THE PHYSIOLOGICAL EFFECTS OF MINERAL OILS ON CITRUS

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INTRODUCTION

In the use of any spray material for control of plant pests the deleterious effects of such materials on the plant itself must be recognized. The studies along this avenue of research were conducted during an investigation leading to the manufacture of an oil emulsion for citrus use. It is through the courtesy of the Haines City Citrus Growers Association, for whom the work was done, that the presentation of this paper is made possible.

The percentage of actual oil used in these experiments was necessarily held at a high level in order to properly evaluate the differences in physiological effects. Deficiencies in soil moisture during the period under discussion have probably also accentuated the results. It should be noted here that no damage has resulted from the widespread use of emulsions similar to those of Experiment No. 2 at concentrations of from 1% to 1.3% actual oil during the summer months of 1938.

TYPES OF OIL DAMAGE

Primary Physiological Effects

Emulsions of the heavier distillates have been in use since the turn of the century. Since that time the literature on the

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1Paper read before the December 1938 meeting of the Fla. Ent. Soc.
subject of damage resulting from the use of the oil emulsion has become extensive. The following references cannot be considered complete, but only as showing the trend of the work. Volck (1)² and Knight, Chamberlin and Samuels (2) have shown that oil penetration is greatest in those areas where stomata are located but not necessarily confined to those areas. Knight and Cleveland (3) have reported that the amount of penetration is associated with the angle of contact, which accounts for the greater penetration on old foliage, especially where the cutin has been destroyed by insects, abrasions or ordinary wear and tear.

Yothers (4) has recorded the drop of large percentages of old leaves starting about three days following oil treatment. Other types of damage were noted in lesser degrees. Gray and DeOng (5) have tabulated the "chronic" injuries to citrus due to applications of heavy oils which leave oil films on leaves or twigs for days or weeks. Twigs and even larger limbs are stunted or killed. Fully matured leaves, especially if senile, are more susceptible to injury from neutral oils, while young leaves are more susceptible to injury from oils of lower sulphonation.

DeOng, Knight and Chamberlin (6) have shown that oils of from 51% to 60% sulphonation resulted in heavier defoli-ation and twig death than did neutral white oils of 98% sulphonation. They have also called attention to the temperature factor. DeOng (7) has further suggested that apparently the 1st or 2nd treatment with sulfuric acid or sulfur dioxide removes the parts dangerous to plants and insects. Smith (8) has shown that the amount of leaf drop following oil applications to citrus is correlated with the amount of oil deposited, and increases with higher viscosities and lower sulphonations. DeOng, Knight and Chamberlin (6) have described the characteristic effects following the use of neutral white oils as: more or less heavy leaf drop principally of senile or semi-senile leaves; drop of tree-ripe fruit; inhibition of normal color in lemons; drop of green Valencia oranges during humid weather and retardation of ripening.

Magness and Burroughs (9) have found that an oil film on the surface of stored apples may have a distinct effect on gaseous exchange. The evolution of carbon dioxide to oxygen was reduced, but analysis of the air in the inner cellular spaces

²Refers to literature cited on page 28.
showed an increase in the ratio of carbon dioxide to oxygen. Burroughs (10) has noted a reduction in the amount of starch produced in apple leaves that seem to have been arrested in their growth by an application of an oil spray.

Kelley (11) has found that both saturated and unsaturated oils retarded transpiration on deciduous fruits, when applied to the lower leaf surfaces where the stomata are located.

Secondary Physiological Effects

Shamel and Pomeroy (12) have shown a correlation between number of leaves on Valencia trees and the fruit sizes. In other papers: Shamel, Pomeroy and Carc (13) and Shamel and Pomeroy (14) have shown similar relationships in Navel oranges and Marsh grapefruit. Magness, Overley and Luce (15) have shown correlations between leaf area and size of crop on apples and pears.

Spuler, Overley and Green (16) have stated that oil sprays, particularly those of high viscosity, cause metabolic disturbances in the foliage (of apples) which is reflected in decreased size and color of fruit. The extent to which these disturbances decrease the size and color of fruit is dependent on the load of fruit on the trees, the soil moisture and the variety of fruit.

Fudge (17) has shown that while magnesium deficiencies "bronze" foliage of grapefruit and cause excessive defoliation under heavy cropping, the succeeding alternation of bearing results, not because of a magnesium deficiency, but principally because of a limited and inefficient leaf area.

EXPERIMENT NO. 1

A tank mix application was made on February 25th to Valencia trees, using an oil of 70 seconds viscosity and 83% U. R. at a concentration of 12½% actual oil. Application was thorough, inside and outside, with use of two nozzle guns. This tank mix depended chiefly on the agitation of the paddles for stability. Such agitation was found to be slightly deficient with the result that the last portion left in the spray tank contained a higher percentage of actual oil than did the first portion. Therefore the first group of trees (nine) received a lesser percentage of oil than did the last group (five).

There was general growth of a good green color, averaging five inches in length at the time of application. Bloom was heavy with some fruit set, some blossoms open and some unopened blossom buds. A 33° F. temperature was recorded the night
following the application with minimum temperatures from 46° to 64° during the following week (maximums 76° to 84°).

Primary Oil Damage Symptoms

General shadowing of both old and new foliage occurred, with marginal burn of a slight degree appearing on new foliage after several days. The distal portions of the petals of the unopened bloom spread apart to allow the pistil to protrude and brown spots appeared on the outer surface of the petals. Despite these abnormalities, the blossoms opened normally. There was some drop of mature leaves, being greatest in the second group of trees but no counts were made. At the end of 10 days 39% of the young set fruit on the treated trees was yellow in color or shed; while only 18.3% showed these conditions on the untreated trees.

The most outstanding effect of this application was the drop of tree-ripe fruit of the 1937 crop. On April 22nd (56 days after application) a count of all fruit on the ground showed an average of 52.6 for the sprayed trees against 5.4 for the untreated. This drop was greatest in the second group of treated trees (Table No. 1).

Fruit crops were recorded as the number of fruit which could be observed from the ground to a six-foot level while slowly walking around the trees. This has proven to be a very reliable comparative criterion. The average of two counts (April 22nd and September 3rd) revealed 51.4 fruit per treated tree as against 76.7 per untreated tree. This decrease in fruit crop is correlated with the percentage of young set fruit paled or dropped by the oil application and is considered a direct effect of the application.

Secondary Physiological Effects

On September 3rd the treated fruit averaged 6.65 cm. in diameter while the untreated averaged 6.7 cm. From the work of Shamel and Pomeroy (12) the fruit on the treated trees would be expected to be smaller in size than those on the untreated trees due to loss of foliage resulting from oil application. That this did not occur is considered to be due to the fact that the oil also dropped a percentage of the fruit crop and probably in proportion to leaf drop; the leaf-fruit ratio remaining undisturbed.

June growth appeared more rapidly on the treated trees. On June 1st 21.75% of the spring growth terminals on the
treated trees showed burst buds, while only 7.2% showed the same condition on the untreated.

Due to dry conditions during the spring of this year (1938) there was an exceedingly heavy June bloom. On September 3rd there was an average of 18.9 June bloom fruit on the treated trees as against 26.8 on the untreated.

EXPERIMENT NO. 2

On May 12th adjacent Valencia trees were treated with an oil of 70 seconds viscosity and 83% U. R. at 1½% concentration and emulsified with succeedingly larger amounts of the same material in the proportions of 1, 2 and 4. Thus the actual deposit of oil on the tree surfaces was succeedingly decreased. The spray was applied by the author as a thorough outside coverage and a similar inside coverage as afforded by the force of 500 pounds pressure, with the use of a 6-nozzle gun. Minimum temperatures during the week following application varied from 57° to 72° F. (Max. 87-94°.)

At the time of the application the fruit averaged 3.7 cm. in diameter with slight variations between trees. All trees were in a thrifty condition, spring growth hardening and no wilt in spite of lack of rain. The crop varied as follows: Tree No. 1, light, 20 fruit; No. 2, medium, 70 fruit; No. 3, heavy, 195 fruit; No. 4, light, 29 fruit; No. 5, light, 15 fruit; and No. 5-II, heavy.

Trees Nos. 1, 5 and 5-II received no oil. Tree No. 2 received an emulsion containing 23 cc. emulsifier per gallon; No. 3 one containing 46 cc.; and No. 4 one containing 92 cc.

Symptoms of Oil Damage

The mature leaves of the 1937 fall flush began to drop 24 hours after treatment and continued a little over one-half month. This drop was recorded by counting the number of leaves on the ground from the “drip” of the tree outward to the square of the tree at two to three day intervals. The average drop for the untreated trees was 104.5; while for the treated trees it was 54.3. This drop was in approximate proportion to the tree size and not in relation to amount of emulsifier (Table No. 2). The heavy drop of mature leaves would be expected as shown by the work of Knight and Cleveland (8) which indicates that oil penetration is greatest on old foliage and that this penetration cannot be controlled to any great extent. It should be considered that the deposit of oil was heavy in all cases and probably
exceeded the minimum requirements necessary for mature leaf drop in even the most “tight” formula used.

Drop of spring fruit began a few days after treatment and continued for about a month (Table No. 2). As the amount of emulsifier was increased, the droppage was decreased.

Drop of spring foliage was tabulated by counting the number of leaves on 50 spring growth terminals and the number of fresh leaf scars indicating dropped leaves. Two counts were averaged (May 17 and June 1), showing a decreasing amount of droppage as the emulsifier was increased (Table No. 2).

All sprayed trees showed very definite shadowing of leaves and fruit. On the day following the application 99% of the spring leaves and 100% of the spring fruit showed shadow. This shadow appeared to be slightly more continuous with the lower amounts of emulsifier. No shadow was evident on the untreated trees. Even 141 days later, on September 30th, a few fruit on the treated trees showed slight shadowing.

There was no burn evident on foliage and only one fruit (on Tree No. 3) showed burn.

Secondary Physiological Effects

As noted above, Shamal and Pomeroy (12), Magness, Overley and Luce (15), Fudge (17), any condition which drops large percentages of foliage will have a resultant effect on the physiological balance of the tree. Since the droppage of foliage of 1937 fall growth was more nearly correlated to the size of the trees and number of leaves present, it would be presumed that secondary physiological effects would be nearly constant for all treated trees. This apparently is the case.

The untreated trees showed an average fruit diameter on August 27th of 6.69 cm., while the treated trees averaged 6.1 cm. The fruit size was inversely proportional to size of crop (Table No. 4). The variations between sizes on the treated trees were constant with the variations between sizes on the untreated. Thus, the ratio between 5-II and 5 (untreated) is similar to that between 3 and 4 (treated).

On the first of June counts of 50 spring growth terminals showed an average of 25% with burst buds on untreated trees; while the average was 70% on the treated trees, with no significant difference between trees (Table No. 3).

The June bloom crop averaged 3.3 fruit for the treated trees, with 33 fruit for the untreated (Table No. 4).
SUMMARY

Applications of high concentrations of mineral oils exert a direct effect on Valencia trees. This effect is most pronounced in the droppage of tree-ripe fruit and mature leaves due to their lowered surface tension allowing for greater penetration of oil.

Drop of immature leaves and fruit was in no case as heavy as that of mature leaves and fruit. The surface tension is higher on these parts and the resistance to penetration greater. On such surfaces the minimum amount of oil required for abscission is greater. The effect of varying amounts of oil deposition as influenced by the emulsifier would, therefore, be more marked. This has been shown.

Secondary Physiological Effects

The loss of large numbers of leaves following these heavy applications of oil resulted in three definite physiological responses. The size of immature fruit was retarded, except where the reduction of crop was approximately proportional to reduction in leaf area. The number of fruit borne in the succeeding crop was reduced. The subsequent flush of growth was accelerated. A fourth condition, killing of wood, is sometimes brought about either directly due to oil penetration or as a secondary effect should new growth fail to appear after drop of leaves. In the latter case, sap exchange is interrupted which results in the collapse of the wood cells.

CONCLUSIONS

The value of oil applications for the control of scale pests is well-established. The damages outlined in this paper were brought about by applications of oil of high concentrations at periods of the year which are normally considered untimely for such applications. On the other hand, the same types of emulsions were used throughout the year on hundreds of acres of groves under commercial conditions without damage and with excellent scale control.

The insecticidal and phytocidal properties of mineral oils are closely correlated. Therefore emulsions of these oils must be so timed in their applications to allow maximum deposit without detrimental plant reaction and minimum deposit for thorough pest control. Emulsifying an oil in such a manner as to reduce the oil deposit upon application to the plant does not answer the question.
The premature droppage of foliage, from any cause whatsoever, must be regarded as a detrimental factor in commercial fruit production. Fruit production is the function of foliage. Acceleration in appearance of a growth flush when due to decreased or inefficient foliage conditions signifies a return of the plant to a vegetative state; a physiological response toward maintaining equilibrium of value to the commercial orchardist only when the motivating force has been unavoidable.

LITERATURE CITED

15. MAGNESS, J. R., F. L. OVERLEY and W. A. LUCE. Relation of foliage to fruit size and quantity of apples and pears. Wash. AES Bul. 249, 1931.
### TABLE NO. 1—EXPERIMENT NO. 1—COMPARISON OF TREATED AND UNTREATED TREES.

| Date Checked | Condition | Treated Trees | | | | | Un-treated Trees | |
|--------------|-----------|---------------|-----|-----|-----|-----|------------------| |
| 2/26         | Leaf Shadow | Present | Present | Present | Absent | | | |
| 2/28         | Marginal burn on young foliage | Slight | Slight | Slight | None | | | |
|              | Young set of fruit pale in color | 58.0% | | | 36.0% | | | |
| 3/7          | Young set fruit light in color or dropped | 39.0% | | | 18.3% | | | |
| 4/22         | Average drop of tree-ripe fruit (per tree) | 52.6 | 33.4 | 87.2 | 5.4 | | | |
|              | Average number of 1938 spring fruit per tree (ground to six-foot level) | 47.6 | 57.6 | 29.8 | 65.3 | | | |
| 6/1          | Average percentage of spring growth terminals showing burst buds of June flush | 21.75 | | | 7.2 | | | |
| 9/3          | Average number of 1938 spring fruit per tree (ground to six-foot level) | 55.1 | 65.8 | 35.8 | 88.1 | | | |
|              | Average size of 1938 spring fruit in diameter | 6.65 cm. | | | 6.7 cm. | | | |
|              | Average number of 1938 June fruit per tree (ground to six-foot level) | 18.9 | 24.9 | 8.0 | 26.8 | | | |

### TABLE NO. 2—EXPERIMENT NO. 2—DROP OF LEAVES AND FRUIT FOLLOWING OIL APPLICATION.

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Amount Emulsifier</th>
<th>Mature Leaves (number)</th>
<th>Spring Foliage %</th>
<th>Spring Fruit Number</th>
<th>Spring Fruit Percentage*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>46</td>
<td>4.43</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>23 cc.</td>
<td>373</td>
<td>7.23</td>
<td>31</td>
<td>44.3</td>
</tr>
<tr>
<td>3</td>
<td>46 cc.</td>
<td>456</td>
<td>4.46</td>
<td>47</td>
<td>24.1</td>
</tr>
<tr>
<td>4</td>
<td>92 cc.</td>
<td>800</td>
<td>3.99</td>
<td>5</td>
<td>17.2</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>163</td>
<td>2.01</td>
<td>2</td>
<td>13.3</td>
</tr>
</tbody>
</table>

*Based on crop from ground to six-foot level.
TABLE NO. 3—EXPERIMENT NO. 2—Percentage of Spring Terminals Showing Burst Buds of June Growth June 1, 1938.

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Amount Emulsifier</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Check</td>
<td>38.0</td>
</tr>
<tr>
<td>2</td>
<td>23 cc.</td>
<td>72.0</td>
</tr>
<tr>
<td>3</td>
<td>46 cc.</td>
<td>66.0</td>
</tr>
<tr>
<td>4</td>
<td>92 cc.</td>
<td>72.0</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>12.0</td>
</tr>
</tbody>
</table>

TABLE NO. 4—EXPERIMENT NO. 2—Cropping.

<table>
<thead>
<tr>
<th>Tree No.</th>
<th>Amount Emulsifier</th>
<th>Size of Crops</th>
<th>Average Size Spring Fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Spring Crop</td>
<td>June Crop Spring Fruit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5/12/38</td>
<td>8/27/38</td>
</tr>
<tr>
<td>1</td>
<td>Check</td>
<td>20</td>
<td>31</td>
</tr>
<tr>
<td>2</td>
<td>23 cc.</td>
<td>70</td>
<td>76</td>
</tr>
<tr>
<td>3</td>
<td>46 cc.</td>
<td>195</td>
<td>215</td>
</tr>
<tr>
<td>4</td>
<td>92 cc.</td>
<td>29</td>
<td>31</td>
</tr>
<tr>
<td>5</td>
<td>Check</td>
<td>15</td>
<td>27</td>
</tr>
<tr>
<td>5-II*</td>
<td>Check</td>
<td>--</td>
<td>161</td>
</tr>
</tbody>
</table>

*5-II Check is a further untreated tree which had a heavy crop of fruit and which was counted for cropping conditions to show comparison with No. 3 treated tree which also had a heavy crop.

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