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# TEXAS AGRICULTURAL EXPERIMENT STATION

A. B. CONNER, DIRECTOR
COLLEGE STATION, BRAZOS COUNTY, TEXAS

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DIVISION OF ENTOMOLOGY

# California Red Scale and Its Control in the Lower Rio Grande Valley of Texas

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**In cooperation with U. S. Department of Agriculture.
†As of March 1, 1932.

The California Red Scale is capable of doing such serious damage to citrus trees in the Lower Rio Grande Valley that its control is one of the major problems of citrus fruit production in this region. Environmental conditions are apparently so favorable for the development and multiplication of this insect that it is probably more active in the Valley than in any of the other citrus-producing areas of the United States.

Infested host plants and neglected orchards furnish sources of reinfestation so that scale control by fumigation was impractical. Fumigation has given very satisfactory control for relatively short periods of time, but under the conditions of these experiments, reinfestation occurred within a period of five months following the treatments.

Oil emulsion sprays of the quick-breaking type, in which medium to heavy oils are used, have given very satisfactory control of red scale when applied thoroughly at the proper season. Emulsions of this type were more effective and safer to use than the soap, oil, and water combinations. Hard water adds to the complications incident to the use of the soap emulsions.

Most of the proprietary oil sprays which are sold in the Lower Rio Grande Valley were found to be effective in controlling red scale when used under the conditions of these tests.

Spraying with oil emulsion during the summer season gave more effective scale control than did spraying at any other season. Trees which received their first spraying after the first of August produced scale-blemished fruit. Those sprayed during the winter season only were invariably reinfested by harvest time.

Two applications of oil emulsion during the summer season (May and July) were more effective against scale than was a single summer application. However, where scale control the previous season was satisfactory, it is probable that a single, well-timed application during the summer season would keep red scale under control. It should be pointed out that control measures directed against the red scale will control most of the other types of scale insects which infest citrus trees in this region.

The nature of the citrus tree makes it difficult to cover all parts of the tree thoroughly with liquid spray. Satisfactory control depends entirely upon bringing the oil spray in contact with the insect, and unless the spraying is done properly, the results secured may be unsatisfactory.

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# CALIFORNIA RED SCALE AND ITS CONTROL IN THE LOWER RIO GRANDE VALLEY OF TEXAS

S. W. Clark and W. H. Friend

The major citrus-producing area of Texas is located in the three counties in the southernmost tip of the State. The oldest acreages are found in Hidalgo and Cameron counties. A rapid expansion of the industry, however, is being made in Willacy County. The latest census figures (1932) compiled by the United States Department of Agriculture show that 7,864,000 citrus trees have been planted in orchard form in this area.

The climate of this section is semi-arid and sub-tropical. The annual rainfall is about 23 inches, but the distribution is very uneven and irrigation is practiced to maintain proper soil-moisture conditions. The average mean monthly temperature during the growing season, March 1 to November 1, is about 70 degrees F.* Mean monthly temperatures for the period from November 1 to March 1, are usually above 60 degrees F.* The relative humidity during the summer season averages about 70 per cent.* The prevailing direction of the wind is southeast and the total run of the wind per day often exceeds 200 miles. The average velocity is about eight miles per hour, but gusts of considerable intensity are frequently experienced, particularly during the spring season.

The principal insect pest attacking citrus in the Lower Rio Grande Valley is the California red scale, *Chrysomphalus aurantii* Mask. The first infestation of California red scale in the United States was reported by J. H. Comstock† at Los Angeles, California, in 1880. This infestation appeared on lemon trees imported from Australia.

Infestations of economic importance were first noted in the Valley in 1922, in orchards near Harlingen. It is very probable that the first infestations in this area occurred on some of the early importations of nursery stock from California. Infested nursery stock was undoubtedly the principal factor in the early spread of this pest throughout the Valley.

In 1925, the Valley Experiment Station instituted a series of experiments relative to the control of this insect. The data presented in this publication are the result of six seasons' observations of this pest under actual field conditions.

## EARLY ATTEMPTS AT CONTROL

Most early attempts toward the control of scale insects on citrus in the Valley were directed against purlple scale, *Lepidosaphes beckii* (Newman), Florida red scale, *Chrysomphalus aonidum* Linn., and chaff scale, *Parlatoria pergandei* Comstock.

Soap, oil, and water combinations were the only materials avail-

*Based on five-year average.
†Report of the U. S. Commissioner of Agriculture,1880, pp. 293-295.

able for the control of these pests. Where infestations of California red scale became severe, these combinations were used with rather indifferent success. With the advent of soapless oil emulsions of the quick-breaking type, it became evident that this insect could be satisfactorily controlled with this type of material. However, the cost and uncertainty regarding many of these early proprietary materials was such that fumigation was attempted. Fumigation gave little relief, as the cost, the results obtained, and the shortness of the season during which effective fumigation could be done, made this method of control impractical.

## NATURE AND IMPORTANCE OF INJURY

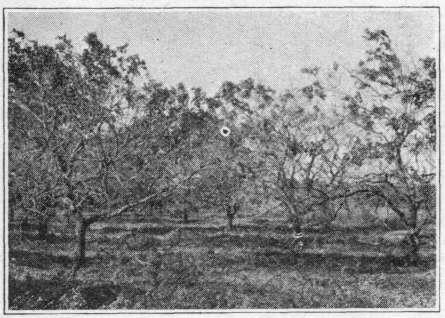

Fig. 1. Grapefruit grove severely defoliated by California red scale.

It was early recognized that red scale was a more serious pest than the other species of scales infesting citrus in this section. Yellowing of foliage, lefoliation, and dropping of fruit caused the growers to realize the necessity for controlling this insect.

The limited supply of grapefruit heretofore produced in this section has caused packers and shippers to be lenient in the grading of fruit in regard to scale infestation. With the increasing supply of fruit, it is only a matter of time until government standards for the grading of citrus fruit are adopted. With the universal adoption of these standards, more critical consideration of the problem of scale control will be necessary, in order to meet the requirements.

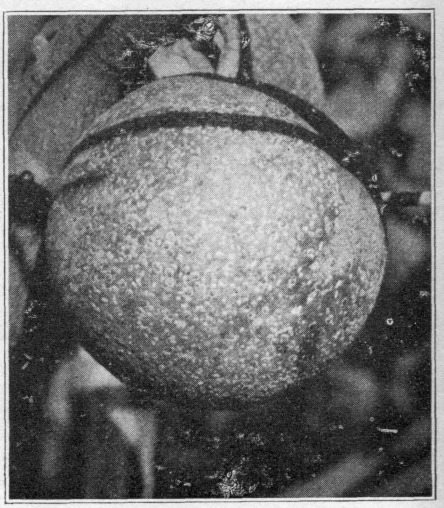

Fig. 2. Red scale on grapefruit.

Red scale injures citrus in several ways. It attacks all parts of the tree, including the limbs, twigs, fruit, and leaves. It not only causes dropping of the fruit and defoliation of the tree, but may kill large branches in cases of severe infestation (Figs 1 and 3). The injury to the tree is caused by the toxic effect of the feeding, devitalization

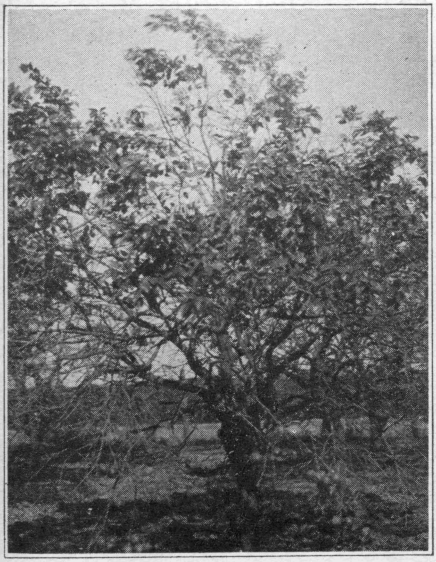

Fig. 3. Grapefruit tree injured by red scale showing severe defoliation and killing of large limbs.

due to loss of sap, destruction of the chlorophyll, and by interference with the normal functions of the tree. The scale on the fruit detracts greatly from its marketable value by affecting its appearance (Fig. 2).

A severe infestation of red scale not only affects the fruit crop during the season in which the damage occurs but may cause a decrease in the crop for several seasons to come. A case is known where an infestation resulted in practically a total loss of fruit for the season. The average yield in this instance was only 20.66 pounds per tree. Approximately a 75 per cent reduction in yield resulted for two subsequent seasons. Many similar cases of severe injury could be cited; however, actual data as to loss of fruit are not available. Thousands of pounds of fruit, which have fallen from the trees on account of injury by red scale alone, have been buried during the last few years. There is no practical way to arrive at a definite measure of the injury caused to the trees by red scale, but it is safe to assume from general observation that the loss in the Valley is very great. This loss is not readily noticed by the average grower, but is reflected in gradually lessened fruit yields.

## DESCRIPTION OF THE INSECT

The female red scale has a thin, slightly convex, circular scale covering, varying from one to two millimeters in diameter (Fig. 4). There is a central exuvia or raised point on the scale covering.

The insect found underneath the scale is nearly round and is light yellow in color (Fig. 5). The scale covering has a reddish cast or may be more or less transparent. Those with the reddish scale coverings are

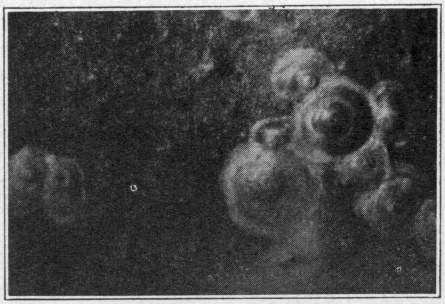

Fig. 4. Enlarged view of red scale showing male and female scales. The two scales on the left are males x 8.

commonly known as red scales, *Chrysomphalus aurantii* Mask., while those with the transparent coverings are called yellow scales,*Chrysomphalus aurantii* var. *citrinus* Coq.

Fig. 5. Photomicrograph of adult female red scale x 50.

The male scale of this species is elongated and much smaller than the female scale (Fig. 4). The mature male is winged and mobile (Fig. 6). The wings are very fragile and probably serve principally for aids in transportation in the wind and not for actual flights of any considerable distance.

## LIFE HISTORY AND HABITS

### Methods of Study

In March, 1929, work was started on the life history of the red scale. Field-grown Euonymus plants were used as the hosts in the first rearing work. Inability to perfect a satisfactory technique on these plants made it necessary to discontinue their use. Potted sour-orange seedlings were then used and proved satisfactory as host plants. These plants were kept under shelter in the insectary, which was screened on all sides. This environment very closely approximated the natural orchard conditions.

The red scale gives birth to living young or "crawlers" (Fig. 7). Ten "crawlers" were placed on a leaf which was isolated from the remainder of the plant by a ring of petroleum jelly. Transfers were made with a camel's-hair brush. The "crawlers" were allowed to settle and develop

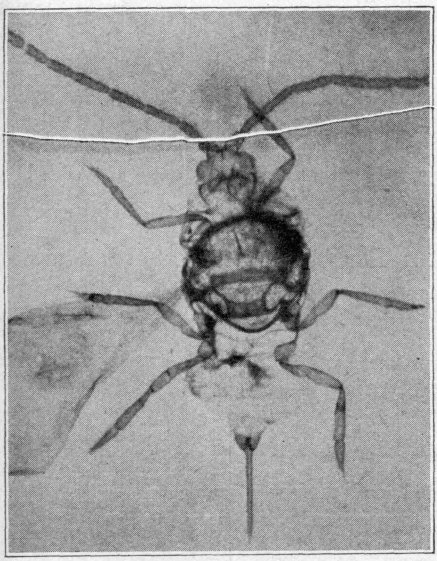

Fig. 6. Photomicrograph of adult male red scale x 50. One wing removed.

normally, but as they neared maturity, all except one of the females on a single leaf were removed. These isolated females were the individuals upon which records were taken. The male scales were allowed to remain until it was certain they had emerged, in order to insure fertilization of the females. It has been continuously noted throughout this work that the majority of the young emerged early in the morning, except when extremely humid conditions prevailed. Most of these "crawlers" settled down to feeding and the production of scale coverings within two hours after emergence. No attempt was made to determine the length of time from actual birth until emergence from beneath the scale covering of the mother. The production of young was recorded at 4 o'clock each afternoon. The young scale "crawlers" which had emerged that morning were completely covered at this time by their white, circular coverings, which facilitated rapid and accurate counting of the young which emerged during each 24-hour period.

Fig. 7. Photomicrograph of red scale crawler x 20.

### Emergence of Young

The emergence of red scale "crawlers" over a period of 14 months was recorded and is presented in Table 1. The total number of insect days is the summation of the number of days during the month on which all the females under test could have produced one or more young. The number of producing days is the summation of the days on which one or more young was produced.

The minimum production occurred in February with an average of .43 young per day per female. The maximum production occurred during May when 46 females averaged 2.18 young each per day. The peak of production occurred during May, June, and July, but production in general continued to be high until October. The production of young is apparently influenced by temperature more quickly than by humidity.

Table 2 summarizes the data of the life history of all the individuals

Table 1. Average number of young emerging by months, and climatological conditions over the period covered in the life history work.

| Month | Total Insect Days | Number Producing Days | Total Number Young Produced | Average No. Young Per Insect Day | Climatological Conditions | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Mean temperature F. | | | Av. Relative Humidity % | | |
| | | | | | Max. | Min. | Mean | Max. | Min. | Mean |
| November 1929 | 95 | 42 | 116 | 1.22 | 71.7 | 56.0 | 61.9 | 100.0 | 45.0 | 84.0 |
| December 1929 | 126 | 68 | 111 | .88 | 70.3 | 49.0 | 59.6 | 97.0 | 45.5 | 81.7 |
| January 1930 | 163 | 52 | 85 | .52 | 64.2 | 45.3 | 54.7 | 99.5 | 42.0 | 79.5 |
| February 1930 | 112 | 35 | 48 | .43 | 77.9 | 55.5 | 66.7 | 97.0 | 44.0 | 77.2 |
| March 1930 | 196 | 79 | 137 | .70 | 76.6 | 54.5 | 65.5 | 95.0 | 24.5 | 59.7 |
| April 1930 | 385 | 259 | 524 | 1.36 | 88.0 | 62.8 | 75.4 | 89.5 | 52.0 | 76.3 |
| May 1930 | 810 | 662 | 1765 | 2.18 | 88.2 | 72.4 | 80.3 | 97.5 | 68.5 | 85.0 |
| June 1930 | 1440 | 1213 | 2988 | 2.07 | 87.7 | 74.5 | 79.6 | 100.0 | 70.0 | 85.3 |
| July 1930 | 1422 | 1154 | 2786 | 1.95 | 95.5 | 71.8 | 82.6 | 92.0 | 64.0 | 78.2 |
| August 1930 | 798 | 615 | 1332 | 1.67 | 96.2 | 72.1 | 84.2 | 84.5 | 55.5 | 72.4 |
| September 1930 | 704 | 565 | 1193 | 1.69 | 94.8 | 72.0 | 83.4 | 94.5 | 54.5 | 69.6 |
| October 1930 | 1653 | 1168 | 2180 | 1.32 | 83.9 | 66.5 | 75.2 | 95.5 | 65.5 | 79.6 |
| November 1930 | 1231 | 492 | 744 | .60 | 73.3 | 57.4 | 65.4 | 97.5 | 55.0 | 81.9 |
| December 1930 | 574 | 216 | 316 | .55 | 67.6 | 48.8 | 58.2 | 97.0 | 54.5 | 79.7 |

used in this phase of the project. It will be noted that there is considerable difference between the maturation periods. These periods were approximately half as long during the summer and fall as during the winter and spring. The maximum number of young which emerged from beneath one female in one day was 16. This was probably abnormal; however, emergence of 6 or 7 young per day was not uncommon. The maximum total length of life was 261 days for female No. 51, which settled in September, 1929; the minimum was 57 days for female No. 207, which settled in June. The length of the young-producing period varied during the year from 15 to 197 days. The total number of young per female varied from a maximum of 300, produced during the summer, to a minimum of 27 produced during the early fall.

Table 2. Maturation Period, Length of Life, and Length of Young-Producing Period of Red Scale Females Maturing Within Given Months, 1929—1930.

| Month | Maturation Period (Days) | Length Life (Days) | Length Young Producing Period (Days) |
|---|---|---|---|
| November | 53.7 | 191.5 | 137.8 |
| December | 91.0 | 217.0 | 126.0 |
| January | 102.0 | 258.0 | 156.0 |
| March | 123.0 | 233.8 | 110.7 |
| April | 88.3 | 172.1 | 83.8 |
| May | 53.9 | 128.8 | 75.0 |
| June | 50.1 | 93.5 | 43.4 |
| July | 43.1 | 92.5 | 49.4 |
| August | 40.1 | 99.0 | 58.9 |
| September | 42.5 | 110.0 | 67.5 |

The number of individuals upon which the various records were taken varied during the winter and spring from 5 to 23; and varied during the summer and fall from 49 to 68.

## Settling of the Larvae

Only a comparatively small percentage of "crawlers" liberated in the insectary "settled" and actually produced mature scales. The transfers were made with a camel's-hair brush from which all but two or three of the hairs had been clipped. This facilitated the transfer and was not injurious to the larvae. A record of the number of scales which settled was made about three weeks after transferring. Conditions in the insectary closely approximated natural conditions, and the young scales were subject to the wind and sun, as they would have been in the field. It was apparent that the larvae preferred to settle upon the young, tender twigs and leaves, but would settle upon the older leaves of the potted plants.

Table 3 shows the percentage of "crawlers" settling at different months of the year. The season appears to have considerable effect on the number of young actually settling and maturing.

Under Valley conditions the larvae seem to prefer to settle upon the fruit, as usually this is the first portion of the tree to show any great abundance of scale. There seems to be little difference between infestation of the leaves and infestation of the twigs.

### Proportion of Sexes

The proportion of male larvae to female larvae settling at different months of the year, is shown in Table 4. Apparently the larger numbers of males which are produced is necessary to insure fertilization of the females. These males do not appear to be any more abundant during any one portion of the season; in fact, they can be found rather easily at nearly any period of the year.

Table 3. Percentage of Crawlers Settling on Leaves in Various Months of the Year 1930

| | Month Liberated | | | | | |
|---|---|---|---|---|---|---|
| | April | May | June | July | August | October |
| Number Liberated | 410 | 100 | 90 | 380 | 560 | 340 |
| Number Settled | 128 | 58 | 40 | 102 | 349 | 228 |
| Per cent Settled | 31.2 | 58.0 | 44.4 | 26.8 | 62.3 | 67.0 |

## MEANS OF SPREAD

Red scale probably was introduced and spread throughout the Valley by means of infested nursery stock. There is slight possibility that infested fruit was also a factor. The spread of scale locally is effected largely by wind, birds, lady beetles, and other orchard-inhabiting insects. The wind and birds are undoubtedly the major factors. Some spread is caused by man in his cultural operations. Dr. H. J. Quayle* states that the maximum distance travelled by red scale young upon smooth paper was 111 inches when the temperature was 91 degrees Fahrenheit and that of the 319 individuals tested on orchard soil, only 14 crossed strips of soil three inches in width. It can readily be seen, according to these data, that the chances of spread over orchard soil, from tree to tree, would be comparatively remote.

Table 4. Proportion of Sexes Among Crawlers Settling in Various Months of the Year 1930

| | Young Liberated | | | | | | |
|---|---|---|---|---|---|---|---|
| | April | May | June | July | August | October | Total |
| Total No. Settled | 128 | 58 | 40 | 102 | 349 | 228 | 905 |
| Number Males | 86 | 35 | 26 | 61 | 170 | 141 | 519 |
| Number Females | 42 | 23 | 14 | 41 | 179 | 87 | 386 |
| Per cent Males | 67.2 | 60.4 | 65.0 | 59.8 | 48.7 | 61.9 | 57.3 |
| Per cent Females | 32.8 | 39.6 | 35.0 | 40.2 | 51.3 | 38.1 | 42.7 |

## HOST PLANTS

Red scale† attacks a large variety of plants in the Valley. Some of these may be as severely infested as citrus. It should be noted that

*Red or Orange Scale. California Exp. Sta. Bul. No. 222, 1911, p. 130.
†For the purpose of this Bulletin, both red and yellow scales are designated as red scale.

infestations on the various plants may serve as sources for reinfestation when they are located near the citrus grove.

A list of the host plants upon which red scale has been taken, their degree of susceptibility, and their use, is shown in Table 5.

Table 5. Host Plants of the California Red Scale in the Lower Rio Grande Valley.

| Host | Degree of Infestation | Use |
|---|---|---|
| Ash (Green) | Moderate | Shade tree |
| Asparagus plumosus | Moderate | Mostly used as an ornamental |
| Athel | Heavy | Commonly used as windbreak |
| Australian Pine | Light | Promising windbreak plant |
| Avocado | Heavy | Fruiting plant |
| Bauhinia | Moderate | Ornamental, rarely used |
| Carob | Light | Ornamental |
| Castor Bean (Fig. 8) | Heavy | Ornamental |
| China berry | Moderate | Shade tree |
| Citrus | Heavy | Commercially important |
| Elm (Moline) | Light | Shade tree |
| English Ivy | Light | Ornamental |
| Euonymus (Fig. 9) | Heavy | Ornamental |
| Grape | Moderate | Commercial possibilities |
| Hackberry | Light | Shade tree |
| Horseweed (Leptilon canadense) | Moderate | Weed occurring in orchards |
| Hibiscus mutabilis | Light | Ornamental |
| Jasmine humile | Light | Ornamental |
| Ligustrum japonicum | Moderate | Ornamental |
| Ligustrum lucidum | Moderate | Ornamental |
| Locust (Black) | Light | Shade tree |
| Locust (Honey) | Light | Shade tree |
| Mexican poinsetta | Light | Ornamental |
| Mulberry | Heavy | Shade tree |
| Oleander | Light | Commonly used as ornamental windbreak plant |
| Palm | Light | Commercial possibility |
| Privet (Amur-River) | Moderate | Ornamental |
| Privet (California) | Moderate | Ornamental |
| Ragweed (Ambrosia artemisiifolia) | Moderate | Weed occurring in abundance in orchards |
| Rose | Moderate | Ornamental |
| Salt Cedar (Tamarix) | Heavy | Ornamental |
| Sago palm | Heavy | Ornamental |
| Sesbania cannabina | Light | Promising cover crop |
| Wild olive | Light | Native plant-not common |
| Willow | Moderate | Ornamental |

Infestations on athel, the most popular windbreak plant used at the present time, are quite common. The presence of red scale on this plant, when close to an orchard, provides a ready source of reinfestation to citrus. Infestations on oleander and Mexican poinsetta are of infrequent occurrence and usually limited to a few scales well scattered over the plants, and are probably not a serious menace to the grove.

Red scale has been taken on horseweed and ragweed in a single instance. Scales in all stages were present upon these weeds which were growing close to the trees and, in many cases, extended into the branches. Such infested weeds would constitute sources of reinfestation to citrus.

## NATURAL CONTROL

### Predators

The twice-stabbed ladybeetle, *Chilocorus bivulnerus* Muls., is the most

important of the natural enemies of red scale in this locality. The adults are hemispherical, glossy black, with two red spots on the wing covers. The eggs are yellowish, elongated, cylindrical objects and are laid either singly or in groups anywhere on the plants. The larvae are covered with many long, branched spines and are black in color. They pupate in the last larval skin usually on the undersides of the limbs and may be found in great masses when scales are abundant (Fig. 10). The twice-stabbed ladybeetle is a voracious feeder and can consume many adult scales during its lifetime. Both larvae and adults feed on the scale.

### Parasites

Two parasites, *Aphelinus chrysomphali* Mercet. and *Prospaltella aurantii* (How.), have been reared from the red and the yellow forms of the California red scale, respectively. *Aphelinus chrysomphali* Mercet. is quite abundant and may be seen with but little trouble during the greater portion of the year. *Prospaltella aurantii* (How.) has been reared only a single time from yellow scale and is evidently rather rare in this region. This species was quite abundant on this occasion but has never been observed since, and the writers are at a loss to account for the apparent disappearance of this parasite.

### Entomogenous Fungi

In 1928, the black fungus, *Myriangium duriaei* Mont., was commonly noted on red scale. Climatological conditions were abnormal that year with much rainfall and high humidity. Under ordinary conditions, the climate in this locality is not favorable to the growth of parasitic fungus organisms upon red scale.

### Temperature

Some interesting records on the effect of low temperatures on scale mortality were obtained during the winter of 1929-30, when temperatures in this section ranged lower than usual. Within a few hours following the occurence of a temperature of 32 degrees F. in December, crawlers were observed emerging when the temperature had reached 63 degrees. Later in this month, following three consecutive nights, December 22, 23, and 24, when the minimum temperatures were 29, 28, and 33 degrees, respectively, 7 females produced a total of 8, 6, and 10 young on December 25, 26, and 27, respectively. The coldest weather of this winter occurred during the period January 16 to 25, inclusive. The mean temperature for the 10-day period was 40.72 degrees, which is the record cold spell for this section. This unfavorable weather apparently had little effect on emergence of crawlers. Eight females produced a total of 21 crawlers during the 3-day period immediately following the cold spell. All of these females except two survived and continued to produce young until spring. One of the two which died was accidently killed. Observations made in the grove during

the three-day period above mentioned showed young emerging.

The percentage of dead scales found on old leaves increased from 58.7 per cent in December, 1929, to 84.2 per cent in March, 1930. This record of mortality is approximately the same as that of 83.9 per cent recorded in a similar way in April, 1928, following an average winter.

## CONTROL BY FUMIGATION

The rapid expansion of the citrus industry in the Rio Grande Valley created an urgent demand for information concerning the control of California red scale, the major pest. The pressing nature of this situation made it advisable to test control measures from the very beginning of the work with this insect.

Early efforts in controlling the red scale in the Lower Rio Grande Valley with materials then available had not given satisfactory results, largely because there was no definite information concerning the time of applying oil sprays in controlling scale insects under Valley conditions.

Since fumigation had proved so successful in controlling this pest in California, it seemed advisable to test this method under Valley conditions.

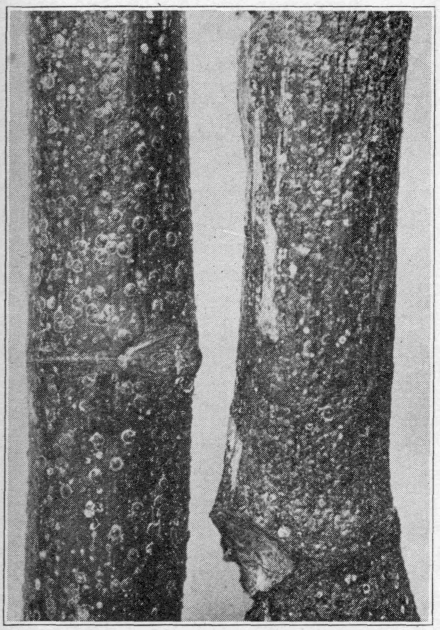

Fig. 8. Red scale on castor bean—slightly enlarged.

**Fumigation Experiments 1926:** Experiments in the control of red scale by fumigation were cyanide, acid, and water, according to the old pot method, divided into three groups: winter, spring, and summer treatments. Fumigation with sodium and fumigation with two brands of commercial cyanide dust were tried this season.

During the winter months, fumigation with rather high concentrations of gas caused little or no injury to the trees and gave an excellent scale kill. From this experience, it was thought that winter fumigation offered considerable possibilities. However, reinfestation occurred during late July and August, and scale damage was noticeable on these trees.

Daylight fumigation during April, using 75 per cent and 50 per cent concentrations of gas from cyanide dust, was very disastrous. No night fumigation was done. Injury by the gas was to the fruit and young flush of growth. This damage amounted to a heavy loss of fruit on many trees.

A block of 100 trees fumigated during May produced an excellent crop of fruit practically free from scale. This fumigation was done with a different brand of material from that used in April. The work was done at night, using 100 per cent dosage.

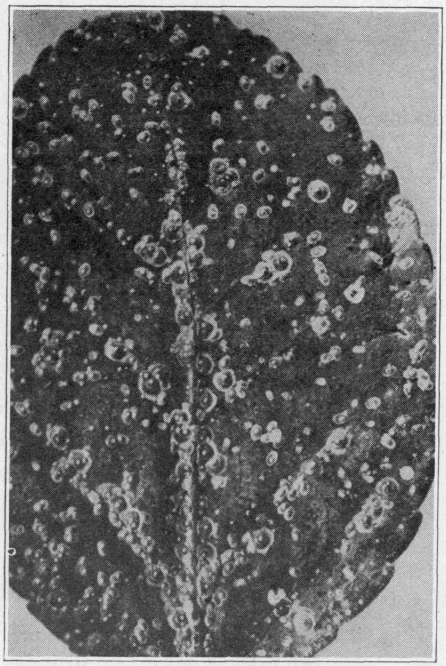

Fig. 9. Red scale in all stages of growth on Euonymus leaf—slightly enlarged.

**Fumigation Experiments, 1927:** The first fumigation done during this year was confined to the winter season. All fumigation was done at night with 100 per cent dosage. One plat was fumigated when there was no wind blowing, and the others were treated when there was sufficient wind to rustle the tents. The trees were just beginning to bloom at the time the treatment was given. From the standpoint of scale kill, there was 96 to 100 per cent dead scale on the treated trees, as compared with 76.2 to 89.3 per cent dead scale on the untreated trees. However, reinfestation occurred during the spring and summer months, spreading from infested trees nearby, showing that even perfect kills cannot be depended upon to prevent scale injury when infested trees are relatively close.

The data on scale-spread, in Table 7, were taken on the basis of a number of leaves known to be free from scale. These were tagged for observation later, and after the spread of scale was counted, a new set of scale-free leaves was tagged. A count of 1,344 leaves in February and another of 1,222 leaves in March showed no increase during this period. An extraordinary increase in the number of scale resulted during the period April 30 to September 9. As will be noted in Table 6, the post-fumigation mortality was highly satisfactory.

Table 6. Results of Fumigation in February, 1927, upon Red Scale

| Plat No. | Fumigation | No. Trees | Per cent Dead Before Fumigation, Feb. 5 | Per cent Dead After Fumigation, Mar. 14 |
|---|---|---|---|---|
| 1 | Feb. 15, 1927 | 12 | 80.3 | 99.6 |
| | Check | 1 | 93.9 | 89.3 |
| 2 | Feb. 15, 1927 | 12 | 80.3 | 98.8 |
| | Check | 1 | 88.5 | 76.2 |

In July of this same year, a block of sixty-eight trees was fumigated with calcium cyanide dust. The scale mortality from this fumigation was not as satisfactory as it should have been, judging from the experience of the previous season. Some injury resulted, the most noticeable of which was burning of the tender growth and some pitting of the fruit.

Table 7. Scale-Spread to Leaves after February Fumigation, 1927.

| Counts taken | Plat No. | No. Leaves Used | No. Scale | No. Scale per Leaf Average |
|---|---|---|---|---|
| 4/30/27 | 1 | 515 | 102 | .198 |
| | Check | 54 | 8 | .148 |
| | 2 | 514 | 137 | .266 |
| | Check | 58 | 24 | .413 |
| 9/9/27 | 1 | 159 | 7,959 | 50.05 |
| | Check | 20 | 462 | 23.10 |
| | 2 | 166 | 13,955 | 84.06 |
| | Check | 25 | 2,331 | 93.24 |

Fumigation in August produced exceptional results. Mortality records showed that 98.3 to 99.2 per cent of the scale insects were dead. The injury was about the same as that observed in July.

The July and August fumigation was conducted on rows which had received previous treatments of oil emulsion sprays early in the season. Under ordinary conditions, without the protection oil sprays would give, the infestation before August might be so great that considerable damage would be done to the trees.

**Fumigation Experiments 1928:** In February of 1928, a block of 240 trees was fumigated with calcium cyanide dust. As late as June 1, counts showed that 98 to 100 per cent of the scale were dead. This scale kill was very satisfactory (Table 17); however, it was necessary to spray with oil emulsion during September, in order to stop the severe injury which red scale was causing. Enormous amounts of fruit fell from the trees in this block during August and September. Slight injury from the fumigation could be noted on a few trees. The cost of the fumigation treatment, which was 95 cents per tree, was excessive, considering the amount of protection it afforded.

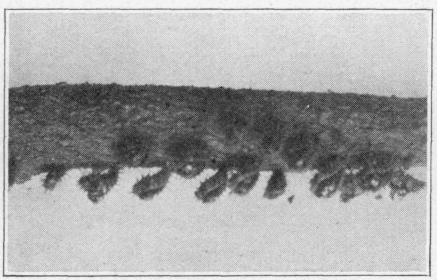

Fig. 10. Pupae of the twice stabbed lady beetle on under side of grapefruit limb.

The cost of fumigation, and the fact that both spraying and fumigation would be necessary, made it advisable to discontinue the fumigation experiments.

## CONTROL BY SPRAYING

The first concerted efforts at controlling scale insects in the Lower Valley with power spraying were made in 1923. At this time power

spraying machinery began to be generally distributed. Only two brands of oil sprays were then being offered for sale in the Valley. As the need for adequate methods of controlling scale insects became evident, other proprietary oil sprays were introduced. These materials differed in composition and the formulas of most of them were changed by the manufacturers from one season to the next, in an effort to minimize the danger of spray injury and to afford greater protection from scale. This was the evolutionary period in the development of oil sprays, as exemplified by the better types now available to Valley growers. This situation caused a chaotic condition to develop in regard to the selection of the kind of oil emulsion for use in scale control work.

In the course of the early work of testing materials, it was obvious that information should be secured regarding the proper time for making the applications, in order to secure the best results.

### Tests on Time of Application

The grapefruit trees used in these tests were five years of age when the work was started and were of the Marsh variety. The plats consisted of rows of twelve trees each. Sufficient guard space to eliminate border effect was allowed in all cases. The size of the test plats varied from 4 to 9 trees.

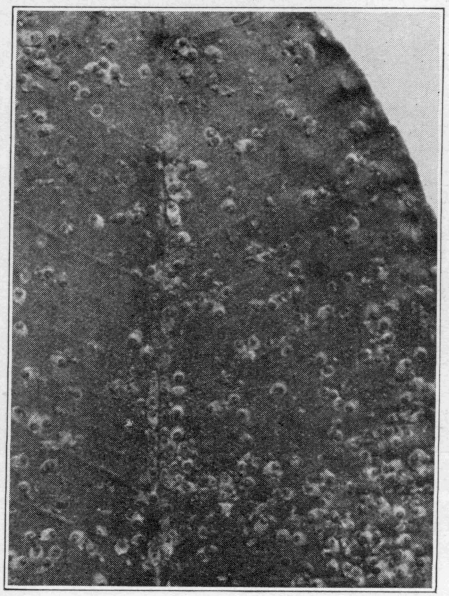

Fig. 11. Chaff scale. Often mistaken for red scale.

Applications were made with a power spray rig capable of maintaining a pressure of 350 pounds when delivering 10 gallons of spray per minute. During the seasons of 1926, 1927, and 1928, spray guns with small disk apertures (1/16 to 5/64) were used in applying the oil sprays. Bean "all spray" rods with three nozzles each were used in applying the materials during the last two seasons.

An effort was made to spray the trees in a thorough manner without using an excessive amount of material. The average amount of spray solution applied per tree varied from 8 gallons in 1926 to 18 gallons in 1930. In extreme cases, it seemed advisable to apply as much as 25 gallons of spray per tree, in order to insure proper coverage.

The formula for the stock emulsion of the sprays used in the 1926 and 1927 tests is as follows:

| | |
|---|---|
| Potash fish oil soap | 2 pounds |
| Lubricating oil | 2 gallons |
| Water | 1 gallon |

This is known as the Government formula for "Boiled Emulsion." In all later tests oil emulsions of the quick-breaking type were used. The term "quick breaking" is used to designate a type of oil emulsion in which the oil is in the form of a film around small particles of colloidal material and separates as free oil when applied under high pressure.

**Test on Time of Application 1926:** The government formula for oil emulsion was used exclusively in these tests. Winter spraying was ineffective in controlling red scale this season. Some difficulty was experienced by reinfestation coming from adjoining plats. In many cases there were more live scale per leaf 35 to 40 days after spraying than there were when the spray material was applied. This fact demonstrated clearly the importance of thorough coverage of all portions of the tree with the spray materials.

**Test on Time of Application 1927:** Considerable difficulty was experienced in this series of tests in keeping the emulsion from separating in the spray tank, due to the salts in solution in the spray water, which was taken from the irrigation canals. Caustic potash and potash fish oil soap were used in attempts to "soften" the water, but the results secured were not entirely satisfactory. After numerous tests had been made to determine the proper material for use in softening the water, it was noted that where the government formula oil emulsion was used in water which contained Bordeaux, there was very little oil separation. During the remainder of these tests, Bordeux 1/2-1/2-50 was used with this oil emulsion. There was considerable variation in the actual scale mortality resulting from spraying with this material (Table 8). Excessive injury to the trees and fruit occurring with the May and June applications made this material of questionable value for general use. Defoliation, burned fruit, shadowed fruit, yellowed foliage, and dwarfed young twigs all appeared on the

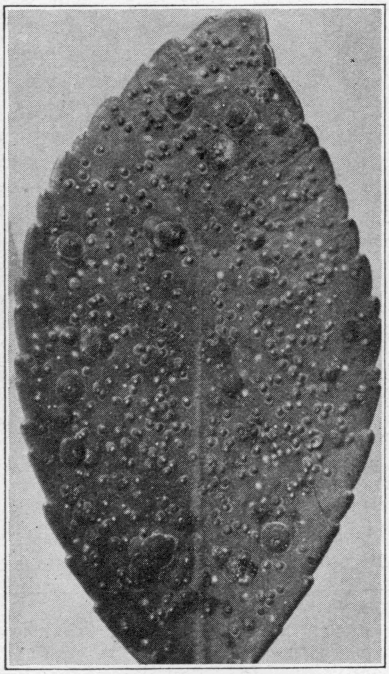

Fig. 12. Florida red scale. May be mistaken for California red scale. This scale is purplish black in color.

sprayed trees. The schedule of spraying with this material was discontinued with the June application.

Table 8. Relation of Time of Application of Spray to the Percentage of Dead Scales, 1927.

| Row | Treatment (Sprayed) | Per cent Dead on Date Indicated* | | | | | |
|---|---|---|---|---|---|---|---|
| | | Jan. 27 | Mar. 7 | April 8 | May 18 | June 7 | July 27 |
| 31 | April, June | ..... | ..... | 63.0 | 65.3 | ..... | 93.1 |
| 35 | Feb., Apr., May, June | 41.1 | 82.3 | 43.9 | ..... | 66.5 | 91.2 |
| 29 | Feb., Apr., June | 66.7 | 74.7 | ..... | 82.9 | ..... | 90.4 |
| 24 | Jan., Apr., June | 63.4 | 85.9 | ..... | 42.6 | ..... | 89.3 |
| 26 | Feb., April | 58.5 | 81.0 | ..... | 74.5 | ..... | 84.6 |
| 25 | Jan., Apr., May | 63.4 | 74.1 | ..... | 83.5 | ..... | 83.2 |
| 28 | Feb., Apr., May | 51.2 | 86.0 | ..... | 87.0 | 62.7 | ..... |
| 27 | Feb., Apr., May | 60.5 | 91.1 | ..... | 94.0 | 61.7 | ..... |
| 34 | May, June | ..... | ..... | ..... | 22.1 | 47.1 | ..... |
| 32 | Feb., Apr., May | 49.0 | 71.0 | ..... | 46.5 | 42.0 | ..... |
| 33 | April | ..... | ..... | 54.0 | 54.9 | ..... | ..... |
| 30 | February | 58.1 | 75.3 | ..... | ..... | ..... | ..... |

*Records made during the same months as the spraying are based on prespray counts.

It should be noted that plats which received applications of oil sprays as late as June showed a higher percentage of dead scale than did plats which received applications in April or before. The results of this work indicate that summer spraying was more effective in scale control than was winter or spring spraying.

**Test on Time of Application 1928:** The red scale infestation in the Station grove this season was the most severe that had ever been experienced. Trees which were not sprayed, sprayed only during the winter, or sprayed with "light" oil sprays were severely defoliated, and in some instances, all trees in certain plats shed practically all of their fruit and foliage. The plats of unsprayed and winter-sprayed trees were the most severely damaged. Trees sprayed twice during the summer with "heavy" oil sprays (100 seconds, Saybolt) retained their foliage and most of their fruit.

Table 9. Relation of Time of Application of Spray to the Percentage of Dead Scales, 1928.

| Row | Material | Time Sprayed | Per Cent Dead** | | |
|---|---|---|---|---|---|
| | | | May | July | August |
| 22 | Oil Emulsion No. 2 2% Heavy Oil | May, July | 80.0 | 87.7 | 81.2 |
| 23 | Oil Emulsion No. 2 2% Heavy Oil | May | 89.6 | 81.8 | 9.2 |
| 26 | Oil Emulsion No. 1, 2% | Feb., May, July | 87.8 | 68.2 | 60.2 |
| 27 | Oil Emulson No. 1, 2% | May, July | 89.8 | 59.6 | 56.0 |
| * | Oil Emulsion No. 1, 2% | July | 78.6 | 35.4 | 36.3 |
| 24 | Oil Emulsion No. 1, 2% | Feb., July | 74.0 | 33.5 | 22.2 |
| 19 | Oil Emulsion No. 1, 2% | Feb. 24—1% Feb. 25—2% | 93.2 | 24.9 | 10.0 |
| 25 | Oil Emulsion No. 1, 2% | February | 89.9 | 52.4 | 9.6 |
| 28 | Oil Emulsion No. 1, 2% | May* | 81.8 | 76.2 | 9.2 |
| 30 | Oil Emulsion No. 1, 2% | May | 80.4 | 72.3 | 8.8 |
| 15 | Oil Emulsion No. 1, 2% | May | 37.6 | 52.1 | 6.1 |
| 13 | Oil Emulsion No. 1 3% Light Oil | February | 99.6 | 19.4 | 10.4 |
| *** | Unsprayed | | 79.6 | 20.8 | 8.7 |

*Average of two plats (16 and 29).
**Records made during the same months as the spraying are based on prespray counts.
***Average of three plats (14, 17, and 18).

As will be noted in Table 9, oil emulsion No. 2, utilizing the heavy oil, applied in May and July, gave a higher percentage of scale mortality at the August count than did any other treatment. The single application

in May, of this emulsion, and the lighter oil sprays in single applications gave equally as poor results as where the trees were unsprayed. The lighter oil spray applied in May and July gave much better results than when the applications were made at other times, with the exception of the February, May and July applications. However, the latter treatment was no better than the May and July applications, and evidently the February spray was superfluous.

A single plat of trees (row 19) showed severe defoliation and complete loss of fruit crop by July. Since this was the only plat receiving spray treatment on two successive days, the unusual amount of injury was apparently caused by some other factor than red scale. The first spraying consisted of an application of a 1% mixture of "light" oil spray in February only, followed in 24 hours with an application of a 2% solution of the same material.

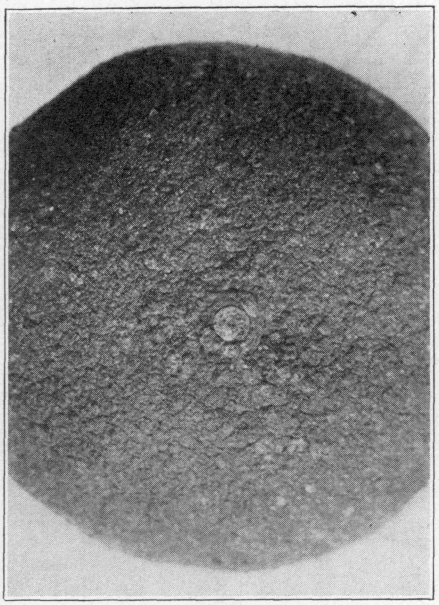

Fig. 13. Grapefruit completely encrusted with red scale.

**Test on Time of Application 1929:** It was realized from previous work that the scale-spread from row to row may have influenced the results. Therefore, the plats were arranged so that alternate rows constituted check plats. These check rows were sprayed in May and July with an oil emulsion, using a heavy oil of low volatility. The results secured (Table 10) show that the check rows were kept practically free from scale. This same oil spray was used in all of the tests on time of application during 1929. The percentage of scale killed was not used as a measure of the effectiveness of the various spray treatments as in 1928, because it appeared that increases in scale population on young leaves and fruit, and on mature fruit furnished a more reliable measure.

The scale counts shown in Table 10 were taken at the end of each month. One hundred and sixty young, scale-free leaves per plat were tagged at the begining of each month. The number of scales settling on these leaves was used as the measure of the efficiency of the spray treatments. The results indicate that winter spraying was effective in reducing the scale population during the early part of the season only. Plats receiving single applications of oil spray per season, and a plat sprayed at monthly intervals with lime-sulphur solution, were more heavily infested with

Table 10. Results of Tests on Time of Application of Spray in 1929 as Indicated by the Average Increase or Decrease in the Number of Scales on Each Leaf

| Row | Treatment Sprayed | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks |
| 37 | August | 2.6 | .2 | + 2.4 | 8.7 | .8 | + 7.9 | 18.7 | .4 | + 18.3 | 1.6 | 3.3 | — 1.7 |
| 33 | July & Sept. | 7.9 | .0 | + 7.9 | 10.7 | .2 | + 10.5 | 2.4 | .5 | + 1.9 | .6 | 1.5 | — .9 |
| 29 | May & August | .3 | .3 | .0 | .0 | .2 | — .2 | 1.5 | .5 | + 1.0 | .6 | .6 | .0 |
| 18 | February & July | .1 | .1 | .0 | 1.7 | .8 | + .9 | 2.1 | .8 | + 1.3 | 1.0 | .8 | + .2 |
| 21 | May & July | .0 | .5 | — .5 | 1.7 | .7 | + 1.0 | .6 | 1.0 | — .4 | .6 | .2 | + .4 |
| 31 | May & September | .0 | .0 | .0 | .1 | .1 | .0 | 1.5 | .2 | + 1.3 | 2.5 | .5 | + 2.0 |
| 27 | July | 3.8 | .4 | + 3.4 | 17.2 | .2 | + 17.0 | 3.0 | .3 | + 2.7 | 3.3 | .9 | + 2.4 |
| 23 | May | .3 | .6 | — .3 | .0 | .2 | — .2 | 3.8 | .5 | + 3.3 | 3.9 | .1 | + 3.8 |
| 16 | February & May | .1 | .8 | — .7 | .0 | .8 | — .8 | 4.9 | .6 | + 4.3 | 9.8 | 1.1 | + 8.7 |
| 14 | February | 7.1 | 1.4 | + 5.7 | 4.8 | 1.6 | + 3.2 | 15.4 | .7 | + 14.7 | 21.5 | .7 | + 20.8 |
| 35 | Lime Sulphur (Monthly | .3 | .1 | + .2 | 6.1 | .3 | + 5.8 | 22.1 | .6 | + 21.5 | 57.4 | 4.2 | + 53.2 |
| 39 | Unsprayed | 8.0 | .1 | + 7.9 | 18.7 | 1.0 | + 17.7 | 22.5 | .1 | + 22.4 | 15.8 | .4 | + 15.4 |

*Check rows are all others not included above from Row 13 to Row 40, inclusive. Sprayed in May and July with oil emulsion. Average for checks consists of average for both checks, one on either side of plat.

scale at the close of the spraying season than were the check plats (sprayed in May and July), except in the case of the plat of trees sprayed during the month of August. However, it will be noted in Fig. 15 that August spraying alone can not be depended upon where clean fruit is the major consideration. The May and July applications of oil sprays, as used on the check plats, gave more satisfactory control of scale this season than any other treatment used.

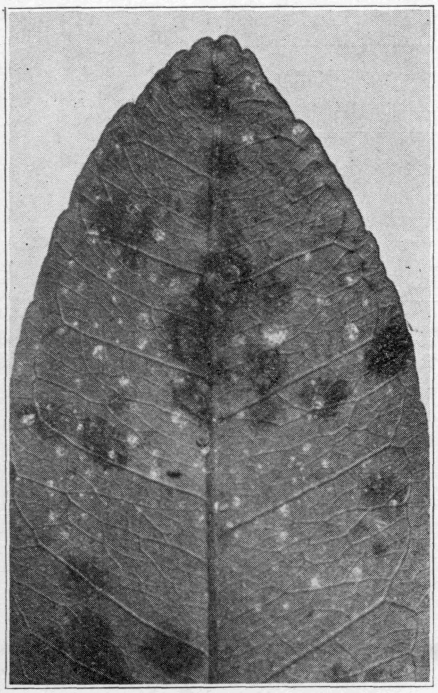

Fig. 14. Red scale injury to grapefruit leaf. Dark areas surround location of scales which may be present upon upper or lower side of the leaf.

Table 11 gives the increases or decreases in the scale population on the fruit by months. Fruits were tagged at the beginning of the season and the increases shown are actual increases in numbers of scale over the previous count. It will be noted that there is a consistent increase in the case of the winter-sprayed, lime-sulphur-sprayed, and on the unsprayed plats. The winter and May, or winter and July sprayings gave only slightly better control than did the May or July spraying alone. The extraordinary increase of scale on the lime-sulphur-treated plat over the unsprayed plat was undoubtedly due to the repellent action of the lime-sulphur on the parasites and predators of the scale. These results rather closely paralell the scale-spread to the leaves.

The results of the time of application experiments as expressed in relative amounts of scale on the mature fruit, are presented in Table 12. Plats of trees sprayed both during May and July produced a higher percentage of commercially clean fruit than did any of the other plats. Plats receiving both February and summer applications produced fruit which was no better than that produced on plats receiving a single oil spray treatment during the summer season. Fruits from trees sprayed a single time per season were more heavily infested with scale than were fruits from plats receiving two summer applications. Trees which were sprayed with lime-sulphur solution at monthly intervals were partially defoliated and produced fruit which was so heavily infested with scale as to be unmarketable. The unsprayed trees were severely damaged by scale this season.

Table 11. Results of Tests on Time of Application of Spray in 1929 as Indicated by the Average Increase or Decrease in the Number of Scales on Each Fruit.

| Row | Treatment Sprayed | June | | | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease Compared with Checks |
| 37 | August | .0 | .1 | — .1 | 5.8 | 3.3 | + 2.5 | 3.4 | 2.0 | + 1.4 | 2.5 | 3.4 | — .9 |
| 21 | May & July | .0 | .2 | — .2 | 3.5 | 1.0 | + 2.5 | 2.9 | 2.0 | + .9 | 1.3 | 1.3 | .0 |
| 29 | May & August | .3 | .2 | + .1 | 3.8 | 2.8 | + 1.0 | .9 | 1.0 | — .1 | 1.2 | 1.1 | + .1 |
| 23 | May | .0 | .1 | — .1 | 1.9 | 1.0 | + .9 | 1.1 | 1.8 | — .7 | 1.6 | .8 | + .8 |
| 27 | July | 1.0 | .1 | + .9 | 10.6 | 4.3 | + 6.3 | 2.6 | 3.3 | — .7 | 2.6 | 1.4 | + 1.2 |
| 31 | May & September | .0 | .1 | — .1 | .9 | .4 | + .5 | .3 | .1 | + .2 | 1.5 | .3 | + 1.2 |
| 33 | July & September | 1.3 | .0 | + 1.3 | 10.6 | 1.0 | + 9.6 | 5.1 | .2 | + 4.9 | 1.9 | .6 | + 1.3 |
| 16 | February & May | .6 | .8 | — .2 | 4.9 | 2.8 | + 2.1 | 3.0 | 4.4 | — 1.4 | 6.6 | 1.5 | + 5.1 |
| 18 | February & July | 1.4 | .1 | + 1.3 | 15.1 | 1.0 | +14.1 | 5.7 | 2.9 | + 2.8 | 11.8 | 1.9 | + 9.9 |
| 14 | February | 1.1 | 1.0 | + .1 | 5.7 | 3.5 | + 2.2 | 21.8 | 3.1 | +18.7 | 23.2 | .2 | +23.0 |
| 35 | Lime Sulphur (Monthly | 1.5 | .1 | + 1.4 | 17.5 | 2.1 | +15.4 | 59.4 | 2.1 | +57.3 | 179.3 | 3.5 | +175.8 |
| 39 | Unsprayed | 11.7 | .0 | +11.7 | 19.6 | 3.2 | +16.4 | 10.6 | 1.7 | + 8.9 | 24.8 | .7 | +24.1 |

*Check rows are all others not included above from Row 13 to Row 40, inclusive. Sprayed in May and July with oil emulsion.

**Test on Time of Application 1930:** The same general plan as that used during the season of 1929 was followed in 1930. The results are expressed in terms of scale-spread to young leaves and fruit, and amount of scale on mature fruit.

Table 12. Effect of Time of Application of Spray Materials on Production of Clean and Infested Fruit at Harvest, 1929.

| Row | Treatment (Sprayed) | Clean Fruit % | Lightly Infested % | Moderately Infested % | Heavily Infested % |
|---|---|---|---|---|---|
| Checks* | May & July | 80 | 18 | 2 | 0 |
| 21 | May & July | 90 | 8 | 2 | 0 |
| 31 | May & September | 84 | 16 | 0 | 0 |
| 29 | May & August | 80 | 19 | 1 | 0 |
| 16 | February & May | 74 | 17 | 9 | 0 |
| 18 | February & July | 71 | 28 | 1 | 0 |
| 33 | July & September | 67 | 32 | 1 | 0 |
| 27 | July | 67 | 31 | 2 | 0 |
| 37 | August | 64 | 35 | 1 | 0 |
| 23 | May | 62 | 34 | 4 | 0 |
| 14 | February | 22 | 56 | 21 | 1 |
| 35 | Lime Sulphur (Monthly) | 0 | 4 | 47 | 49 |
| 39 | Unsprayed | 21 | 59 | 19 | 1 |

*Average of 14 plats.

The results secured in 1930 are summarized in Tables 13, 14, and 15. The average increases or decreases in scale population on young leaves as compared with the check treatment (May and July spraying) are shown in Table 13. It should be noted that, in general, the trees which received even a single spraying of oil emulsion during the summer period were comparatively free from scale in September. Trees which were sprayed only during February were very heavily infested with scale. Unsprayed trees were also very heavily infested with scale at the close of the season.

It is evident from this year's results that the plats which had received good control of scale during the previous year, with the double summer applications of oil spray, could have received approximately the same degree of protection this year with a single summer application.

The amount of scale on the growing fruit on different plats, was determined at monthly intervals. The increases on the treated plats during the 30-day periods, compared with the increases on the corresponding check plats, are presented in Table 14. The most noticeable increases occurred during the month of July, except in the case of the plats receiving an application of oil spray during June. The differences noted in the unsprayed plats are undoubtedly due to treatments in previous seasons and the small number of samples used. During the previous season row 35 had received applications of lime-sulphur (Table 12) from which no scale control was received. Row 37 had been sprayed in August and good control was received. Row 39 was a border row and subjected to dry winds at intervals, which caused some defoliation.

The degree of scale infestation on the mature fruit was determined at harvest. The data in regard to this phase of the project have been summarized in Table 15. A single spraying in July with oil emulsion was very effective, as measured by the percentage of clean fruit produced on the plats receiving this treatment. Plats receiving two sprayings

Table 13. Results of Tests on Time of Application of Spray in 1930 as Indicated by the Average Increase or Decrease in the Number of Scales on Each Leaf.

| Row | Treatment Sprayed | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks |
| 29 | June, August | 27.4 | 27.9 | — .5 | 1.4 | 2.4 | — 1.0 | .3 | .8 | — .5 |
| 18 | February, July | 2.4 | 18.4 | — 16.0 | .8 | .5 | + .3 | .3 | .3 | .0 |
| 27 | July | 87.3 | 37.5 | + 49.8 | 15.2 | 2.0 | + 13.0 | .8 | .7 | + .1 |
| 31 | June | 23.6 | 18.6 | + 5.0 | .2 | 4.2 | — 4.0 | .3 | .2 | + .1 |
| 33 | July | 36.4 | 31.9 | + 4.5 | 6.3 | 3.8 | + 2.5 | .3 | .1 | + .2 |
| 23 | June | 64.4 | 23.9 | + 40.5 | 1.9 | 2.1 | — .2 | 1.1 | .1 | + 1.0 |
| 21 | June | 22.8 | 26.2 | — 3.4 | .9 | .5 | + .4 | 7.9 | .2 | + 7.7 |
| 16 | February, June | .0 | .6 | — .6 | .3 | .3 | .0 | 9.7 | 1.0 | + 8.7 |
| 14 | February | .3 | 1.5 | — 1.2 | 2.7 | .5 | + 2.2 | 57.3 | 1.2 | + 56.1 |
| 39 | Unsprayed | 37.5 | 16.1 | + 21.4 | 13.1 | 1.4 | + 11.7 | 5.4 | .1 | + 5.3 |
| 37 | Unsprayed | 45.9 | 20.0 | + 25.9 | 25.3 | 2.5 | + 22.8 | 12.3 | .1 | + 12.2 |
| 35 | Unsprayed | 141.1 | 34.0 | + 107.1 | 47.9 | 3.0 | + 44.9 | 14.3 | .0 | + 14.3 |

*Check Rows are all others not included above from Row 13 to Row 40, inclusive. Sprayed in May and July with oil emulsion.

Table 14. Results of Tests on Time of Application of Spray in 1930 as Indicated by the Average Increase or Decrease in the number of Scales on Each Fruit.

| Row | Treatment Sprayed | July | | | August | | | September | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks | Average Increase for Plat | Average Increase for Checks* | Increase or Decrease compared with Checks |
| 18 | February, July | 18.1 | 16.0 | + 2.1 | 5.5 | 15.6 | − 10.1 | 23.9 | 44.9 | − 21.0 |
| 16 | February, June | 7.0 | 17.7 | − 10.7 | 7.2 | 19.5 | − 12.3 | 31.6 | 44.6 | − 13.0 |
| 21 | June | 17.5 | 14.8 | + 2.7 | 5.4 | 12.7 | − 7.3 | 20.0 | 32.7 | − 12.7 |
| 31 | June | 18.1 | 15.4 | + 2.7 | 1.7 | 4.2 | − 2.5 | 22.9 | 30.1 | − 7.2 |
| 29 | June, August | 29.5 | 20.1 | + 9.4 | 8.1 | 5.0 | + 3.1 | 24.8 | 30.2 | − 5.4 |
| 33 | July | 27.5 | 14.6 | + 12.9 | 10.9 | 3.6 | + 7.3 | 28.8 | 24.5 | + 4.3 |
| 14 | February | 10.3 | 13.0 | − 2.7 | 30.3 | 37.2 | − 6.9 | 66.9 | 60.0 | + 6.9 |
| 23 | June | 34.4 | 18.5 | + 15.9 | 20.2 | 12.5 | + 7.7 | 49.1 | 23.9 | + 25.2 |
| 27 | July | 66.2 | 25.7 | + 40.5 | 32.4 | 7.3 | + 25.1 | 75.3 | 27.3 | + 48.0 |
| 37 | Unsprayed | 62.7 | 20.3 | + 42.4 | 3.1 | 1.5 | + 1.6 | 11.5 | 16.5 | − 5.0 |
| 39 | Unsprayed | 40.7 | 18.8 | + 21.9 | 5.4 | 7.5 | − 2.1 | 13.0 | 13.1 | − .1 |
| 35 | Unsprayed | 79.0 | 17.3 | + 61.7 | 41.3 | 2.2 | + 39.1 | 103.8 | 21.9 | + 81.9 |

*Check Rows are all others not included above from Row 13 to Row 40, inclusive. Sprayed in May and July with Oil emulsion.

during the summer period produced no significant increases of clean fruit over plats receiving a single July treatment. The plats sprayed in February only and in February and June received the same treatment during the 1929 season. These results demonstrate clearly the importance of the previous season's treatment.

Table 15. Effect of Time of Application of Spray Materials on Production of Clean and Infested Fruit at Harvest, 1930.

| Time of Application | Clean Fruit % | Lightly Infested % | Moderately Infested % | Heavily Infested % |
|---|---|---|---|---|
| June & August* | 81 | 18 | 1 | 1 |
| July*** | 80 | 20 | 0 | 0 |
| June & August | 76 | 23 | 1 | 0 |
| February & July | 73 | 25 | 2 | 0 |
| June** | 66 | 33 | 1 | 0 |
| February & June | 22 | 55 | 21 | 2 |
| February | 6 | 40 | 29 | 25 |
| Unsprayed** | 54 | 46 | 0 | 0 |

*Average of 14 plats (Check treatment).
**Average of 3 plats.
***Average of 2 plats.

**Summary—Tests on Time of Application:** The data presented in Tables 8 to 15 show that during the period covered by these experiments, summer spraying was more effective than winter or spring treatments. Two applications of oil spray during the summer season, with a 60-day interval, gave consistently better results than other two-application schedules. Single applications of oil spray during the summer period were equal in effectiveness to double spray treatments where one of the sprays was applied in the winter or early spring. In general, fruit being grown for early market should not be sprayed with oil emulsion within 45 to 60 days of harvesting time. Spraying too close to marketing time is likely to influence coloring of the fruit.

Experience has shown that fall applications of oil spray should be used only where a summer application has failed to give satisfactory control. The probable occurrence of excessive rainfall during the fall season is another reason for the inadvisability of fall spraying for red scale control.

While the results of these tests show that two applications of oil spray for the control of red scale give more satisfactory results than a single treatment, this should not be interpreted to mean that two applications of oil spray will be required under all conditions. Single sprayings with oil emulsion during the period from May to July inclusive can be expected to give economical control of red scale, provided the proper materials are used and are applied in such a manner as to insure coverage of all parts of the tree. The actual time at which the spraying should be done is influenced by a number of factors, and will need to be determined

by each individual grower. The application should be delayed as late as possible for the production of fruit unblemished by scale.

## Comparison of Materials

The same kind of trees were used and the same general plan followed in testing the more important proprietary spray oils as were used in the time of application tests. It was obvious, relatively early in the experiment, that results secured with soap, oil, and water combinations were quite variable, due principally to the varying degrees of "hardness" of the water available for spraying. This seemed to indicate the need for more knowledge concerning the efficiency of the more promising proprietary oil sprays available to Valley growers. These tests were initiated for the purpose of observing the results obtained with oil sprays of different types when applied under field conditions, over a period of years. It should be realized that oil sprays for use on citrus trees were in the developmental period at the time the tests were started, and, in many cases, these materials have been modified from year to year, in an effort to increase their efficiency.

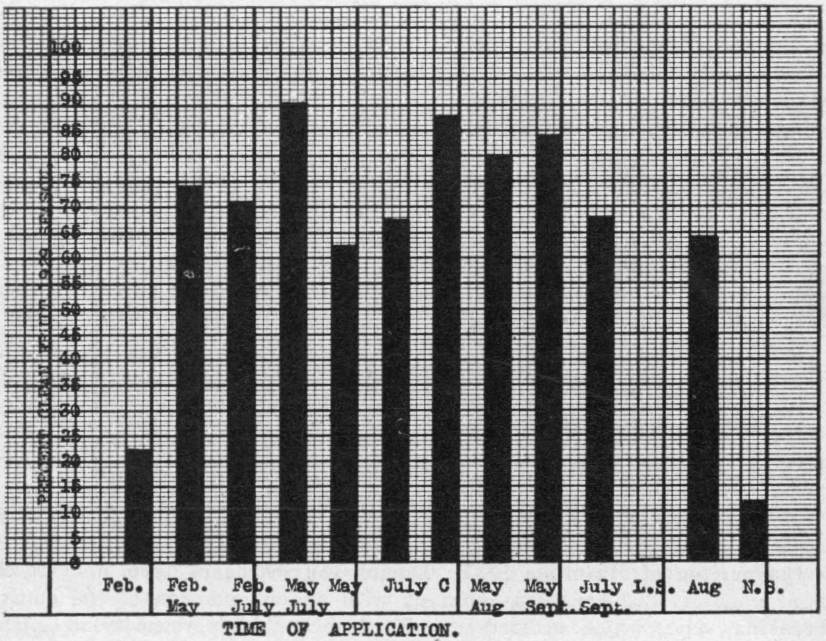


Fig. 15. Effect of time of application of spray materials on percentage of commercially clean fruit 1929.

The oil sprays commonly used in the Valley have been grouped into three general classes, as regards the viscosity of the oil used in their manufacture. These classes of oils are designated as "light," "medium," and "heavy." The light oil has a low viscosity, while the heavy oils have a high viscosity. These classes may be further divided as to the volatility (rate of evaporation) of the oil. For convenience, these sub-classes have been designated as "quick-drying" or high volatility and "slow-drying" or low volatility. In general the more viscous or "heavy" oils evaporate more slowly than the "light" oils, but this is not true in all cases. "Purity" of the oil, as measured by the percentage of unsaturated hydrocarbons present, has been recognized as a factor of importance in the reaction of the tree to the oil. The lower the percentage of unsaturated hydrocarbons present in an oil, the greater is the degree of purity.

The physical and chemical properties of the spray oil used are not the only factors responsible for the variations in tree reactions. The general vigor of the trees, climatic conditions, and method of applying the material are other factors which affect the amount of injury caused by oil sprays.

Table 16. Effect of Application of Different Spray Materials upon Red Scale, 1927.

| Plat No. | Material | Dates Sprayed | % Dead before Spraying | % Dead May* | % Dead *July |
|---|---|---|---|---|---|
| 5 | Oil Emulsion No. 1 2% Heavy Oil, Quick-breaking Type | April, June | 74.7 | 89.3 | 89.0 |
| 1 | Government Formula 2% | April, June | 78.9 | 64.1 | 87.6 |
| 3 | Miscible Oil No. 1-2% plus Lime-Sulphur | April, July | 74.5 | 90.9 | 97.8 |
| 2 | Miscible Oil No. 1-2% plus Lime-Sulphur | April, July | 55.4 | 90.1 | 97.5 |
| 11 | Oil Emulsion No. 2 3% Light Oil, Quick-breaking Type | April, July | 60.4 | 72.0 | 86.8 |
| 12 | Government Formula 2% | April, July | 59.4 | 71.6 | 83.0 |
| 9 | Miscible Oil No. 2-2% | April, July | 26.6 | 33.7 | 65.5 |
| 8 | Miscible Oil No. 2-2% | April, July | 28.0 | 32.2 | 64.0 |
| 7 | Oil Emulsion No. 2 2% Light Oil, Quick-breaking Type | April, July | 31.9 | 65.4 | 60.4 |

*Counts made 30 days after spraying.

**Comparison of Materials 1925:** During the season of 1925, a block of approximately 300 trees was sprayed with an oil emulsion of the quick-breaking type, which utilized an oil of rather high viscosity and low volatility. The results secured with this material were superior to those secured with the soap, oil, and water type of emulsion. The cost of this particular material, however, was such that its use in commercial spraying was impractical. A cheaper proprietary emulsion of this same

general type was also used, but was so injurious to the trees that its further use was discontinued. While the proprietary oil sprays offered for sale in the Valley in 1925 were an improvement over those offered in 1924, it should be pointed out that proprietary oil sprays were still in the experimental stage.

**Comparison of Materials 1927:** The effectiveness of the various proprietary compounds used in 1927, as indicated by the per cent mortality, is given in Table 16. The miscible oils used showed marked variation in their scale-killing power. Miscible oil No. 2 also had a decidedly unfavorable effect upon the tree.

There was a large difference in the percentage of dead scales resulting from the use of oil emulsion No. 1, which utilized a heavy, slow-drying oil, and oil emulsion No. 2, which utilized an oil of rather high volatility. This difference, in favor of the heavy oil, is more significant when attention is called to the fact that one application of the light oil was applied about 30 days later than the heavy oil. Where the light oil was increased to a three per cent strength, from the standpoint of scale kill, the two applications nearly equalled the double application of the heavy oil.

Treatments on plats 1, 2, 3, 8, 9, and 12 caused excessive amounts of tree and fruit injury. Miscible oil No. 1, without the lime-sulphur, was substituted in the second spray on plats 8 and 9.

**Comparison of Materials 1928:** Table 17 shows the percentage of dead scales following eight proprietary spray treatments. Applications of these oil sprays were made in May and July. Fumigation was done in February. The April count was the prespray count for the May spraying, and the July count was the prespray count for the July spraying, and the post spray count for the May spraying. The same applies to the August count.

There was considerable variation in the effectiveness of the different materials. It is interesting to note that emulsion No. 2, at 2 per cent strength, gave a fairly satisfactory scale kill, but when lime-sulphur was added, at the rate of six pounds of dry powder to 100 gallons of spray, the kill was reduced materially. The heavier oil sprays gave a consistently higher degree of control than did the lighter oil sprays.

The scale kill on the fumigated plats was very satisfactory early in the season; however, reinfestation occurred so rapidly that the scale control was unsatisfactory during the latter part of the summer. The rows 25b and 35b represent two rows in a block of 240 trees utilized in this fumigation experiment. The results secured with fumigation this season emphasized the fact that winter control measures, regardless of how efficient, are of little value in affording protection to the trees throughout the season, especially where infested trees are relatively close.

**Comparison of Materials 1930:** The results of the proprietary spray treatments for 1930, as expressed in amount of scale on the mature fruit, are presented in Table 18. As a general rule, those emulsions

Table 17. Effect of Application of Different materials upon Red Scale, 1928.

| Plat No. | Treatment | Sprayed | Date | % Dead Before 1st Spraying | Date | % Dead Before 2nd Spraying | Date | % Dead |
|---|---|---|---|---|---|---|---|---|
| Checks* | Oil Emulsion No. 1 2% Light Oil | May & July | 4/28 | 79.7 | 7/10 | 64.9 | 8/16 | 70.9 |
| 32 | Oil Emulsion No. 3 2% Medium Oil | May & July | 5/7 | 91.0 | 7/12 | 74.8 | 8/20 | 90.2 |
| 38 | Oil Emulsion No. 6 2% Heavy Oil | May & July | 4/27 | 81.4 | 7/17 | 81.2 | 8/23 | 86.4 |
| 21 | Oil Emulsion No. 7 2% Heavy Oil | May & July | 4/28 | 76.2 | 7/10 | 86.0 | 8/16 | 86.1 |
| 36 | Government Formula Oil Emulsion 2% Heavy Oil | May & July | 4/27 | 94.5 | 7/17 | 94.0 | 8/23 | 81.5 |
| 37 | Oil Emulsion No. 2 2% Light Oil | May & July | 4/27 | 95.6 | 7/17 | 86.9 | 8/23 | 81.2 |
| 34 | Oil Emulsion No. 4 2% Medium Oil plus Calcium Caseinate | May & July | 5/7 | 74.6 | 7/13 | 82.8 | 8/21 | 64.5 |
| 39 | Oil Emulsion No. 2 2% Light Oil plus Lime Sulphur | May & July | 4/27 | 92.7 | 7/18 | 40.0 | 8/24 | 56.8 |
| 25b | Calcium cyanide | February Fumigated | 6/1 | 99.8 | 7/20 | 83.0 | 8/24 | 54.8 |
| 35b | Calcium cyanide | February Fumigated | 5/8 | 100.0 | 7/20 | 29.0 | 8/24 | 21.2 |

*Average of 5 Plats.

utilizing the slow-drying oils gave a higher percentage of commercially clean fruit. Emulsion No. 1 gave a rather high percentage of clean fruit, but also caused severe defoliation. This was the only emulsion which produced any tree damage. As will be noted, there is considerable variation in the efficiency of the various materials. The records were taken on the basis of 100 fruit per plat.

Table 18. Effect of Various Proprietary Oil Sprays upon Production of Clean and Infested Fruit at Harvest, 1930.

| Treatment | Time of Application | Clean Fruit % | Infested Lightly % | Moderately Infested % | Heavily Infested % |
|---|---|---|---|---|---|
| Emulsion No. 8 Heavy Oil | June | 76 | 23 | 1 | 0 |
| Emulsion No. 6 Heavy Oil | June | 76 | 20 | 4 | 0 |
| Emulsion No. 1. Light Oil | June | 75 | 22 | 3 | 0 |
| Emulsion No. 7 Heavy Oil | June | 68 | 30 | 2 | 0 |
| Emulsion No. 5 Medium Oil | June | 63 | 37 | 0 | 0 |
| Emulsion No. 3 Light Oil | June | 53 | 40 | 7 | 0 |
| Emulsion No. 4 Light Oil | June | 48 | 48 | 4 | 0 |
| Emulsion No. 2 Medium Oil | June | 43 | 48 | 8 | 1 |

**Comparison of Materials 1931:** Numerous tests have been conducted with the tank-mixture method of using oil sprays. This method consists of mixing the oil, emulsifier, and water together in the spray tank and maintaining a uniform mixture by means of proper agitation. The method used in these tests consisted of adding an oil soluble emulsifier to the oil and pouring this mixture directly into the spray water to which had been added a casein spreader. Another method upon which observations have been made consisted of adding the oil to the spray water which contained powdered blood albumen and fuller's earth.

The advantage of the tank-mixture method is in its saving over the cost of proprietary oil emulsions and the fact that it provides a spray of known composition. The successful use of this method depends upon several factors of which the skill of the operator and the adaptability of the spray rig are the most important. Many rigs in use in this section are not suitable for applying oil in this manner, but most of them can be remodeled so as to properly handle these mixtures. The main point in this connection is that an agitator speed of approximately 200 r. p. m. should be maintained.*

Seventeen different oils were tried at this Station in 1931 and the results indicate that the tank-mixture method of using oil sprays is practicable under Valley conditions. Since these tests have been conducted for a single season only, they are not reported in this bulletin.

**Summary of Comparison of Materials:** The soap, oil, and water sprays

* Smith, R. H. The Tank-Mixture Method of Using Oil Spray. Cal. Ag. Exp. Sta. Bul. 527, p. 32.

were the first materials to be used in an effort to control red scale in the Valley. The percentage of scale killed resulting from the use of these materials was fairly satisfactory; however, the wide variation in tree reactions where these materials were applied, made their use inadvisable.

The oil emulsions of the quick-breaking type that were first placed on Valley markets, gave very efficient red scale control, but the strength at which they had to be used and the resultant high cost practically prohibited general use of these materials. As each year passed, and the manufacturers changed their formulas to improve their products and meet competition, better sprays became available to the average grower. As experimentation was carried out by the manufacturers, oil sprays became more efficient in killing scale, with less unfavorable results to the trees.

The various kinds of oil emulsions offered for sale in this section vary widely in their purity, viscosity, and volatility. The physical and chemical properties of the better proprietary oil emulsions used for spraying citrus trees are so variable that it is difficult to describe them by a set of specifications that do not also include some of the spray materials that are unsatisfactory. Under the conditions of these tests, most of the brands of oil sprays used gave good control of red scale, without causing noticeable injury to the trees. The formulas of most of these oil sprays are changed from year to year, in an attempt to better the product or to meet competition.

All of the oils used in the tank-mixture method of application test gave satisfactory control of red scale during the 1931 season.

## ACKNOWLEDGMENT

The first research work dealing with the control of red scale at the Valley Substation was planned by Dr. F. L. Thomas and W. H. Friend. Active work on the project was started in September, 1925, under the leadership of E. Hobbs. Mr. Hobbs was succeeded by M. McPhail. Mr. McPhail served as entomologist during the period from October, 1926, to September, 1927. Portions of the data collected by these workers have been incorporated in this bulletin. The work since April, 1928, has been conducted by the senior author, who is also responsible for all photographs and tables in this publication.

Thanks are due Dr. F. L. Thomas for his helpful suggestions and encouragement throughout the progress of this work.

## SUMMARY

1. California red scale, *Chrysomphalus aurantii* Mask., is the chief insect pest affecting citrus in the Lower Rio Grande Valley of Texas.

2. Red scale has been found infesting 35 varieties of plants in the Lower Rio Grande Valley.

3. Red scale not only decreases the market value of the fruit from

infested trees, but weakens and, in extreme cases, destroys its hosts.

4. Red scale gives birth to living young throughout the whole year in the Valley.

5. The maximum rate of production of young occurs during the summer and early fall months.

6. The broods of red scale are continuous and overlap to such an extent that differentiation between the generations is impossible.

7. The low temperatures that occurred during the winter of 1929-1930 had little effect upon the emergence of young scale or upon the normal winter mortality of red scale.

8. Fumigation with hydrocyanic acid gas, under the conditions of these experiments, gave satisfactory scale kill, but the proximity of infested host plants and the climatic conditions which prevailed during these tests were not favorable for the general use of this method of scale control.

9. Oil emulsion sprays of the quick-breaking type, utilizing slow drying oils, have proved to be more effective in scale control than those using a more rapid drying oil.

10. Many of the proprietary oil sprays used in these tests gave satisfactory control of red scale when applied at the proper time.

11. Oil sprays during the summer period were more effective in scale control than were those applied at other seasons of the year.

12. Plats of trees, heavily infested with scale, sprayed once with oil emulsion during May and once during July produced higher percentages of clean fruit than did those plats receiving single applications.

13. Where scale control secured during the previous season was satisfactory, it is probable that a single, well-timed application of oil emulsion spray during the summer season will keep red scale under control.

14. Lime-sulphur solution was ineffective in red scale control when applied six times at monthly intervals throughout the spring and summer season.

15. The tank-mixture method of applying oil sprays is apparently practicable under Lower Rio Grande Valley conditions.

16. The importance of thorough coverage of all portions of the citrus tree with the oil spray has been clearly demonstrated during the progress of these experiments.