<td>350</td>
<td>Soap</td>
<td>High</td>
<td>1-4</td>
</tr>
<tr>
<td>6 Control (water)</td>
<td>-</td>
<td>-</td>
<td>Low</td>
<td>-</td>
<td>50</td>
</tr>
</tbody>
</table>

*H. setariae, A. pomi, A. spiracola.
The addition of soap with increased the stickiness of the
emulsion to be used with soap at the time of application.

For the reason that the more practical

concentrations of a stock emulsion, especially in the

emulsion and nurse the solution both tend to reduce the

attracted wall of the emulsion to some extent.

Then that be even by the emulsion to some extent to the

stickiness of a stock emulsion, as in Item 6, the most

appropriate and the stock emulsion to give no increased

of soap is added to the stock emulsion and not to the

very stickiness of the emulsion. When one-fourth of a

percent such a concentration makes a concentration that is

the concentration when the need in proportion of not more than

free not only is compatible with the emulsion in

stock emulsion when incorporated with it as a concentration.

Toxicty of this increased in the emulsion for increased

may be added to the stock emulsion to give 25 percent over the use of

emulsion alone, and 50 percent over soap alone. A soap

increased the stickiness of stock emulsion no. 50, Item 7.

The addition of one-fourth percent of soap, Table

-65-
of an oil containing such extracts, Item 6, but not sufficiently so as to warrant the added cost of the extracts.

Sulphur (from one to five percent), petroleum nitrogenous bases, chinchona alkaloid salts, or pine oil did not increase the toxicity of the oil emulsions to aphids.

Nicotine added to either the stock emulsion or the diluted spray was the only really efficient spray for aphids. These tests demonstrate the toxic nature of nicotine to aphids.
<table>
<thead>
<tr>
<th>Item</th>
<th>Spray Base</th>
<th>Additional Material Added to Stock Emulsion</th>
<th>Percent Soap in Combina-</th>
<th>No. of</th>
<th>No. of</th>
<th>Range in Percent Kill</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Water</td>
<td>None</td>
<td>0.25</td>
<td>3</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>Water</td>
<td>None</td>
<td>0.25</td>
<td>3</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>3</td>
<td>Stock 200</td>
<td>None</td>
<td>None</td>
<td>5</td>
<td>24</td>
<td>35 to 86</td>
</tr>
<tr>
<td>4</td>
<td>&quot;</td>
<td>None</td>
<td>0.25</td>
<td>3</td>
<td>7</td>
<td>97</td>
</tr>
<tr>
<td>5</td>
<td>&quot;</td>
<td>0.5 to 1 percent nicotine</td>
<td>None</td>
<td>4</td>
<td>13</td>
<td>96 to 100</td>
</tr>
<tr>
<td>6</td>
<td>&quot;</td>
<td>0.2 to 0.4 percent nicotine</td>
<td>0.25</td>
<td>2</td>
<td>6</td>
<td>99</td>
</tr>
<tr>
<td>7</td>
<td>&quot;</td>
<td>1 pound pyrethrum per gallon</td>
<td>None</td>
<td>1</td>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>8</td>
<td>&quot;</td>
<td>1 pound pyrethrum per gallon</td>
<td>0.25</td>
<td>3</td>
<td>4</td>
<td>96</td>
</tr>
<tr>
<td>9</td>
<td>&quot;</td>
<td>1 pound Cube' per gallon</td>
<td>None</td>
<td>1</td>
<td>2</td>
<td>94</td>
</tr>
<tr>
<td>10</td>
<td>&quot;</td>
<td>1 to 5 percent sulphur; petroleum nitrogeneous bases; Chinchona alkaloid salts; pine oil</td>
<td>None</td>
<td>7</td>
<td>17</td>
<td>25 to 82</td>
</tr>
</tbody>
</table>
Oyster Shell Scale, *Lepidosaphes ulmi* Linn.

The tests of dormant oil emulsions against the eggs of the oyster shell scale were conducted in the laboratory by a standard procedure. Twigs having over-wintering scale were collected, graded, sprayed and placed in moist sand to grow until the young scale hatched. The young scale were removed and counted as fast as they hatched.

Experiments were conducted with twenty-five different oil emulsions, most of which were tested at 5, 8, and 10 percent concentrations. The results are shown in Table 13. These experiments demonstrate clearly that only a high concentration (10 percent) of oil emulsion is effective against the eggs of this scale. Even at high concentration good wetting must be secured if control is to be obtained.

Under field conditions somewhat lower dilutions have given good results due to the effect of the residual oil left on the bark following an application of oil spray. The presence of oil on the twigs destroys many of the young migrating scale.

The best results in control of this insect were secured by the application of an oil spray at the time the young scales were hatching. At this season the young scale
are sensitive to oil and are easily killed by oil sprays. The results of field trials are shown in Table 14. Young oyster shell scale hatch at a season of the year (May–June–July), when their host plant is in full foliage. Although practically any oil applied at two percent concentration will give control of this scale, the oil selected for application should be safe to apply on foliage. The white oil emulsions marketed as summer oils have proven the most satisfactory.
Table 13

TABLE SHOWING THAT A TEN PERCENT CONCENTRATION OF AN OIL EMULSION IS REQUIRED TO DESTROY EGGS OF OYSTER SHELL SCALE (Laboratory test)

<table>
<thead>
<tr>
<th>Item</th>
<th>Type of Emulsion Tested</th>
<th>No. of Emulsions Tested</th>
<th>No. of tests*</th>
<th>Relative Efficiency at Percent Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>1</td>
<td>Commercial oils</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Experimental</td>
<td>9</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Miscible Oils</td>
<td>6</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Boiled fish oil soap emulsions</td>
<td>6</td>
<td>4</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>Experimental oils</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(White oil stocks)</td>
<td>1</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

*A test is considered 10 twigs with 10 overwintering oyster shell scale each. The 100 scales per test each contained from 40 to 80 eggs.*
<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae</th>
<th>Composition</th>
<th>Emulsion</th>
<th>Emulsifier</th>
<th>Injury to Foliage</th>
<th>No. Formulae Tested</th>
<th>No. Tests Relative Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Soluble oil No. 17</td>
<td>Paraffin oil Miscible</td>
<td>Petroleum soap</td>
<td>Yes</td>
<td>1</td>
<td>3</td>
<td>99.3</td>
</tr>
<tr>
<td>2</td>
<td>Stocks 3050 and 3060</td>
<td>White oil stock + pyre-thrum + sulphur</td>
<td>Gum</td>
<td>Yes</td>
<td>2</td>
<td>14</td>
<td>99.7</td>
</tr>
<tr>
<td>3</td>
<td>Stock 430</td>
<td>White oil stock + pyre-thrum</td>
<td>Gum</td>
<td>No</td>
<td>1</td>
<td>6</td>
<td>96.0</td>
</tr>
<tr>
<td>4</td>
<td>Commercial</td>
<td>White oil stocks</td>
<td>Inert</td>
<td>No</td>
<td>2</td>
<td>11</td>
<td>95.5</td>
</tr>
<tr>
<td>5</td>
<td>Control</td>
<td>Water</td>
<td>No</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Table 14

EFFICIENCY OF OIL SPRAYS FOR OYSTER SHELL SCALE AT TIME OF HATCH
(Field Tests)
European Elm Scale, *Gossyparia ulmi* Linn.

The rapid spread of the European Elm Scale in nurseries and cities has attracted considerable attention. Dormant oil emulsions, similar to soluble oil 17, at 4 percent concentration have been tested against this pest. This oil has given a very high degree of control where good wetting is obtained and when the oil is applied in the spring before the elm foliage appears.

The control of young European elm scale by summer oil sprays has not been as satisfactory because of the wide distribution of the young over the leaves. To obtain the highest degree of control by summer applications (at the time of hatch), the oil must possess a high wetting power and should contain nicotine at the same concentration as that recommended for aphids. Complete covering of the foliage with the spray is essential if a satisfactory control is to be obtained.

Cleveland (1931) found that stock emulsion No. 200 used at 2 percent concentration gave excellent control of hatching scale when four pounds of (30 percent) potassium fish oil soap were added to each 100 gallons of dilute emulsion. He found the addition of soap necessary in order to secure adequate wetting of the foliage and insects. No injury
resulted from his sprays on American and Cornish elms, applied July 15 at Monroe, Michigan.

Fruit Tree Leaf Roller, *Archips argyrospila* Walk.

The control of Fruit Tree Leaf Roller by the application of lead arsenate sprays has not given uniformly satisfactory results according to Regan (1923), Wakeland (1925), Flint and Bigger (1926) and Harman (1928). The feeding of the larvae can be checked with lead arsenate sprays, but special sprays are necessary using high dosages of lead arsenate. All authors agree that the logical method of control is against the egg stage of the insect.

Oil emulsions have given the most satisfactory control of leaf roller eggs in the laboratory and in the field. Wide variations have been found to exist between the various oil emulsions tested. Under field conditions it is seldom that sprays can be applied thoroughly enough to strike every egg mass on the tree. For this reason field trials of the same oils and concentrations have not given as high a mortality as have laboratory tests. This is in accord with the findings of Penny (1921). Comparable results were obtained in field tests (not included in this paper) where the oil sprays listed in Table 15, Items 1, 5, 6, 7 and 12,
were given field trials.

Regan (1923) claims that unless 75 percent of the eggs can be killed the expense of the spray is not warranted.

Experiments of Flint and Bigger (1926), Harman (1928), Tolles (1931) and Parrott, et al (1931) show that less than 6 to 8 percent actual oil in an emulsion will not give control of leaf roller eggs. These tests further indicate that the quicker breaking emulsions will kill the eggs at a lower concentration than the slow breaking emulsions. The cold mixed Bordeaux or Kayso emulsions have been the most efficient because of their quick breaking properties.

Laboratory data given in Table 15, Items 1 and 2, on leaf roller eggs illustrate the superior killing power of cold-mixed emulsions. With an actual oil content of 4 percent the 4-4-50 Bordeaux and calcium caseinate emulsions gave a 100 percent kill of eggs. Commercial soluble oil No. 7 is the only soluble oil giving a complete kill at a low concentration. The non-miscible properties of this oil in hard water would not make it a practical commercial emulsion for other than leaf roller or similar insect control. Only a small portion of this emulsion would remain in suspension without constant agitation. Boiled fish oil soap emulsion, Item 4, with a large oil droplet size and quick breaking, gave almost as high mortality of eggs as did the oils under
Items 1, 2 and 3.

Soluble oil No.3350, Item 5, Figure 7-B has the same emulsifier ratio as soluble oil No.17, Item 12, but contains a 225 second viscosity oil. The higher viscosity oil produces an emulsion that does not disperse as readily as does oil No.17. As a result the diluted soluble oil No.3350 tends to separate out of the water phase, giving to the emulsion a quick breaking property. The same characteristic is exhibited by commercial Soluble Oil No.7 to an even greater extent. Neither of these oils has sufficient emulsifier to completely disperse the oil particles when diluted with hard water.

Emulsions included in Items 6 to 11 vary in certain ingredients from soluble oil No.17, Item 12. The cresylic acid in soluble oil No.5110 and extra emulsifier in soluble oil No.22 did not increase the toxicity materially. The addition of one percent free nicotine, nicotine sulphate 1-300, or petroleum base did not increase the kill over that exhibited by soluble oil No.17. In all of the experiments the quick breaking soluble oils tested at 6 percent concentration gave a satisfactory control of leaf roller eggs. This is significant because of the wide use of soluble oils commercially for the control of this insect.
As ovicides for leaf roller eggs, emulsions with large oil droplets such as occur in cold-mixed emulsions are more efficient than commercially prepared emulsions when compared at equal concentrations. Certain quick breaking soluble oils will give a commercial control of leaf roller if they are carefully applied at a concentration of 3 percent or greater. The viscosity of oils between 63 and 350 seconds is not of major importance except as it affects the breaking property of the emulsion. A soluble oil containing an oil of 47 seconds of viscosity was not efficient against the eggs of the fruit tree leaf roller.
<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae No.</th>
<th>General Composition</th>
<th>Ratio of Micron Emulsion Range to Stock of Oil Droplets</th>
<th>Physical Properties of Dilute Spray</th>
<th>No. Egg Mass Tested</th>
<th>Relative Efficiency in Percent Eggs Killed</th>
<th>Percent Concent. of Spray</th>
<th>49</th>
<th>64</th>
<th>80</th>
<th>44</th>
<th>60</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stock</td>
<td>D.P. Oil in Bordeaux*</td>
<td>104</td>
<td>1-20</td>
<td>1-11</td>
<td>Very quick breaking</td>
<td>50</td>
<td>30</td>
<td>100</td>
<td>100</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Stock</td>
<td>D.P. Oil in Kayso**</td>
<td>104</td>
<td>1-20</td>
<td>1-19</td>
<td>Very quick breaking</td>
<td>10</td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Comm. Oil No.7 Soluble</td>
<td>140</td>
<td>-</td>
<td>0-100</td>
<td>Very quick breaking</td>
<td>20</td>
<td>20</td>
<td>100</td>
<td>100</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>III. Form. EFOS</td>
<td>D.P. Oil in KFOS</td>
<td>104</td>
<td>1-5.7</td>
<td>3-8</td>
<td>Very quick breaking</td>
<td>40</td>
<td>30</td>
<td>10</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8350</td>
<td>Soluble</td>
<td>225</td>
<td>1-9.0</td>
<td>1-2</td>
<td>Very quick breaking</td>
<td>50</td>
<td>20</td>
<td>-</td>
<td>95</td>
<td>88</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>5110</td>
<td>Soluble + 0.5% croslyc acid</td>
<td>83</td>
<td>1-6.7</td>
<td>1-5</td>
<td>Quick breaking</td>
<td>40</td>
<td>40</td>
<td>-</td>
<td>79</td>
<td>83</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>22</td>
<td>Soluble</td>
<td>83</td>
<td>1-6.0</td>
<td>1-5</td>
<td>Quick breaking</td>
<td>30</td>
<td>40</td>
<td>20</td>
<td>72</td>
<td>94</td>
<td>98</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>8340</td>
<td>Soluble</td>
<td>104</td>
<td>1-9.0</td>
<td>1-3</td>
<td>Quick breaking</td>
<td>40</td>
<td>20</td>
<td>-</td>
<td>52</td>
<td>57</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>8360</td>
<td>Soluble + 1% free nicotine</td>
<td>83</td>
<td>1-9.0</td>
<td>1-4</td>
<td>Quick breaking</td>
<td>30</td>
<td>30</td>
<td>-</td>
<td>61</td>
<td>59</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>8370</td>
<td>Soluble + petroleum bases</td>
<td>83</td>
<td>1-9.0</td>
<td>1-6</td>
<td>Quick breaking</td>
<td>40</td>
<td>20</td>
<td>-</td>
<td>52</td>
<td>58</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>17</td>
<td>Soluble + Na₂SO₄</td>
<td>83</td>
<td>1-9.0</td>
<td>1-6</td>
<td>Quick breaking</td>
<td>30</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>69</td>
<td>94</td>
<td></td>
</tr>
</tbody>
</table>

*4-4-50 Bordeaux
**2 ounces Kayso per gallon of oil.

(Table continued on page 98)
Table 15, cont'd.

<table>
<thead>
<tr>
<th>Item</th>
<th>Formulae No.</th>
<th>General Composition</th>
<th>Ratio of Emulsion to Stock Vis.</th>
<th>Micron Range of Oil Droplets</th>
<th>Physical Properties of Dilute Spray</th>
<th>No. Egg Masses Tested</th>
<th>Relative Efficiency in Percent Eggs Killed</th>
<th>Percent Concent. of Spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>17</td>
<td>Soluble</td>
<td>83</td>
<td>1-9.0</td>
<td>1-6</td>
<td>Quick breaking</td>
<td>50 60 30 47 75 96</td>
<td>40 60 80 40 60 80 60</td>
</tr>
<tr>
<td>13</td>
<td>Comm. Oil No.1</td>
<td>Soluble</td>
<td>350</td>
<td>-</td>
<td>1-4</td>
<td>Not quick breaking</td>
<td>30 20 10 26 61 67</td>
<td>60 80 40 60 80 40 60</td>
</tr>
<tr>
<td>14</td>
<td>Comm. Oil No.2</td>
<td>Soluble</td>
<td>47</td>
<td>-</td>
<td>1-4</td>
<td>Not quick breaking</td>
<td>- 20 - 6</td>
<td>60 80 40 60 80 40 60</td>
</tr>
<tr>
<td>15</td>
<td>Control</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>Water</td>
<td>110 110 110 0.0 0.0 0.0</td>
<td>60 80 40 60 80 40 60</td>
</tr>
</tbody>
</table>
Fleas, *Pulex irritans* Linn.

The economic importance of fleas as a pest of rural communities is not generally recognized or appreciated. The author made a survey of several counties in central Illinois and found a large number of farmsteads infested with fleas. Reports from farm advisers located in other counties indicated that similar conditions were present over a large section of the state.

Tests carried on over a period of three years indicate that soluble Oil No.17 at five percent concentration will give a satisfactory control of fleas. Premises (interiors of barns, out-buildings, etc.) must be thoroughly cleaned of litter, dust and other refuse. The area is then sprayed with a five percent oil emulsion and the floors thoroughly soaked. From three-hundred to eight-hundred gallons of dilute spray covers the average farmstead. One application is sufficient for light infestations but two or three treatments at intervals of two weeks are recommended in heavily infested areas.
DORMANT OILS WITH FUNGICIDES

Under some conditions it is practical to use sprays that contain an emulsion and a fungicide. The most common fungicides contain either copper or sulphur. Dormant peach and apple trees will withstand relatively high concentrations of either oil emulsion or lime sulphur without injury. It is therefore possible to spray dormant trees with oil emulsions mixed with some fungicides. Such sprays are very useful in the control of scale and peach leaf curl on peach, and scale and apple scab on apple. The properties of such sprays will depend upon the fungicide added.

The use of copper in the form of Bordeaux has been widely tested and has proven successful in most respects. Emulsions containing soap can be added to Bordeaux if the concentration of the uncombined copper or calcium is not sufficiently high to reverse the type of emulsion.

Most soap emulsions flocculate in the presence of inert forms of sulphur. "Flotation", a type of very finely divided precipitated sulphur obtained in the manufactured gas industry from a process known as liquid purification, combines with an inert emulsified oil, such as oil 210, to make an oil-sulphur combination possessing unusual properties, Fig.9,
In these experiments three different types of concentration were
computed. The results and the concentration are shown in Figure 2.

The results of two years of tests with spruce

their fungicidal value.
supplied in the opposite sex with the same type to increase

conditions: degree (1970) suggested the use of extreme

combinations within the thought possible to use under other

mixtures. Currin et al. (1979) described the ten or fifteen
suggest the addition of staple trees to all-time survival

stages of their development. Together with a

and together with a (1974) it is apparent that second emulsion to these even in the document

and together with a (1973). The finding is in accord with the results of a different

emulsion and the interaction of these oil in the spore mixture.

not mix with the supernatant without the separation of the

and look emulsion that contains soap at the emulsifier will

emulsion in the presence of the supernatant. All milled others

when the most sensitive is that of the separation of the

The essence of supernatant to emulsions, partitioning.
Spruce can be used in forest trials with emulsion separation. Such

with the supernatant with each other, separately.

(1970) extreme made with extreme stage emulsifiers, as

and B. These properties are described by particles and with

101
tested— a miscible oil at two percent concentration, a proprietary emulsion recommended for use with lime sulphur, and Stock 210. All were applied in the dormant, tip green*, and delayed dormant stages of tree development. The sprays applied while the trees were dormant did not show injury from any of the materials. With the trees in the tip green, the emulsion alone did not injure, but lime sulphur either alone or mixed with oil emulsion gave very noticeable injury. In the delayed dormant, when the leaves were beginning to unfold, all of the sprays produced some injury. The least injury occurred on the oil emulsion sprayed trees; those receiving lime sulphur were badly burned, and those receiving the mixture of oil and lime sulphur were so severely burned that the leaves did not develop further. The oil emulsion sprayed in the cluster bud stage resulted in very noticeable injury to the unfolding leaves and flower clusters. Dutton (1932) finds that, "there is evidence that the presence of oil with lime-sulphur renders lime-sulphur injury more severe or causes its development when lime-sulphur without oil would not produce injury." Although sometimes recommended, the spraying of fruit trees with oil emulsion and lime sulphur is not a safe practice.

*The tip green stage of bud development is when the bud scales have parted sufficiently to show the green new tissue that has been developing within the expanding bud. This stage precedes by a few days the rapid expansion of new leaves.
Figure 3

Illustrating the relation in days between bud development of apple and safety when sprayed with oil emulsion, liquid lime sulphur, or a mixture of both. The first spray was applied in the following periods of tree development: dormant, tip green, delayed dormant, cluster bud (only 2 percent oil).
DELAYED DORMANT APPLICATIONS OF OIL SPRAYS

For a number of years there has been a tendency to delay the application of oil sprays for the control of San Jose scale as late as possible in the season in order to kill such aphids as were hatched. Very few cases of injury are reported from stable oil sprays applied when the trees are strictly dormant. Felt (1913) reported less injury when oils were applied just before growth started in the spring than in fall applications. deOng (1926) observed that the blooming date was influenced by the season of application, recording that the early winter applications produced a stimulating effect, while the applications after bud development had started had a retarding effect. Kelly (1930a) suggests that injury observed from the early fall applications was due to winter injury that followed the breaking of the rest period by an application of oil.

In Illinois commercial practice, the dormant spraying of apple and peach with oils for scale has been followed for ten consecutive years without measurable effects on the crop production. Experimentally, seven annual dormant applications of a two percent miscible oil have not produced noticeable changes in tree development. A parallel test, where an eight
percent oil was applied, gave a distinct retardation of bud development for about seven days. This retardation, although very apparent at the time, was completely covered by normal tree growth in about six weeks after bud development started.

In a series of tests that has been conducted four years, quite similar results have been obtained. In the test are included an unsaturated miscible oil at 2 percent, applied in the fall, winter and spring dormant, and the delayed dormant; boiled fish oil soap emulsion at 3 percent and the miscible oil at 8 percent concentration, both applied in the spring dormant. In one year the fish oil soap emulsion, and for three years the 8 percent miscible oil, have shown a retarding effect on leaf development. In all cases the retardation was no longer noticeable six weeks after the buds started to open. There have been no injurious effects on any of the trees receiving the 2 percent oil spray in the dormant regardless of the season at which they were sprayed.

As shown in Figure 3, if the oil spray is delayed in application until the leaves begin to unfold or later, injury in the form of burning of the new leaves may result.

In many sections, spray schedules on apples call for a spray of lime sulphur very early in the season for the control of apple scab. This spray is often applied in the cluster bud stage of development. Figure 3 shows the effect
of oil emulsion and lime sulphur on foliage. Serious burning will usually result. The same condition can be approached where the oil spray is delayed and followed soon after by an application of summer strength lime sulphur. Figure 4 summarizes the experiments to determine the interval of time that should elapse between the oil spray and a spray of lime sulphur. It appears to be relatively safe to apply lime sulphur two weeks after an application of oil emulsion.

Yothers, et al (1930) found that two to three weeks should elapse before an oil spray on citrus was followed by a sulphur spray or dust for the control of citrus rust mite. Overholser and Overley (1930) found under Washington conditions that oil sprays previous to July 1 caused injury to fruit and foliage following a delayed dormant application of lime-sulphur.
SUMMER OILS WITH FUNGICIDES

The need of an oil emulsion with fungicidal properties has been recognized. Many attempts have been made to combine sulphur, copper and their derivatives with both summer and dormant oil emulsions. Other materials that have exhibited fungicidal properties have been tested but most of them have been discarded as unsatisfactory. Although sulphur is widely used as a fungicide, it will produce injury even in small quantities when used with oil according to de Ong (1928,c). Hoerner (1929) suggests that "Penetrol" is compatible with flowers of sulphur and safe on apple foliage if the two are mixed with water before they are combined. Talbert and Swartwout (1931) state that, "Lubricating oil emulsions have been used throughout the summer in applying the regular summer combination applications, using the oil at one percent and two percent with the standard insecticidal and fungicidal spray, lime-sulphur and Bordeaux with lead arsenate."

This finding is not in accord with the general knowledge of sulphur and oil combinations. Oil emulsions containing certain forms of copper are relatively safe on foliage but the spray has low insecticidal efficiency and it
is difficult to store because of its corrosive action on metal. Oil emulsions may be added to well-made Bordeaux without danger of injury but the Bordeaux reduces the efficiency of the oil emulsion according to Porter and Sazama (1930).

Oil emulsions containing derivatives of furfural show promise but are not completely satisfactory as insecticides or fungicides.

To our present knowledge there is no material sufficiently toxic to fungi that can be added to an oil emulsion without interfering with either the insecticidal efficiency of the oil emulsion or with the toxicity of the fungicide to fungi. The reduced efficiency of emulsions with fungicides was demonstrated in experiments with codling moth larvae, Table 6, and Figure 2. In these experiments, fungicides added to the pyrethrum sprays reduced their average efficiency from 88 to 66 percent and the white oils without the pyrethrum from 34 to 33 percent. Fungicides that were partially soluble in the oil phase of the emulsion had less effect on efficiency than the flocculent materials such as flowers of sulphur or Bordeaux.
Figure 4

Illustrating by days the relative safety to apple foliage between a dormant or delayed dormant oil spray for scale and the first lime sulphur spray for apple scab.
THE DISTRIBUTION OF A UNIT VOLUME OF SPRAY MATERIAL

The total volume of any spray material required to cover a certain block of fruit trees has not been a settled question in the minds of many horticulturists. They have been led to believe that there are wide differences in the spreading and covering properties of certain spray materials. Salesmen of insecticides often claim that this or that material will give a greater spread that would reduce the actual cost of a spray to cover an orchard.

There are certain factors involved in the practice of spraying that influence the amount of material required to cover a certain number of trees. Some of these factors are: the type of equipment, number and size of nozzles, pressure, visibility, wind direction, type of workmen doing the work, and the care with which the workmen attempt to wet the trees thoroughly. If the workmen are given a standard set of equipment and have uniform weather conditions, the amount of material that they will use will vary but slightly regardless of the physical properties of the spray material applied. This fact is in accordance with the findings of Swingle and Snapp (1931). It is brought out also in the records of commercial orchards that use large amounts of materials for
each spray. In well equipped orchards the variations can usually be accounted for by adverse weather conditions.

Additional proof that the volume of spray material necessary to cover a unit number of trees is relatively constant is given in Table 16. The information presented is the summary of two series of tests, one conducted in the fall and the other in the spring, using the same orchard and materials but varying the men and equipment. There was no variation in the time required to spray a unit volume of material. The concentration of the spray material had little influence on total area covered. There was a difference of almost one tree per one-hundred gallons of spray material between the commercial miscible oil sprays and boiled fish oil soap emulsions or lime sulphur. This difference perhaps resulted from the fact that the last two materials named are almost colorless on the trees and there is a slight tendency for the workmen to spray a little longer in each place before recognizing that all of the surfaces have been wetted.
<table>
<thead>
<tr>
<th>Item No.</th>
<th>Spray Material</th>
<th>Percent Concentration</th>
<th>No. Gallons per Test</th>
<th>No. Tests</th>
<th>Coverage by 100 gallons of spray material with 1 gun</th>
<th>No. Trees</th>
<th>Time in Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Commercial Oil No. 17</td>
<td>2.0</td>
<td>200</td>
<td>4</td>
<td>14.8</td>
<td></td>
<td>23.3</td>
</tr>
<tr>
<td>2</td>
<td>Commercial Oil No. 2</td>
<td>6.5</td>
<td>200</td>
<td>4</td>
<td>14.5</td>
<td></td>
<td>23.6</td>
</tr>
<tr>
<td>3</td>
<td>&quot;Illinois Formula&quot;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>13.1</td>
<td>23.0</td>
</tr>
<tr>
<td>4</td>
<td>Lime Sulphur</td>
<td>10.0</td>
<td>200</td>
<td>4</td>
<td>13.6</td>
<td></td>
<td>22.5</td>
</tr>
</tbody>
</table>
SUMMARY AND CONCLUSIONS

The effects on insects and plants of the physical properties of petroleum oil emulsions limit each type of emulsion to restricted fields of insecticidal usage.

The physical properties of oil emulsions can not be associated with some forms of plant injury which follow applications of oil sprays. Such plant disturbances are associated with general vigor, stage of growth, soil moisture and food relations.

Petroleum oil emulsions formed with soap are generally toxic to foliage irrespective of the saturation or viscosity of the petroleum oil.

The amount of emulsifier present in an emulsion predetermines to some extent the physical nature of the emulsion and to a greater extent its insecticidal value. The emulsions which possess the larger oil droplets are the more toxic to insects and the less toxic to plants.

The viscosity of a petroleum oil determines to a limited extent its safety to growing plants. The lighter oils, 50 seconds of viscosity or less, are less toxic to plants but are not as efficient insecticides. Oils of greater than 100 seconds of viscosity tend to create
physiological disturbances within the growing plant.

A laboratory study of the larvicidal efficiency of emulsions indicates only a limited possibility of increasing the mortality of codling moth larvae by changes in the physical properties of an emulsion.

The technical white oil emulsions are relatively safe on foliage if they possess the proper degree of saturation, viscosity, oil droplet size and an inert emulsifier.

White oil emulsions are practical in the late brood codling moth sprays in order to avoid arsenical residues on the fruit. The white oil emulsions alone are not equivalent to lead arsenate in larvicidal efficiency but when combined with nicotine sulphate they are comparable to lead arsenate in the control of the late brood codling moth larvae.

The addition of extracts of the plant poisons such as pyrethrum, derris or tobacco to emulsions increases materially the toxicity of the emulsions as contact insecticides. Of the plant poisons, nicotine alone was stable to exposure under field conditions. Toxicity to foliage was not influenced by the addition of plant extracts to the emulsions.

White oil emulsions can be used as oxicides in codling moth control either alone or included in the lead arsenate
sprays. The combined spray has excellent ovicidal and larvicidal properties.

The most satisfactory control of red spider was obtained by the use of a technical white oil emulsion at a concentration of one percent.

For the control of San Jose scale, the most efficient emulsions contained relatively large oil droplets associated with high wetting and quick breaking properties.

The efficiency of emulsions against aphids depended on high wetting and low stability or the presence of limited quantities of nicotine. An emulsion containing nicotine was more efficient if it contained a substance to promote high wetting.

Oyster shell scale was adequately controlled with a two percent white oil emulsion applied about the time the young scales hatched. A miscible or soluble oil applied in the dormant stage of development at high concentration gave a satisfactory control of this insect.

A miscible or soluble oil used at a concentration of four percent adequately controlled European Elm scale when applied as a delayed dormant spray. Some difficulties were encountered in controlling this insect with summer sprays.

Stability was the dominant physical property of an emulsion that was efficient in killing the eggs of the fruit
tree leaf roller. The less stable emulsions were the most efficient.

Oil emulsions at a concentration of five percent gave excellent control of fleas on farmsteads.

Dormant oil emulsions can be used with sulphur fungicides in the dormant stage of tree development. If used after the buds start to swell, serious injury may result.

There is danger of injury if oil emulsions are applied in the delayed dormant stage of tree development, particularly when sulphur is to be used in the later sprays for the control of fungus diseases.

It is doubtful if fungicides of the more common types can be used with summer emulsions without disturbing the efficiency of the emulsion or causing injury to the plant tissue when they are applied to foliage.

The volume of spray material necessary to cover a unit number of trees is relatively constant, irrespective of the nature of the spray material applied.
THE PRESENT TREND OF OIL SPRAYS

The use of oil emulsions for codling moth control in late brood sprays, particularly when mixed with nicotine sulphate, is very promising.

Sprays of oil emulsions for the late brood codling moth larvae have given excellent results in the reduction of lead arsenate residues.

The larvicidal limits of oil emulsions are fairly well established.

The use of oil emulsions with lead arsenate sprays show promise in the control of codling moth larvae.

The use of petroleum oil as a carrier for plant poisons is recognized.

Oil emulsions are giving a control of scale insects superior to all other sprays for scale.
LITERATURE CITED

Abbott, W.S.
1926 Determining the Effectiveness of Dormant Treatments Against the San Jose Scale. Journ.Econ.Ent. 19: 258-260.

Ackerman, A.J.

Better Fruit

Burroughs, A.M.

Chandler, S.C., Flint, W.P., and Huber, L.L.

Cleveland, C.R.
1931 An Experiment With Summer Oil for the Control of the European Elm Scale, Gossyporia ulmi L., Journ.Econ.Ent. 24: 349-355.

Compton, C.C.
1931 Red Spider Control in the Greenhouse.

Cook, A.J.
Cutright, C.R.  

Davis, J.J.  

Davis, J.J., Yothers, W.W., Ackerman, A.J., and Haseman, L.  


deOng, E.R., and Knight, H.  

deOng, E.R.,  

deOng, E.R., Knight, H. and Chamberlin, J.C.  

deOng, E.R.  


Flint, W. P.  

Flint, W. P., and Farrar, M. D.  

Ginsburg, J. M.  


Gray, G. P., and deOng, E. R.  

Green, E. L.  

Griffin, E. L., Richardson, C. H., and Burdette, R. C.  

Harman, S. W.  

Headlee, T. J., Ginsburg, J. M., and Filmer, R. S.  

Headlee, T. J.  
Herbert, F.B.  

Herbert, F.B., and Leonard, M.D.  

Herbert, F.B.  

Hoeumer, J.L.  

Hurt, R.H.  

Kelley, V.W.  


Knight, H., Chamberlain, J.C., and Samuels, C.D.  

Lathrop, F.H., and Sazama, R.F.  
Leonard, M.D.  
1930  

Lodeman, E.G.  
1899  

Mason, A.F.  
1928  

Newcomer, E.J., and Yothers, H.A.  
1927  

1932  

Overholser, E.L., and Overley, F.L.  
1930  

Overley, F.L., and Spuler, A.  
1928  

Parrott, P.J., Hartzell, F.Z., Glasgow, H., and Harman, S.W.  
1931  

Penny, D.D.  
1921  
The Results of Using Certain Oil Sprays for the Control of the Fruit Tree LeafROLLER in the Pajaro Valley, California. Journ. Econ. Ent., 14: 428-433.

Porter, B.A., and Sazama, R.F.  
1930  
Regan, W.S. 1923  

Regan, W.S., and Davenport, A.B. 1928  

Regan, W.S. 1929  
Results of Insecticide Tests for the Control of Codling Moth and Observations on Codling Moth Activity in the Yakima Valley, Washington. California Spray Chemical Co., Berkeley, California.

1930  
Results of Insecticide Tests for the Control of Codling Moth and Observations on Codling Moth Activity in the Yakima Valley, Washington. California Spray Chemical Co., Berkeley, California.

Smith, R.H. 1929  

1930  

1931  

Spuler, A., and Dean, F.P. 1930  

Swingle, H.S., and Snapp, O.I. 1931  
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Year</th>
<th>Title</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>and Swartwout,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H.G.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
-126-

Yothers, W.W.  
1918  

Yothers, W.W., and Winston, J.R.  
1924  

Yothers, W.W., and Mason, A.C.  
1930  
ACKNOWLEDGEMENTS

The author wishes to thank the Crop Protection Institute, its Committee and Chairman, Professor W.P. Flint, for their guidance in the development of this project; the Standard Oil Company of Indiana for the funds used in the project and for experimental samples prepared and furnished through their entomological staff and chemists; the Natural History Survey, University of Illinois, Urbana, for permission to use the equipment employed in the investigation; the members of the staffs of the University of Illinois and Iowa State College for experimental material and assistance in the carrying on of the investigation, taking of data, and evaluation of the results; Dr. L.L. English, former investigator of this project, who has furnished much time and effort in the collection and evaluation of data.
VITA

I was born at Lawrence, Kansas, on October 15, 1901. My father's name is Edwin Oscar Farrar (deceased). My mother's maiden name was Nellie Dyer.

I attended the grade schools at Abilene, Kansas, and graduated from the Abilene High School in 1920. I then entered Iowa State College, Ames, Iowa, from which I received the degree of Bachelor of Science in August, 1925. I majored in Zoology and Entomology under Dr. Carl J. Drake. Later I entered the South Dakota State College, Brookings, South Dakota, where I received the degree of Master of Science in August, 1927, majoring in Entomology under Professor M.C. Severin.
A. Scale used in estimating size of oil droplets. A unit on the scale is 0.1 micrometer.  
B. Soluble Oil No. 17  
C. Soluble Oil No. 49  

Figure 5. Photomicrographs of Emulsions Used in Experiments.
Figure 6. Photomicrographs of Emulsions Used in Experiments.
Figure 7. Photomicrographs of Emulsions Used in Experiments.
A. Stock Emulsion, "Illinois Formula", Boiled Fish Oil Soap Emulsion.

B. Commercial Soluble Oil No. 1.

C. Commercial Soluble Oil No. 2.

D. Commercial Soluble Oil No. 6.

Figure 3. Photomicrographs of Emulsions Used in Experiments.

B. Stock Emulsion No. 210 plus an equal amount by weight of "Koppers" "Thylox" Sulphur Paste.

C. Stock Emulsion No. 200.

D. Commercial Stock Emulsion No. 5.

Figure 9. Photomicrographs of Emulsions Used in Experiments.