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Control of the Major Pests of the Satsuma Orange in South Alabama

By

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Control of the Major Pests of the Satsuma Orange in South Alabama

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INTRODUCTION

THE SATSUMA orange, *Citrus nobilis* var. *unshiu* Swingle, has been grown for a number of years along the Gulf Coast in Alabama and neighboring states. It has been found to be attacked by most of the pests which attack oranges in Florida, and the damage from purple scale, rust mite, citrus whitefly, and citrus red mite (spider), is so severe that annual control measures are necessary. Experiments dealing with the life histories and control of these pests have been conducted at the Spring Hill Field Station of the Alabama Experiment Station since 1928. The results of these experiments are given in this bulletin. Because of the inter-relation of insect and disease control, and because of the importance of sour scab, experimental data on the control of scab have also been included.

METHODS

In field experiments the sprays were applied with a power sprayer operated at 250-300 pounds pressure. Because of the small size of satsuma trees and the closeness of the branches to the ground, 6-foot spray rods carrying 2 angle nozzles were used for spraying instead of "spray guns".

The 4-year experiment with 28 spray programs was conducted on a 9-acre block of bearing trees in the southern part of Mobile county. Treatments were applied to 10-tree plots replicated 3 times. The spraying was always supervised and each spray-man sprayed half of each replicate to reduce the personal element in this operation. Treatments were not repeated regardless of subsequent weather conditions.

Records of the field experiments were made by grading the fruit at the time of harvest. The crop from each plot was harvested separately and before it was moved, 100 fruits* from each field box were examined. Fruits without sufficient blemish to reduce the grade were classified as clean.

Except where otherwise noted, the following materials and methods of mixing were used:

Bordeaux Mixture was prepared in the tank with the agitator running. Pulverized copper sulphate (snow) was slowly added to the water before adding the proper quantity of hydrated lime. The 3-3-100 Bordeaux contained 3 pounds of copper sulphate and 3 pounds of hydrated lime in 100 gallons of water.

*In 1937, on account of the large size of the fruits and the threat of cold weather, only 50 from each field box were examined.

Bordeaux-sulphur was prepared by adding wettable sulphur to Bordeaux.

Bordeaux-oil mixtures were made by adding the ingredients to the tank (with agitator running) in the following sequence: water, spreader, copper sulphate, lime, oil.

Commercial lime sulphur having a specific gravity of not less than 32° Baumé was used.

Lime sulphur-wettable sulphur was prepared by adding wettable sulphur to diluted liquid lime sulphur in the tank, with the agitator running.

A white oil having the following specifications was used: **viscosity,** 78-79 seconds at 100° F. by Universal Saybolt Viscosimeter; **unsulphonated residue,** 95 per cent with 38 N. sulphuric acid by the Official Method of the Association of Official Agricultural Chemists; **distillation,** first drop at 316° C., 50 per cent at 357° C., by A. S. T. M. Method D-158-28, with modifications of the California State Department of Agriculture (Calif. State Dept. Agr. Special Publ. 116: 1931-32); **specific gravity,** 0.8410 at 25° C., Westphal balance. This oil was applied by the California tank-mix method (23). The spray tank was supplied with sufficient agitation to maintain a uniform mixture of 1 per cent kerosene in water. In spray practice the required amount of oil was added to the water in the tank. Then 0.25 pound of spreader was slowly added with the agitator running. The spreader was a mixture of 1 part grade A dried blood albumen and 3 parts Fuller's earth.

Commercial dusting sulphur was used in all dusting experiments.

Commercial wettable sulphur was used. In 1935 a brand containing 83 per cent sulphur and 17 per cent inert ingredients was used. In 1936, 1937, and 1938, a brand containing 90 per cent sulphur and 3 per cent blood albumen was used.

PURPLE SCALE

The purple scale, *Lepidosaphes beckii* (Newm.), is a major pest of citrus fruits wherever grown. In this country it was found first in Florida about the middle of the past century and, according to Essig (9), it was apparently introduced into California from Florida in 1888 or 1889. It was first reported in south Alabama in 1914 (5), and has since been the most important insect pest of the satsuma orange in that region.

The purple scale attacks the trunk, limbs, leaves, and fruit (Figure 1). The population may become so dense that whole trees are encrusted and often killed outright. Trees moderately infested may be so weakened that they are killed by freezes which merely defoliate healthy trees. In addition to the damage to the tree itself, this insect retards ripening of the fruit and

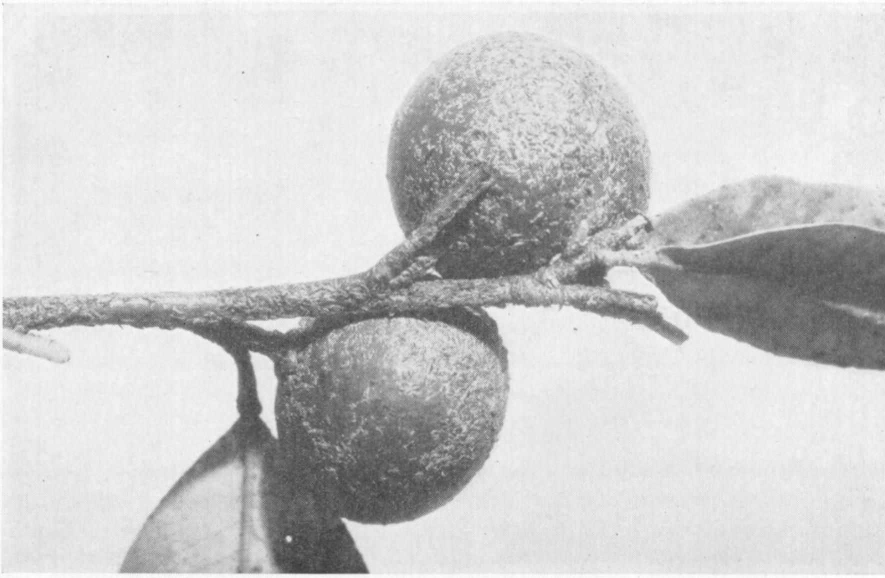


FIGURE 1.—Satsuma Fruits and Twig Infested with Purple Scale (slightly reduced).

lowers its grade. In 1935, 1936, and 1937, on untreated plots, 43.9, 79.2, and 76.4 per cent of the fruit was classed as culls because of the damage from purple scale. In addition, yields were greatly reduced. The enormous reproductive ability of purple scale, its resistance to control measures, and its wide distribution make it a major problem of nearly every citrus grower.

Description

Purple scale is classified as an armored scale, i. e., the insect itself is under a hard protective shell (Figure 2). The covering of the female is shaped like an oyster shell; it varies from light to dark brown in color, and is about 2.8 millimeters long when mature. Under the shell of the mature female may be seen her sac-like body and rows of pearly eggs (Figure 3). The shell of the male is narrower and more uniform in width than that of the female. It is about 1.5 millimeters long and somewhat purplish in color. When mature, the male emerges as a very small, 2-winged insect. The scales feed on the plant juices through a minute thread-like beak which penetrates the plant tissue.

Life History

Life-history studies were conducted on cultures placed in a screened roofless, insectary. When the eggs hatch, the tiny white larvae or "crawlers" move from beneath the shell of the female and crawl over the tree. Within a day or two they

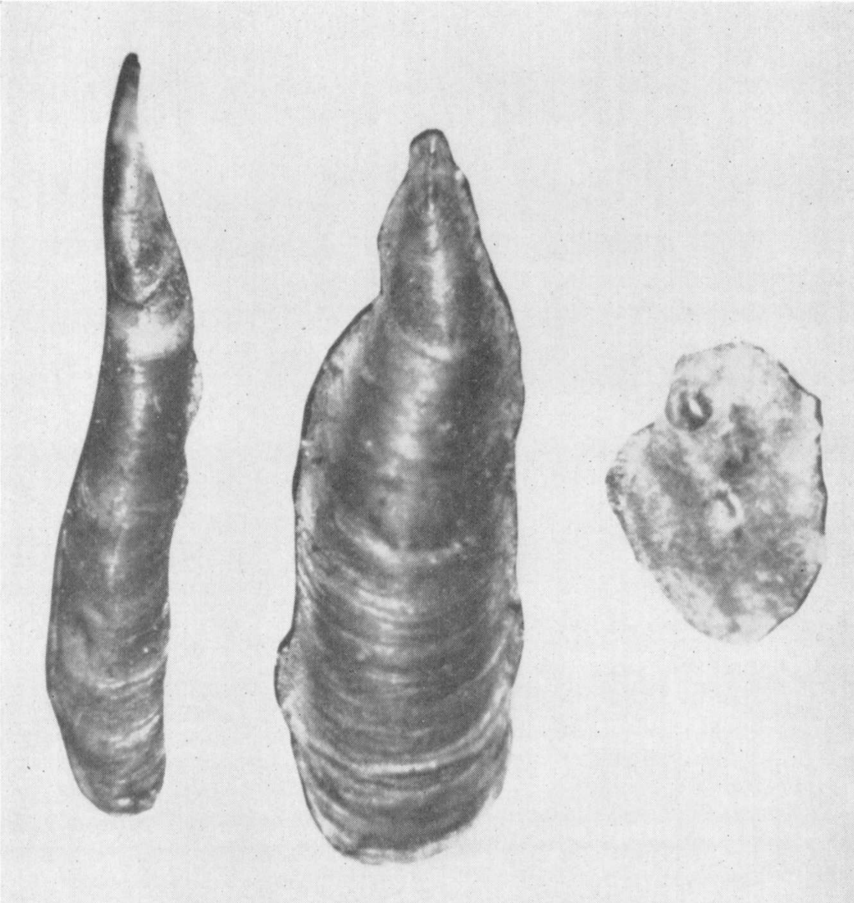


FIGURE 2.—Left, Long or Glover's Scale, *Lepidosaphes gloverii* Pack. Middle, Purple Scale, *Lepidosaphes beckii* Newm. Right, Chaff Scale, *Parlatoria pergandii* Comst. (Enlarged about 36 times).

settle, lose their legs and antennae, and begin to secrete the shell. They molt twice, retaining the cast-off skins as part of the permanent shell. At maturity the winged males emerge from their shells and mate with the females. Soon thereafter the females begin to oviposit. As the eggs are deposited in neat rows, the bodies of the females decrease in size until they occupy only a portion of the smaller end of the shells. The females die after depositing 40 to 60 eggs. All of the shell except the larger end is fastened to the tree with wax and it is from this end that the crawlers emerge.

The results of observations on the development of female scales over a 7-year period are shown in Table 1 and Figure 4.

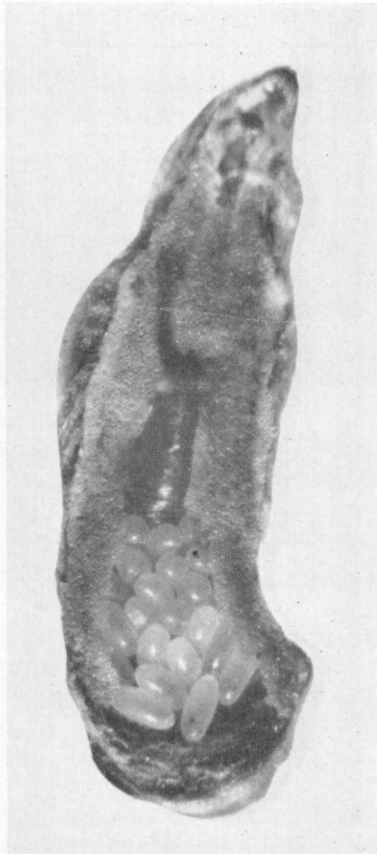


FIGURE 3.—Female Purple Scale in Shell with Eggs. (Enlarged about 36 times).

The time required to reach maturity and begin laying eggs averaged 62.0 days; the minimum being 33 and the maximum 148 days. The incubation period averaged 15.3 days. The range was from 6 to 50, but in the summer months hatching took place in 10 to 15 days. Complete development required an average of 77.3 days. The shortest time observed for complete development was 42, while the longest was 198 days. The usual time required was 50 to 60 days in the summer.

The optimum period for development was from May to August, inclusive. Thirteen broods which originated in these 4 months required an average of 55.0 days for development. Six broods originating in the time from September to January, inclusive, averaged 140.1 days for development from birth to birth.

Seasonal History

Information on the seasonal history of purple scale was obtained by the use of removable *Tanglefoot* bands on infested trees in the field (7). All stages of purple scale may be found throughout the year. Development is retarded by cool weather and may be brought to a standstill by severe cold. With the return of warm days in the winter, development proceeds and crawlers emerge from the shells. Although crawlers may emerge all through the winter,

TABLE 1.—Summary of Life History Data on Female Purple Scales.

Period	Number of days		
	Minimum	Maximum	Average
Birth to first molt	12	44	21.3
Birth to second molt	21	62	34.9
Birth to first egg	33	148	62.0
Incubation	6	50	15.3
Complete development	42	198	77.3

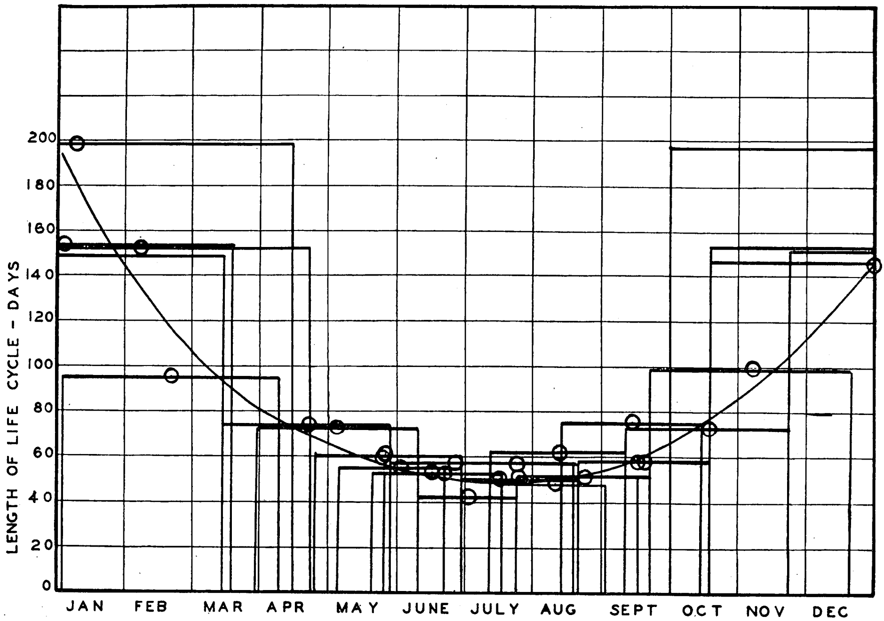


FIGURE 4.—Block Diagram of the Developmental Periods of Purple Scale. The circles are drawn at the mid-point of each period and the smooth curve shows the general relationship between development and season.

there is no "build-up" in the scale population during this season. The period of greatest crawler emergence is from June to October, inclusive. About 80 per cent of the crawlers emerge during these 5 months (Figure 5).

Control

Because of humid conditions and the necessity of spraying satsuma trees for sour scab and the citrus red mite, fumigation has not proved practical for the control of scale insects in south Alabama. Therefore, control measures are confined largely to spraying with oil emulsions. There are, however, seasonal limitations to the use of oil sprays. If applied during the months of April, May, and June, when the fruit is small, there may be excessive fruit drop. If applied during the winter months, the probability of freeze injury is increased. Hence, the use of oil sprays is limited mainly to the months of July, August, and September. Fortunately, it is during these months that the greatest number of larvae (crawlers) are present and it appears that this would be the most effective period for control. Unless an oil spray is applied in July the scale population may become so dense that the trees are seriously damaged, and satisfactory control becomes impractical.

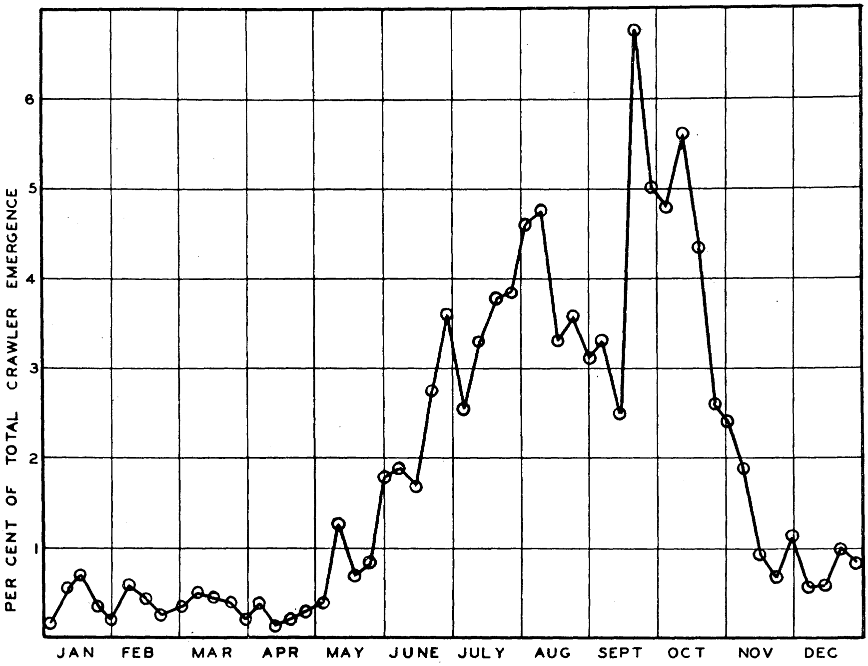


FIGURE 5.—The Seasonal Abundance of Purple Scale Crawlers. Five-year average.

Experiments with Oil and Sulphur Sprays.—Results obtained with sulphur and oil sprays in field plots are given in Table 2. Although lime sulphur-wettable-sulphur was much more effective than lime sulphur alone, 5 applications of this spray per year were not effective enough to maintain satisfactory production of clean fruit. (See Thompson, 24). A spray schedule containing one application of oil spray in July gave much more satisfactory results than any one of the "all-sulphur" treatments.

Experiments with Sulphur Dusts.—Because of the ease and economy of application, the possibility of controlling purple scale by dusting has occured to more than one grower. The data from experiments with sulphur dust (Table 3) indicate that sulphur dust was relatively inefficient for the control of purple scale and that a pyrethrum-derris-sulphur dust was also much less effective than an oil spray. It was concluded, therefore, that dusting with these materials was of little value in controlling the purple scale.

The Effect of the Time of Application and the Number of Oil Sprays on the Control of Purple Scale.—Field tests to determine the number of oil sprays necessary for the control of

TABLE 2.—Results of Experiments with Oil and Sulphur Sprays for Control of the Purple Scale.

Plot No.	Treatment* March	April or May	May or June	July	Aug.	Sept.	Per cent scaly fruit 1935	1936	1937	1938	Av.
17	Bordo-sul	LS & WS		Oil	WS[1]	Oil	2.0	0.7	2.0	0.0	1.2
10	Bordo-sul	LS & WS		Oil	S. dust[1]	LS & WS	3.7	2.8	5.0	0.4	2.9
24	Bordo-sul	LS & WS	LS & WS[2]	LS & WS	LS & WS	LS & WS	7.4	6.7	19.1	8.6	10.4
25	Bordo-sul	LS	LS[2]	LS	LS	LS	5.3	17.7	42.3	[3]	21.7
23	Bordo-sul	WS	WS[2]	WS	WS	WS	31.1	41.0	[3]	[3]	36.0
13	Untreated check						43.9	79.2	76.0	89.2	72.1

*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
WS: wettable sulphur, 7½ lbs. per 100 gals. water.
LS: 1½ gals. liquid lime sulphur per 100 gals. water.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil, July: 1½ gals. 78″ viscosity white oil per 100 gals water (tank mix).
Oil, Sept.: 1¼ gals. 78″ viscosity white oil per 100 gals. water (tank mix).

[1]Omitted in 1935.
[2]Omitted in 1937.
[3]Schedule abandoned because of ineffectiveness.

TABLE 3.—Results of Experiments with Sulphur Dust for Control of the Purple Scale.

1935

Plot. No.	Treatment* March	May	June	July	Aug.	Oct.	Per cent scaly fruit
26	Bordo-sul	LS & WS		Oil	S. dust	S. dust	12.0
27	Bordo-sul	LS & WS	S. dust	S. dust	S. dust	S. dust	33.1
13	Untreated check						43.9

1936

Plot. No.	March	April	July	Aug.	Sept.	Per cent scaly fruit
26	Bordo-oil	LS	Oil	S. dust	S. dust	1.2
27	Bordo-oil	LS	P.D.S. dust	P.D.S. dust	P.D.S. dust	17.5
13	Untreated check					79.2

*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
LS: 1½ gals. liquid lime sulphur per 100 gals. water
Bordo-oil: 6-6-100 Bordeaux plus 1½ gals. 78″ viscosity white oil (tank mix).
Oil, July: 1½ gals. 78″ viscosity white oil per 100 gals. water (tank-mix).
S. dust: ½ to ¾ lb. dusting sulphur per tree.
P.D.S. dust: 5 parts pyrethrum, 5 parts derris, 90 parts sulphur.

purple scale and the most effective time for their application were conducted during 1935-38 (Table 4). The results indicate that if an oil is applied in July and September, nothing is gained by using oil with Bordeaux in March. They also show that in a complete spray schedule, Bordeaux-sulphur applied in March was about as effective as Bordeaux-oil.

The Effect of Insecticide-Fungicide Mixtures on the Control of Purple Scale.—To determine the effect of spring insecticide-fungicide mixtures on the control of purple scale, various sprays were applied to 12 plots. An application of Bordeaux-oil in March gave essentially as good control of scale without a post-bloom spray as with post-bloom sprays of Bordeaux-sulphur, lime sulphur-wettable sulphur, and Bordeaux (Table 5). These same post-bloom sprays caused no practical difference in the percentage of scaly fruit on the series of plots which received Bordeaux as the pre-growth spray. The plot receiving Bordeaux at pre-growth, but with no post-bloom spray, produced an average of 8.4 per cent scaly fruit. Thus, it is evident that all of the fungicide mixtures were effective in reducing purple scale. Bordeaux mixture was the least effective of these fungicides in reducing the abundance of scale, but the data indicate that Bordeaux does not induce an increase in purple scale; it merely fails to depress scale as effectively as Bordeaux mixed with sulphur or oil.

TABLE 4.—Effect of the Number of Oil Sprays and Time of Application on Control of the Purple Scale.

Plot No.	Treatment* March	Treatment* April or May	Treatment* July	Treatment* Aug.**	Treatment* Sept. or Oct.	Per cent scaly fruit 1935	Per cent scaly fruit 1936	Per cent scaly fruit 1937	Per cent scaly fruit 1938	Per cent scaly fruit Av.
16	Bordo-oil	LS & WS	Oil	WS	Oil	1.4	0.9	2.8	0.1	1.3
2	Bordo-oil	LS & WS	Oil	S. dust	LS & WS	7.8	2.1	4.1	0.3	3.7
17	Bordo-sul	LS & WS	Oil	WS	Oil	2.0	0.7	2.0	0.0	1.2
10	Bordo-sul	LS & WS	Oil	S. dust	LS & WS	3.7	2.8	5.0	0.4	3.9
18	Bordo	LS & WS	Oil	WS	Oil	2.7	0.4	0.2	0.3	0.9
6	Bordo	LS & WS	Oil	S. dust	LS & WS	12.5	5.5	7.0	3.0	7.0
13	Untreated check					43.9	79.2	76.0	89.2	72.1

*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938); 1½ gals. (1936) 78″ viscosity white oil per 100 gals. (tank-mix).
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
Bordo: 6-6-100 Bordeaux mixture.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil, July: 1½ gals. 78″ viscosity white oil per 100 gals. water (tank-mix).
Oil, Sept.: 1¼ gals. 78″ viscosity white oil per 100 gals. water (tank-mix).
WS: 7½ lbs. wettable sulphur per 100 gals. water.

**August treatments not made in 1935.

TABLE 5.—Effect of Spring Insecticide-Fungicide Combinations on Control of the Purple Scale*

Pre-growth spray (March)	Per cent scaly fruit—4-year average with post-bloom sprays of			
	Bordo-sul	LS & WS	Bordo	(None)
Bordo-oil	4.1	3.7	3.4	3.4
Bordo	7.2	7.0	7.4	8.4
Bordo-sulphur	1.7	2.9	7.4	9.5
None				16.5

*All plots received oil in July and lime sulphur-wettable sulphur in September. All plots with the exception of the check also received sulphur dust in August of 1936, 1937, and 1938.

Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938), 1½ gals. (1936) 78" viscosity white oil per 100 gals. water (tank-mix).

Bordo: 6-6-100 Bordeaux mixture.

Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.

LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.

Oil, July: 1½ gals. 78" viscosity white oil per 100 gals. water (tank-mix).

Conclusions.—Frequent applications of lime sulphur-wettable sulphur were effective in reducing purple scale, but commercial control was not obtained. Sulphur dust effected little if any control of scale. The most effective control was obtained by following a schedule containing applications of oil in July and September, but these programs cannot be recommended because of their effect on the yield and maturity of the fruit, which will be discussed in another section of this paper. At least one oil spray per year was necessary for the control of scale, but with suitable fungicide mixtures in the spring, there was no need of using oil except in July. The most effective schedule contained applications of Bordeaux-sulphur before growth and after petal fall, oil in July, and sulphur applications in August and September.

RUST MITE

The origin of the rust mite, *Phyllocoptes oleivorus* (Ash.), is unknown, but Yothers and Mason (33) think that it probably came from southeast Asia. It has been a pest in Florida for many years. It occurs in all the citrus-growing regions of the world with the exception of South Africa and the countries around the Mediterranean Sea. In California, the infestation is limited to one or two counties where the greatest damage is to lemons. Oranges are rarely russeted on the Pacific Coast (9). The lemon is the preferred host; then in order of preference come the grapefruit, orange, satsuma, and kumquat (33). The latter is rarely damaged to any extent in southern Alabama, but extensive damage usually occurs on satsumas.

The citrus rust mite infests the twigs, leaves, and fruit. Dense infestations damage the leaves to some extent but the damage to the fruit is much more important. Mites can usually be observed on the new leaves before they are found on the fruit. The first indication of a serious infestation is the appearance of faint black areas on the green fruits. The mites can be seen with a lens on these black areas and the population may become so dense that the fruits appear dusty. If unchecked, the damage will increase until whole fruits appear rusty, dry, and rough (Figure 6).

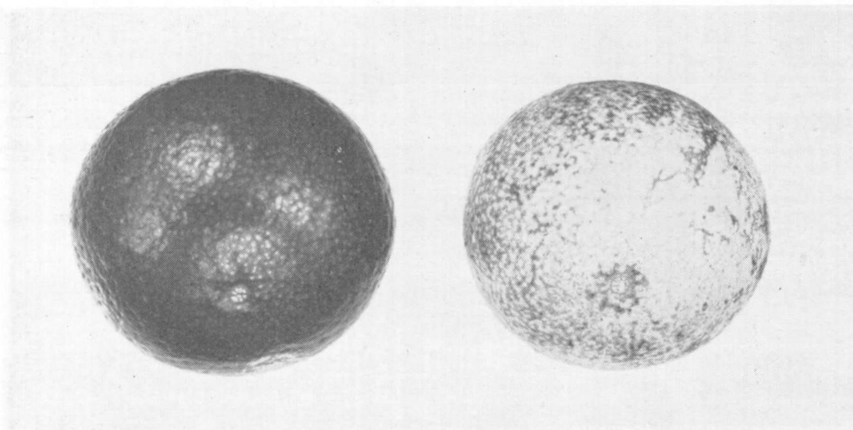


FIGURE 6.—Left, Satsuma Damaged by Rust Mites. Right, Normal Satsuma.

Russeting of citrus fruits was first thought to be due to a fungus, but about 1878 it was found that russeting was caused by a very small mite (33). The first important work on this pest was done by Hubbard (10). While his observations on its life history and habits were accurate, he believed that rust mite improved the quality and keeping properties of the fruit. This was disproved by Yothers and Mason (33), who showed that rust mite reduced the size, thickened the rind, and impaired the quality and market value of the fruit. These investigators pointed out that the apparent good quality of russeted fruit was really due to the fact that it was usually harvested near the close of the season, whereas the bright fruit was harvested as early as possible. Hence, the russeted fruit was tree-ripened. They found that the outer cells of oranges were destroyed by feeding of the mites. The skin became leathery and the fruit lost more water than normally. In a highly competitive market, russets are usually culled and sold at a discount. Unless the rust mite is controlled, 50 to 70 per cent of the fruit may be russeted.

Description

The adult mites are about 0.16 millimeters long and 0.06 millimeters wide near the anterior end. Their bodies slope posteriorly almost to a point, so that they appear wedge-shaped (Figure 7). The adults are orange colored but the larvae are much paler and more difficult to see. Their movement appears slow because of their small size, and in cool weather movement may stop.

FIGURE 7.—Rust Mite (enlarged 100 times).

Life History

Yothers and Mason (33) found that the eggs are laid singly and in small groups. The depressions in the oranges are preferred for oviposition. The eggs hatch in 2 to 4 days in warm weather, the larvae molt twice, and development may be completed in 7 to 10 days. The enormous populations which build up rapidly are due to the short period of development, rather than to the fecundity of the individuals. Male mites have not been observed; the eggs hatch apparently without being fertilized.

Seasonal History

In southern Alabama, rust mites have not been observed in the winter months. Usually they make their appearance on the new foliage the last of April or the first of May and disappear in December.

From the weekly counts of mites on satsuma leaves for 5 years, two curves were made (Figure 8). During 2 years a peak population of mites occurred in the early summer. In these years there was russeting of small fruit but there was no dense population in the fall and mite damage was not extensive. During the 3 other years the early fall population was relatively high and a very dense population occurred in September and October. Under the latter conditions rust mite damage mounts rapidly and control measures may not be successful unless started at the correct time.

Control

Sulphur is a specific remedy for the rust mite. It may be applied either as a dust or spray. Apparently the mites are killed by the sulphur fumes as well as by actual contact. The data on control, presented in Table 6, were obtained in 1935 when the infestation of mites was severe in September and October. Each of 3 plots received Bordeaux-sulphur in March, lime sulphur-wettable sulphur in May, and oil in July. Plot 26, which also received sulphur dust in August and September, produced only 0.8 per cent russeted fruit. Plot 10, which received a lime sulphur-wettable sulphur spray in October, produced 22.5 per cent russets. Although lime sulphur-wettable

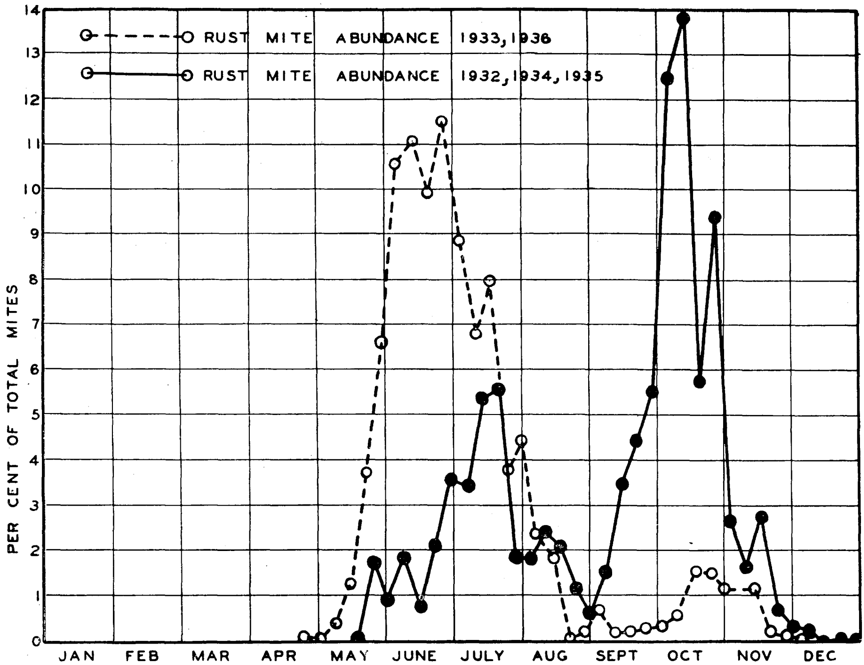


FIGURE 8.—Seasonal Abundance of Rust Mite.

TABLE 6.—Control of the Rust Mite with Oil and Sulphur Sprays and Sulphur Dust, 1935.

Plot No.	Treatment* March	May	July	August	October	Per cent russeted fruit
26	Bordo-sul	LS & WS	Oil	S. dust	S. dust	0.8
10	Bordo-sul	LS & WS	Oil		LS & WS	22.5
17	Bordo-sul	LS & WS	Oil		Oil	53.2
13	Untreated check					77.0

*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil: 78" viscosity white oil; July 1½ gals. per 100 gals. water; October 1¼ gals. per 100 gals. water (tank-mix).
S. dust: approx. 1 lb. dusting sulphur per tree.

sulphur is no doubt as effective as sulphur dust, it was applied too late to obtain satisfactory control. The oil spray which was used on Plot 17 in October was not as effective as the sulphur spray, yet considerable russeting was prevented, when compared to the untreated check. This plot produced 53.2 per cent while the check produced 77.0 per cent russeted fruit. From the data on seasonal abundance of rust mites, it is evident that control measures should be used before the first of October.

There is a natural depression in the population of mites in August and from the data obtained on Plot 26 it appears that August is an opportune time to use sulphur. Also, the weather is usually hot in August and favorable for the action of sulphur. If treatment is delayed until russeted fruit appears and the population of mites has become dense, it may be difficult to prevent serious damage, especially if weather conditions are unsuitable for applications of sulphur.

CITRUS WHITEFLY

Several species of whiteflies infest citrus but the one known specifically as the citrus whitefly, *Dialeurodes citri* (Ash.), is the most important to the satsuma orange industry in southern Alabama. This insect is native to Asia and was probably introduced into Florida between 1858 and 1885 (18). In Florida it is a major pest, but the infestation in California is limited and efforts have been made to eradicate it there. Undoubtedly it would be a more serious pest of satsumas along the Gulf were it not for the occasional freezes which defoliate the trees. Following defoliation and the consequent reduction of the infestation, several years may pass before re-infestation from other host plants reaches economic proportions.

The infestation of whitefly is confined almost entirely to the underside of the leaves. The extent of the devitalization to trees is not known quantitatively, but the larvae certainly remove great quantities of sap. In addition, damage is caused by the black fungus or sooty mold, *Capnodium citri* Berk. & Desm., which grows in the "honey dew" egested by the larvae. The extent of this fungus varies with the degree of infestation and may blacken the whole tree.

If the infestation of whitefly is heavy, it may be necessary to wash the fruit before it can be satisfactorily marketed. Trees infested with the whitefly are more susceptible to injury by abnormally low temperatures (Figure 9).

Description

The eggs are lemon yellow in color and elliptical in shape. They are about 0.25 millimeter in length and 0.10 millimeter in width. One end of the egg is attached to the leaf by a short curved stem so that the long axis of the egg is nearly parallel with the leaf surface (Figure 10). Full grown larvae measure 1.40 millimeters in length by 1.07 millimeters in width. They are flat, elliptical, and pale green (Figure 11). There is little distinction between the larva and pupa. The wings, legs, and antennae of the adults are milk-white. The body is pale yellow. The eyes are jet black. The insects are not true flies for they have 4 wings which are held roof-like when at rest. The average length of the adult is 1.61 millimeters and the width across the wings at rest is 0.91 millimeters.

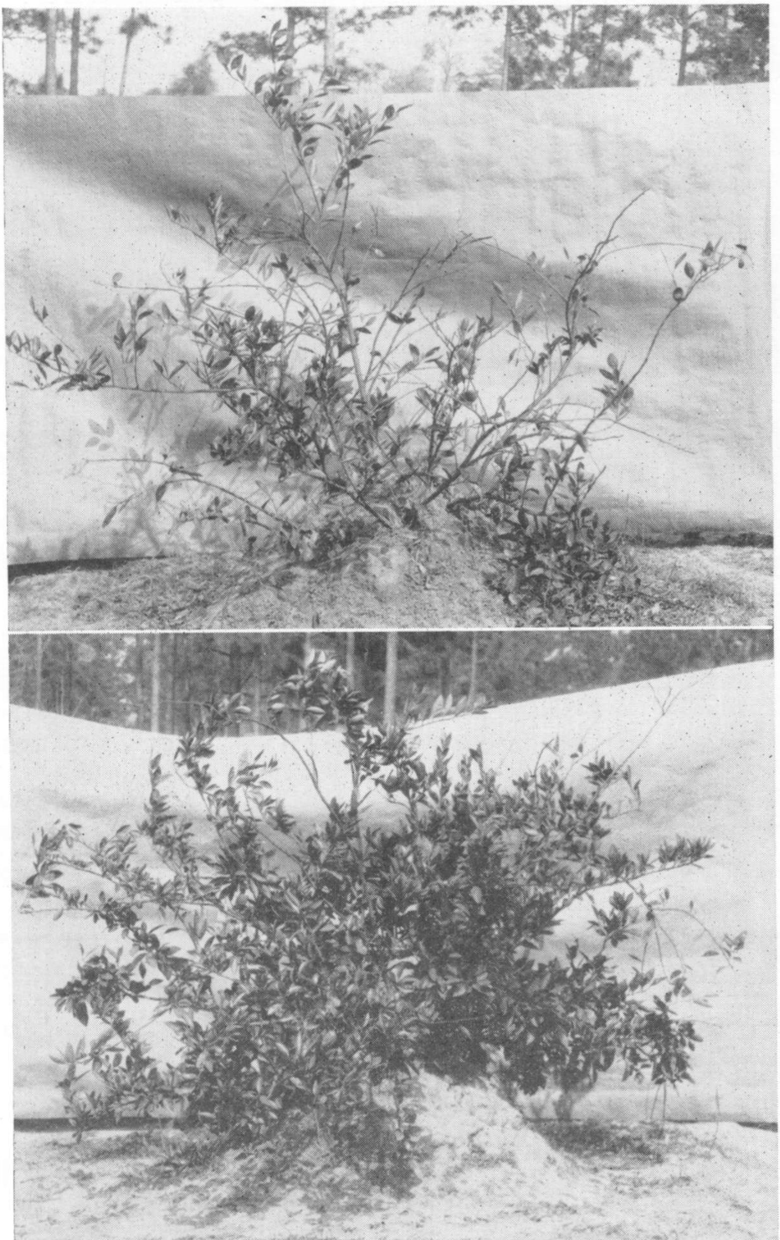


FIGURE 9.—Above, Satsuma Tree Infested with Citrus Whitefly. Below, Uninfested tree. Both photographed after being exposed to a minimum temperature of 17½° F.

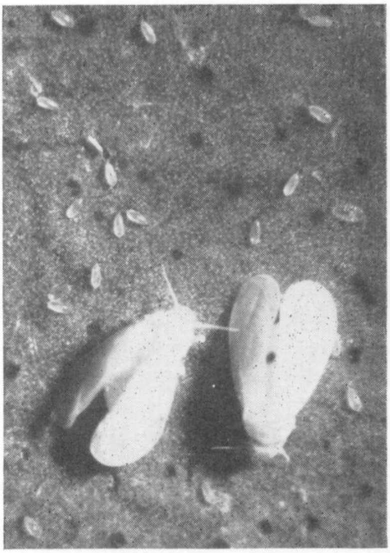


FIGURE 10.—Citrus Whitefly; Eggs and Adults (enlarged about 13 times).

FIGURE 11.—Citrus Whitefly Larvae (Pupae) (enlarged 13 times).

Life History

The eggs are deposited on the under side of new leaves. The deposit of eggs may be so thick that growth is impaired and malformed leaves produced. The eggs hatch in 6 to 21 days, depending on weather conditions, and the minute flat, pale green larvae move about the leaf. They settle in 3 or 4 days, insert their beaks into the leaf, lose their legs and antennae, and remain in the same place until development is complete. As development nears completion, the pupa thickens and the black eyes of the immature "fly" can be seen. The adult emerges through a T-shaped split in the skin. When the wings are dry, it flies to fresh foliage to lay eggs.

In summer, 53 days is about the average time required for development from egg to adult. Broods, which begin in the fall, do not complete development until the following spring (Table 7).

Seasonal History

Whitefly adults begin to emerge in the spring by the time new leaves are an inch long. They congregate in great numbers on this fresh foliage to deposit eggs. Whiteflies usually may be observed the last days of March or the first of April. The earliest emergence was March 10, 1937, following a mild

TABLE 7.—Four-Year Average Developmental Periods of the Citrus Whitefly.

Period	Number of Days: Minimum	Maximum	Average
Incubation	6	21	14.2
Larval and pupal	29	245	69.7
Complete development	41	260	83.9

winter. This emergence was subsequently stopped by a freeze, and did not begin anew until about April 17.

The emergence of first brood adults reaches a peak about the first of May. Then, the population declines and by the latter part of May there is a period of about 10 days without adults. The second brood of adults is also quite distinct, reaching the peak about the first of July. Although the adults decline in number after the second brood, there is no "fly-free" period between the second and third broods. There is overlapping of broods in the latter part of the summer and the adult population reaches its greatest density in September (Figure 12). The adults disappear early in November and the winter is passed in the larval stage on the underside of the leaves.

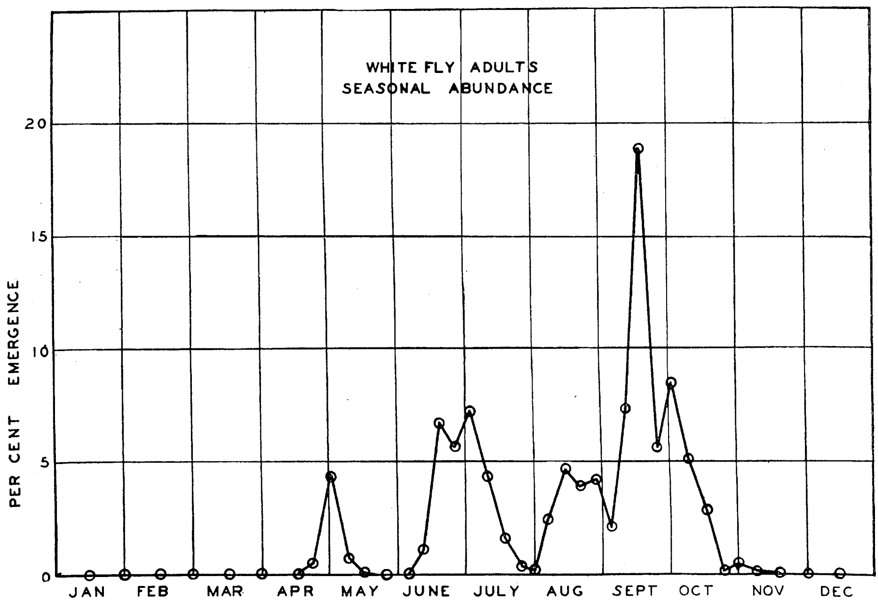


FIGURE 12.—The Seasonal Abundance of Whitefly Adults.

Control

In Florida certain fungi, which are parasitic on the larvae of the citrus whitefly, are an important factor in the control of this insect. Under favorable climatic conditions practical control is obtained without resort to insecticides. Because it is necessary to use one or more fungicidal sprays on satsumas in the spring for the control of sour scab, these beneficial fungi are not effective in controlling whitefly in Alabama.

Oil sprays are very effective in killing the larvae. A stock emulsion, made from an 83 viscosity white oil and powdered skim milk, killed 100 per cent of the larvae on potted satsuma trees when used at oil concentrations of 1, 1.5, and 2 per cent. However, all of the proprietary mixtures were not as effective as this stock emulsion. On a plot of trees sprayed March 10 with 3-3-100 Bordeaux plus 2 gallons of *Florida Volck* per 100, a count showed that 99.2 per cent of the larvae were dead, while on the untreated check the natural mortality was 24.0 per cent.

The optimum time to spray for whitefly control is shortly before emergence of the adults in the spring when only immature stages are present. Since Bordeaux mixture is generally used as a pre-growth spray for sour scab before the emergence of adults, an oil emulsion mixed with Bordeaux can be used to advantage. Sprays are not effective for controlling adults.

THE CITRUS RED MITE (SPIDER)

The citrus red mite, *Paratetranychus citri* McG., is commonly called red spider by growers in southern Alabama. In Florida it is called the purple mite. For a long time it was thought to be the same as the European red mite, *Paratetranychus pilosus* Can. and Franz., which infests deciduous fruit trees, but it was shown by McGregor and Newcomer (13) that the citrus mite was a different species. The citrus mite evidently was first observed as a pest in Florida. According to Boyce (1) it was probably introduced into California about 1890. One of the preferred hosts is *Poncirus trifoliata* Raf. (*Citrus trifoliata* L.) and since the satsuma orange is budded on *P. trifoliata* stock, it is very probable that the citrus red mite has been a pest along the Gulf coast as long as satsumas have been produced in this section. Apparently this species is confined to citrus although there is considerable preference among the varieties. Lemons in California and satsumas on the Gulf coast seem to be preferred to round oranges and grapefruit.

The red mite infests the fruit, leaves, and tender branches but the greatest damage to satsumas is to the leaves. It feeds on both surfaces, producing small gray splotches. Chlorophyll as well as sap is removed and where the infestation is heavy, the whole tree takes on a gray cast.

There is great need for quantitative data on the effect of this pest on the yield and quality of fruit. These data are difficult to obtain because the control and damage by the red mite are integrated with those of the other important citrus pests. Woodworth (28), Quayle and Knight (16), and Boyce (1), all agree that the damage is of major importance in California; defoliation and twig damage may occur according to Boyce. Watson (26) considers the six-spotted mite, *Tetranychus sexmaculatus* Riley, more important than the red mite except in western Florida where satsumas are grown exclusively. The six-spotted mite is of no consequence in southern Alabama.

The citrus red mite is considered a major pest by satsuma growers but it must be ranked below the purple scale and rust mite on the basis of economic loss. Although heavy infestations occur on satsumas, defoliation rarely occurs. Its importance should not be minimized, however, because the heaviest infestation occurs in the early spring when the trees are blooming and setting a crop of fruit. Growers often attribute a light fruit crop to a heavy infestation of mites.

Description

The eggs are spheroidal, or onion-shaped, and are deposited on the fruit, twigs and leaves. They are bright red in color when first deposited but become paler as the embryo develops so that shortly before hatching they are almost colorless. The egg is held in place by microscopic threads reaching from a stalk on the egg to the leaf. The eggs average 0.133 millimeter through the long axis and 0.096 millimeter through the short axis. The stalk of the egg is about 0.112 millimeter long.

The larvae have 6 legs and are pale orange in color when newly hatched. They gradually become dark red. After the first molt the mite has 8 legs and is called protonymph by Newcomer and Yothers (14). A second molt is made to reach the deutonymph stage. Both the proto- and deutonymph are similar to but smaller than the adults. The deutonymph becomes quiescent before the final molt required to reach the adult stage.

As viewed from above the females are dark, almost blackish-red in color and somewhat elliptical in shape. The head and the underside are lighter. Long, spiny hairs, which curve backwards, protrude from tubercles. The legs and spines are paler in color than the body. Through the long axis, the average body length of 10 females was 0.405 millimeter. The short axis averaged 0.294 millimeter.

The males are smaller and more active than the females. They are lighter red in color but usually have a dark red band encircling the body. The legs and spines are pale as in the female, but the legs appear longer because of the smaller body, which is somewhat pointed at each end. Ten males averaged 0.274 millimeter in length and 0.177 millimeter in width.

Life History

Eggs are deposited on both leaf surfaces and, in heavy infestations, on the branches, twigs, and fruit. The greater number is found along the midrib of the lower leaf surface and in rough places, pits, and scab lesions. The eggs hatch in 4 to 31 days depending on the season, but over 50 per cent hatch in 5 to 8 days (Table 8). When the eggs hatch the shell divides into 2 hemispheres, smoothly split through the longer axis. The legs of the larvae are thrust out between the 2 halves of the shell to pry them apart for exit. Two or 3 days are spent in the larval stage, but 8 days may be required in the winter or as little as 1 day in summer before molting. The duration of the protonymph stage may vary from 1 to 7 days, but most of the individuals spend 2 or 3 days in this stage. In warm weather, from 2 to 4 days are spent in the deutonymph stage before the final molt is made to reach the adult. The males wait beside the quiescent female deutonymph to mate after this final molt. During favorable weather a total of 10 to 15 days is required for development from egg to adult. In addition to this period of development, females require 2 or 3 more days before beginning to lay eggs. In the winter a female may live from 20 to 35 days before ovipositing. After reaching maturity the females usually live 15 to 20 days and deposit 20 to 30 eggs. The greatest number of eggs laid was 46, from a female that lived 31 days. As a rule the mites live longer and deposit more eggs in cool weather.

TABLE 8.—Life History of the Citrus Red Mite.

Period or stage	Number of days in period					
	(35 males)			(48 females)		
	Min.	Max.	Av.	Min.	Max.	Av.
Incubation	4	28	8.8	4	31	10.2
Larva	1	6	1.8	1	8	2.2
Protonymph	1	7	2.5	1	6	2.5
Deutonymph	1	8	2.6	1	9	2.8
Complete development	7	49	15.8	7	54	17.7
Pre-oviposition				1	36	5.9
Life cycle[1]	7	49	15.8	8	90	23.7
Adult life span	3	51	13.3	6	59	22.4
Total life span[2]	6	72	20.3	10	118	35.8
Number eggs deposited				1	46	19.0

[1]Apparently the males are sexually mature on becoming adult. Hence the life cycle of males is identical with the period of development.
[2]Time in days from birth to death.

Seasonal History

Weekly egg counts were used as the criterion of seasonal variation in population of the citrus red mite. Thirty leaves were collected from an unsprayed plot every week. A 10-squarecentimeter disk was punched from each leaf and the number of eggs on both surfaces counted. Counts made over a period of 6 years show that the red mite is most abundant in cool weather. The infestation starts building up in the fall and reaches its greatest density in March, April, and May. By June the population has declined, but in some years it may build up by the latter part of the month, and then decline again. Throughout most of the summer and early fall there is scarcely any infestation of the red mite (Figure 13).

Atmospheric temperature is an important factor in determining the seasonal abundance of mites. Woodworth (28) recognized the influence of temperature as early as 1902. He was skeptical about the summer decline being due to a disease because no disease developed on cultures in the insectary. In the interior of California, where maximum summer temperatures are high, the citrus mite is not a problem, but it is a major pest in the more humid and cooler coastal regions (1, 18). Development may be brought to a standstill by a cold wave but the mites survive temperatures below 20° F. and the population builds up as soon as warmer days come. Warm days (not hot days) with cool nights seem to be about ideal for the development of this pest.

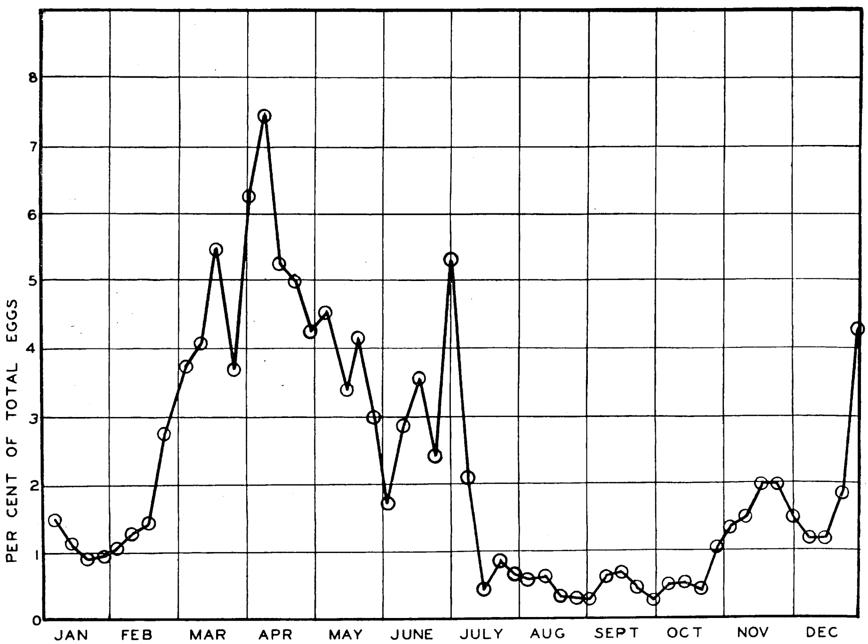


FIGURE 13.—Seasonal Abundance of Citrus Red Mite (Spider) as Indicated by Egg Counts on Satsuma Foliage (six-year average).

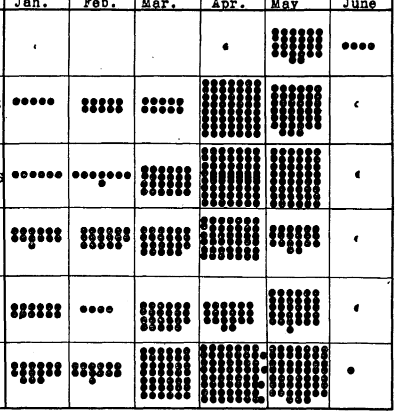
Control

Sulphur, either as a dust or spray, has been the standard remedy for all plant-infesting mites for many years. However, Woodworth (28) noted that sulphur did not give satisfactory control of citrus red mite. In 1932, Quayle (17) stated that sulphur was effective in proper weather conditions but that oil was more reliable because of the enduring residual effect. Boyce (1) pointed out that oil rapidly replaced sulphur for the control of red mite after 1925.

Experiments with Sulphur and Oil Sprays.—As a part of an extensive experiment comparing spray programs for satsuma oranges, monthly counts of the number of red mite eggs on a series of plots were made over a period of 3 years. A program of spraying (Table 9) in which oils were applied in July and October gave almost perfect control until the following May, and it is doubtful that the mite population was of any economic consequence in May. With the October application of oil replaced by lime sulphur-wettable sulphur, the population of mites became dense in April and remained so through May. The plot receiving oil in July had a lower infestation through

TABLE 9.—Control of the Citrus Red Mite with Sulphur and Oil Sprays as Indicated by Egg Counts the First Spring after Treatment.

Plot No.	Treatment* 1935						Number of eggs per 10 sq. cm. of leaf 1936					
	March	May	June	July	Aug.	Oct.	Jan.	Feb.	Mar.	Apr.	May	June
17	Bordo-sul	LS & WS		Oil		Oil						
10	" "	" "		Oil		LS & WS						
24	" "	" "	LS & WS	LS & WS	LS & WS	LS & WS						
25	" "	LS	LS	LS	LS	LS						
23	" "	WS	WS	WS	WS	WS						
13	Untreated check											



*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
LS: 1½ gals. liquid lime sulphur per 100 gals. water.
WS: 7½ lbs. wettable sulphur per 100 gals. water.
Oil: July, 1½ gals. 78" viscosity white oil per 100 gals. water. October, 1 gal. per 100 gals. water (tank-mix).

March than the three plots which had been treated with 5 sulphur sprays. In April, the population became dense on all 4 of the plots. It should be noted that 5 lime sulphur-wettable sulphur sprays were no more effective than lime sulphur or wettable sulphur used separately.

Since the heaviest infestation of red mites usually occurs in March, April and May, the average egg counts for these 3 months were used to compare the effectiveness of the above spray schedules for 3 years (Table 10*). Where oil was applied in the the early fall as well as in July, effective control of mites was obtained through the first spring following treatment and almost perfect control during the subsequent 2 years. Where oil was applied in July, but with sulphur in August and September, satisfactory control was not obtained the first spring after treatment, but in the following 2 springs the control was practically as good as where 2 oil sprays were used. Thus, it seems that once the mites are brought under control, a regular application of oil in July is sufficient. Five applications of both lime sulphur-wettable sulphur and lime sulphur failed to reduce the egg count materially below that of the check.

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*Because of the ineffectiveness of wettable sulphur against purple scale, it was necessary to revise the treatment on Plot 23 after the second year. Hence data from this plot are omitted from Table 10.

TABLE 10.—Control of the Citrus Red Mite with Sulphur and Oil Sprays as Indicated by Egg Counts over a 3-year Period.

Plot No.	Treatment* 1935-1936-1937						Number of eggs per 10 sq. cm. of leaf(1)		
	March	April May	June	July	August	Sept. Oct.	1936	1937	1938
17	Bordo-sul	LS & WS		Oil	WS	Oil			
10	" "	" "		Oil	S. dust	LS & WS			
24	" "	" "	LS & WS	LS & WS	LS & WS	LS & WS			
25	" "	LS	LS	LS	LS	LS			
13	Untreated check								

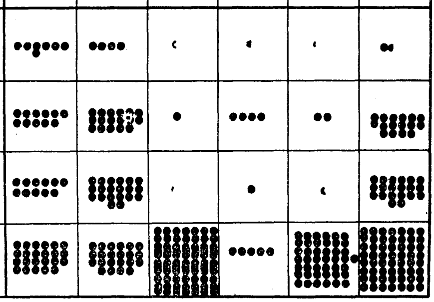
*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
LS: 1½ gals. liquid lime sulphur per 100 gals. water.
WS: 7½ lbs. wettable sulphur per 100 gals. water.
S. dust: sulphur dust, about ½ lb. per tree.
Oil: July, 1½ gals. 78″ viscosity white oil per 100 gals. water. Sept.-Oct., 1 gal. per 100 gals. water (tank-mix).
1) Average, March, April, and May.

Effectiveness of March Insecticide-Fungicide Treatments.—Since the population of red mites reaches its greatest density in the spring, it was important to determine the control obtained by the sprays necessarily used at this time of the year for sour scab. Three plots received oil in July, sulphur dust in August, and lime-sulphur-wettable sulphur in September (Table 11). The schedules differed only in the sprays used in March; the first contained Bordeaux-oil, the second Bordeaux, and the third Bordeaux-sulphur. The average egg counts for January, February, and March indicate the mite population before the March spray was applied, while the average egg counts for April, May, and June indicated the population after the March treatments. Bordeaux-oil was the only March spray that reduced the egg count and maintained mite control through April, May, and June. Following applications of Bordeaux or Bordeaux-sulphur, the egg count increased. This was particularly noticeable in 1938, but the egg count of these 2 plots was much lower than that on the untreated check.

Experiments with Sulphur Sprays and Dust.—Plots receiving 4 and 5 applications of sulphur dust were compared with those receiving 5 applications of sulphur sprays (Table 12). All plots received Bordeaux-sulphur in March. The control on Plots 23, 24, and 25, which received sulphur sprays, apparently was not quite as good as that obtained on the plots receiving

TABLE 11.—Control of the Citrus Red Mite with Insecticide-Fungicide Mixtures Applied in March.

Plot No.	Treatments* 1935-1936-1937				Average number eggs per 10 sq. cm. of leaf 1936		1937		1938	
	March	July	August	Sept.	JFM[1]	AMJ[2]	JFM[1]	AMJ[2]	JFM[1]	AMJ[2]
4	Bordo-oil	Oil	S. dust	LS & WS						
8	Bordo	"	"	"						
12	Bordo-sul	"	"	"						
13	Untreated check									



*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938); 1½ gals. (1936) 78″ viscosity white oil per 100 gals. (tank-mix).
Bordo: 6-6-100 Bordeaux mixture.
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
Oil: 1½ gals. 78″ viscosity white oil per 100 gals. water (tank-mix).
S. dust: sulphur dust, about ½ lb. per tree.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
1) Average, January, February, March; before March treatment.
2) Average, April, May, June; after March treatment.

TABLE 12.—Results of Experiments with Sulphur Sprays and Dusts for the Control of the Citrus Red Mite.

Plot No.	Treatment* 1935						Number eggs per 10 sq. cm. of leaf, 1935-36			
	March	May	June	July	August	October	Dec.	Jan.	Feb.	Mar.
26	Bordo-sul	LS & WS		Oil	S. dust	S. dust	●●	●●	●●●	●●
27	"	"	S. dust	S. dust	S. dust	S. dust	●●●●●●●●●●●●●	●●●●	●●●●●●●	●●●●●●●●●●●●●●●●●●●
28	"	S. dust	S. dust	S. dust	S. dust	S. dust	●●●●	●●	●●●	●●●●●●●●●●●
23	"	WS	WS	WS	WS	WS	●●●●●●●●●●●●●●●●●●●●●●●●●●●	●●●●●●●●●●●	●●●●	●●●●●●●●●●●●●●●●●●●●●●●
24	"	LS & WS	LS & WS	LS & WS	LS & WS	LS & WS	●●●●●●●●●●●●●●●●●●●●●●●●	●●●●●●	●●●●●●●●●	●●●●●●●●●●●●●●●●●●●●●●●●
25	"	LS	LS	LS	LS	LS	●●●●●●●●●●●●●●●●●●●●●●●●	●●●●●●●●●●●●●	●●●●●●●●●●●●●●●●●●●●	●●●●●●●●●●●●●●●●●●●●●●●
13	Untreated check						●●●●●●●●●●●●●●●●●●●●●●●●●●●●●●	●●●●●●●●●●●●●●●	●●●●●●●●●●●●●	●●

*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
LS: 1½ gals. liquid lime sulphur per 100 gals. water.
WS: 7½ lbs. wettable sulphur per 100 gals. water.
S. dust: sulphur dust, about ½ lb. per tree.
Oil: 1½ gals. 78″ viscosity white oil per 100 gals. water (tank-mix).

sulphur dusts. It is evident, however, that there was only a slight reduction below the check in the egg counts on the 5 plots which received "all-sulphur" treatment.

Conclusions.—Sulphur sprays and dusts, although frequently applied, cannot be relied on to control the citrus red mite on satsuma oranges in southern Alabama. This is due to the fact that sulphur is not effective in cool weather when the mite is most abundant. Successful control can be obtained with spray schedules containing an oil application in July only. As an emergency spray, oil may be mixed with the March application of Bordeaux, but for practical reasons, to be explained later, mites should be controlled with a regular oil spray in July. The effectiveness of oil is not only immediate against the mites and eggs, but the persistant residue prevents a re-infestation for several months.

SOUR SCAB

Since the eradication of citrus canker, *Phytomonas citri* (Hasse), sour scab may be considered the most important citrus disease along the Gulf Coast. This disease which is also known as citrus scab and lemon scab, is caused by the parasitic fungus *Sphaceloma fawcettii* Jenkins. It was first noted near Ocala, Florida, in 1885 (19, 27). Winston (27) states that it was largely responsible for the failure of the lemon industry in Florida. Thus far it has been kept out of Arizona and California. The disease was probably introduced into the United States on the satsuma orange, which Winston classifies as "quite susceptible". Sour orange, lemon, calamondin, and tangelo are classified by him as extremely susceptible. Round oranges and kumquats are rarely attacked, while limes and some varieties of grapefruit appear to be immune.

Scab is the disease that causes "bumpy" fruit (Figure 14). Its economic importance to the grower ranks next to purple scale, except possibly in a few isolated groves. In groves which are relatively free of scale, scab is likely to be the major problem.

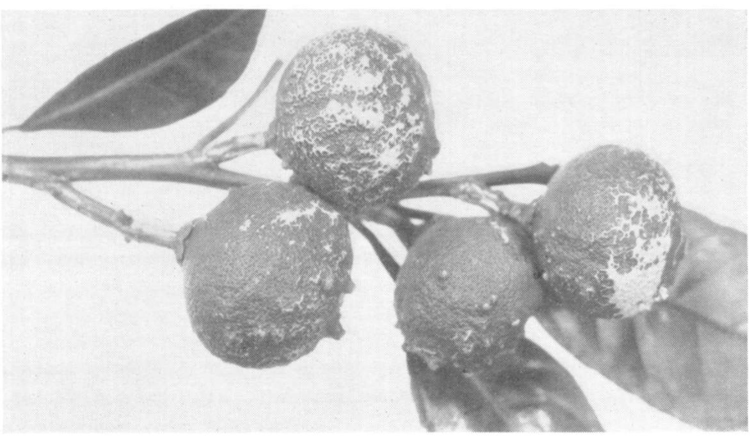


FIGURE 14.—Young Satsuma Fruits Infected with Sour Scab.

Description

The scab organism overwinters on infected twigs and leaves (19). The disease is first noted as small conical bumps on the tender new leaves in the spring. Likewise, the small fruits become bumpy as they are infected. In severe infections the latest growth or "flat wood" is diseased. Rainy weather, fogs, and heavy dew after petal fall contribute to infection (27). Damage to the fruit is of two sorts; young infected fruits drop prematurely (19), and the bumps on the ripe fruit reduce the grade, usually to cull.

Rhoads and DeBusk (19) observed that the virulence of the disease varied greatly from year to year, and this has been substantiated by the experiments in southern Alabama. In 1935, 1936, and 1937, the percentage of cull fruit produced on the untreated checks was 67.5, 29.3, and 36.5, respectively. The control of scab was difficult in 1935 and 1937, but especially so in 1935, when from 25 to 50 per cent of the fruit was culled on plots which received 2 standard fungicide applications. The severe scab infection may have been partially due to improper control the previous year, but there seems to be some relationship between the new growth and time of bloom that accounts for the degree of infection. During the winter of 1934-35, the trees in the above mentioned experiment were partially defoliated by freezes. When growth started in the spring there was a heavy production of new foliage before, or about the time blooming began. Normally, blossoms occur and lose their petals before new growth becomes extensive.

Control

In 1896 it was found that scab could be controlled with Bordeaux mixture (22). In 1919 and 1920 Winston (27), conducted experiments on nursery stock, making rather frequent applications of liquid lime sulphur and testing several concentrations of Bordeaux. Bordeaux mixture, even at low concentrations, was more effective than lime sulphur. For moderate or severe infections he recommended 4 sprayings with Bordeaux, to which was added 0.5 to 1 per cent of oil as an emulsion. In experiments with grapefruit Ruehle (22) found Bordeaux to be the most reliable spray for scab. For severe infections he recommended 2 applications, one before growth and another in the latter part of the blooming period. Ruehle also noted an increase in control due to the cumulative benefits of spraying.

Any spray schedule designed to control the insect pests of satsuma oranges should contain fungicides for the control of scab. Since the fungicides may also be insecticides or advantageously mixed with them, the problem of insect and disease control is one and the same to the grower. Apparently there are no quantitative data on the control of scab on satsumas. Therefore, in comparing a number of spray programs data on scab were taken.

Experiments with Various Fungicide Mixtures.—On a series of 12 plots, Bordeaux-oil, Bordeaux, and Bordeaux-sulphur were used as pre-growth sprays in March. Each spray was applied to 4 plots. Bordeaux-sulphur, lime sulphur-wettable sulphur, and Bordeaux were used as post-bloom sprays following each of the above 3 mixtures (Table 13). There was no essential difference in the effectiveness of Bordeaux-oil, Bordeaux, and Bordeaux-sulphur as pre-growth sprays. Likewise, Bordeaux-

TABLE 13.—Results with Various Fungicide Mixtures* on the Control of Sour Scab over a Period of Four Years.

Pre-growth spray	Per cent scabby fruit on plots receiving post-bloom sprays of				Average per cent scabby fruit
	Bordo-sul	LS & WS	Bordo	None	
Bordo-oil	22.1	14.9	14.0	26.2	19.3
Bordo	16.3	15.9	20.3	24.7	19.3
Bordo-sulphur	17.9	21.2	20.4	20.9	20.1
Average	18.7	17.3	18.2	23.9	
Check				34.6	

*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938), 1½ gals. (1936), 78″ viscosity white oil per 100 gals. (tank-mix).
Bordo: 6-6-100 Bordeaux mixture.
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
All plots, except the check, received oil in July, sulphur dust in August, and lime sulphur-wettable sulphur in September.

sulphur, lime sulphur-wettable sulphur, and Bordeaux were about equally effective as post-bloom sprays, the plots producing an average of 18.7, 17.3, and 18.2 per cent scabby fruit, respectively. Schedules with the post-bloom spray omitted averaged 23.9 per cent scabby fruit or about 6 per cent higher than those containing 2 fungicides.

Experiments with Sulphur Sprays.—The most satisfactory control of scab was obtained with frequent applications of sulphur sprays (Table 14). On a series of 4 plots, Bordeaux-sulphur was used as the pre-growth spray. One plot subsequently received 5 applications of wettable sulphur; the second, 5 applications of lime sulphur; the third, 5 applications of lime sulphur-wettable sulphur; while the fourth received only 2 sprayings with lime sulphur-wettable sulphur after the pre-growth spray. In 1935, when the untreated check produced 67.5 per cent scabby fruit, some apparent reduction in scab was obtained even with the applications of wettable sulphur. An average of only 8.6 per cent of the fruit was scabby during 4 years where Bordeaux-sulphur was applied in March, followed by lime sulphur-wettable sulphur in April, May, July, August, and September. This is about one-fourth of the amount of scabby fruit on the check plot and less than one-half of that on the plots sprayed with pre-growth and post-bloom fungicides only.

Conclusions.—When the infection of scab is relatively light very satisfactory control can be obtained with 2 fungicide sprays. Sufficient reduction in scabby fruit is usually obtained to justify at least 2 sprays. Severe infections require more frequent fungicide applications for satisfactory control. It appears that superior results depend more on frequent applications than on the kind and strength of the fungicide.

TABLE 14.—Percentage of Scabby Fruit on Plots Receiving Frequent Sulphur Sprays.

Plot No.	Treatment*						Per cent scabby fruit				
	March	April	May	July	Aug.	Sept.	1935	1936	1937	1938	Av.
23	Bordo-sul	WS	WS	WS	WS	WS	39.9	1.4	[3]	[3]	20.6
25	Bordo-sul	LS	LS[2]	LS	LS	LS	23.7	0.5	7.1	[3]	10.4
24	Bordo-sul	LS & WS	LS & WS[2]	LS & WS	LS & WS	LS & WS	27.2	0.2	6.9	0.3	8.6
10	Bordo-sul	LS & WS		Oil	S. dust[1]	LS & WS	58.1	2.2	20.8	3.8	21.2
13	Untreated Check						67.5	29.3	36.5	5.5[4]	34.7

*Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
WS: 7½ lbs. wettable sulphur per 100 gals. water.
LS: 1½ gals. liquid lime sulphur per 100 gals. water.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil: 1½ gals. 78" viscosity white oil per 100 gals. water (tank-mix).

[1]Omitted in 1935.
[2]Omitted in 1937.
[3]Discontinued because of failure to control purple scale.
[4]Trees in check plots seriously devitalized by purple scale. Most of scabby fruit probably dropped before harvest.

EFFECT OF SPRAYS ON SATSUMA TREES AND FRUIT

One of the limiting factors in disease and insect control is the effect of the treatment on the plant. Consequently a study of the effects of sprays on satsuma trees and fruit is of great importance.

The Effect of Oil Sprays on the Foliage.—The action of oil emulsions on citrus foliage may be acute or chronic. A distinction between the two types of injury was made by Volck (25) as early as 1903, and later by deOng, Knight and Chamberlin (4) and most of the other workers in this field. An excellent summary of the reaction of citrus trees to oil sprays is given in recent work by Quayle (18).

Acute injury is manifested by leaf burn and occasionally by immediate defoliation. Such injury is usually caused by emulsions made from petroleum oils which have not been refined sufficiently for use on plants in foliage. Most of the oils now used on citrus have been refined by sulphuric acid treatment to give an oil of relatively high "unsulphonated residue". It has been shown definitely that the water-white oils produced by such treatment are safer to use on plants in foliage. Acute injury is seldom experienced by Satsuma growers who use the better grades of oil. However, oils having an unsulphonated residue as low as 62 per cent have been applied to satsuma trees at oil concentrations as high as 4.2 per cent, without showing visible or acute injury. Under critical conditions induced by freezes, improper care of trees, etc., injury from these low grade "unsaturated" oils becomes manifest.

The more important effects of oil sprays are those caused by penetration of the oil into and its persistence on the foliage and fruit. Such injury is classified as chronic. It is evident, from observation, that oils rapidly penetrate leaves. The residue of the less volatile oils may be seen weeks or even months after the application. By the use of a special stain technique, Rohrbaugh (20, 21) made a careful study of the penetration and location of oils applied as sprays. He concluded that the oil went into the tissue by capillarity. By far the greater portion of oil entered leaves through the stomata on the under side. This was noted by other workers also (11, 25). Rohrbaugh found that the oil remained between the cells of the plant tissue and did not enter cells containing protoplasm. The less volatile portions of the oils may remain between the cells throughout the life of the leaf. Yet in spite of this the leaves may appear to be healthy. Oil concentrated along the mid rib and margins of the leaf. It did not penetrate more than two-thirds the depth of the bark of twigs. On fruit the penetration of the oil was no deeper than the oil glands of the rind of oranges. The more volatile oils soon disappeard from the foliage and there was no trace of them after 6 months. Unfortunately these volatile oils are not effective in controlling scale insects.

There is little doubt that the presence of oil within the tissues of citrus leaves inhibits their proper functioning. DeOng, Knight and Chamberlin (4) noted that the senility of leaves was hastened by the presence of oils. Kelly (11) demonstrated that the presence of oil on apple foliage reduced transpiration (loss of moisture). More recently, Eidel'man (8) found that oil sprays decrease photosynthesis in leaves of the mandarin orange and that the penetration of unrefined oils in the leaf tissue increased respiration. The latter is detrimental, he stated, as it results in the expenditure of stored organic substances (carbohydrates). He concluded, further, that defoliation of citrus was not due to the local effect of oil at the juncture of the blade and petiole, but was a result of the physiological disorganization of the whole leaf.

It is evident that the nature of chronic injury to citrus is intricate and its importance can only be determined by a prolonged study of the cumulative effects of oil sprays on the yield and quality of the fruit. These two things are of vital interest to the grower.

Oil Sprays and Freeze Injury.—Yothers and McBride (32) noted that a frost shortly following an application of oil caused injury to citrus trees. This has been generally observed by growers in south Alabama, also.

In order to make a study of this factor, a series of oils varying in viscosity and degree of refinement was applied to vigorous trees on September 18, 1928 (Table 15). The oils were emulsified with potash fish oil soap and applied at concentrations of 2.1 and 4.2 per cent oil. On December 9, 82 days

TABLE 15.—Relative Defoliation of Satsuma Trees Caused by a Freeze 82 Days after the Application of Several Grades of Oil.

Type of oil	Viscosity (Saybolt) (Seconds) (100°F.)	Unsulphonated residue* per cent	Estimated defoliation with oil at concentrations of 2.1%	4.2%
White	51	86	0.0%	0.0%
White	140	90	0.0	10.0
Straw	43	74	0.0	0.0
Straw	59	67	10.0	20.0
Straw	100	62	10.0	60.0

*With 38 N sulphuric acid by method of A. O. A. C.

later, there was a freeze with a minimum temperature of 25° F. It is evident from this experiment that there was a definite relationship between injury, following a freeze, and the degree of refinement and viscosity of the oil. The two oils classified as "white" caused no defoliation at a concentration of 2.1 per cent. At 4.2 per cent, the oil with a viscosity of 140 (Saybolt) caused only 10 per cent defoliation. Of the 3 relatively unrefined oils, the one with a viscosity of 43 caused no defoliation. With an increase in viscosity there was increasing defoliation with these unrefined oils. An oil having a viscosity of 100 and an unsulphonated residue of 62 per cent caused defoliation estimated at 60 per cent, when applied at a concentration of 4.2 per cent.

The Effect of Oil and Bordeaux-oil Sprays on Trees Defoliated by a Freeze.—During the winter of 1929-30 satsuma trees in southern Alabama were completely defoliated by freezes. On March 31, when the new foliage was about three-fourths of an inch long, two sprays containing 1.2 per cent oil were applied in mixtures with 6-10-100 Bordeaux for the control of scab. Both of the oils had a viscosity of 83 seconds Saybolt but differed in their degree of refinement. The white oil had an unsulphonated residue of 86 per cent and the straw oil 64 per cent. Both of these oil mixtures with Bordeaux caused severe defoliation. It was peculiar that the white oil-Bordeaux spray caused defoliation estimated at 90 per cent, whereas the straw oil-Bordeaux caused an estimated defoliation of 40 per cent. To check the possibility of an error in carrying out the experiment, similar applications were made April 9. The results of the first experiment were sustained and, in addition, it was found that Bordeaux alone caused a drop of the new foliage estimated at 25 per cent. The straw oil, alone, caused more injury, largely in the form of burn, than when mixed with Bordeaux. This straw oil-Bordeaux mixture caused less damage to the new foliage than either alone. The white oil-Bordeaux spray was more injurious than the white oil alone (Figure 15).

It was concluded from these experiments that trees which have been defoliated and are covered entirely with new growth should not be sprayed until the foliage has had time to harden. It was also concluded that applications of Bordeaux-oil when used for the control of sour scab and insects, normally should be made before growth starts in the spring.

The Effect of Oil Sprays on Fruit Drop.—Satsuma orange trees blossom excessively and set much fruit that does not mature. The drop of small fruit is general throughout the months of April, May, and June, with the heaviest drop usually in June. By July the fruit is securely attached and does not drop unless there is serious injury to the tree. Naturally, no spray or cultural practice that increases the drop of young fruit should be used.

In California, Woglum (29) found that applications of a heavy (non-volatile) white oil at a concentration of 1.5 per cent caused the dropping of both immature and tree-ripe fruit. At concentrations lower than 1.5 per cent this trouble practically disappeared.

In Alabama, 2 oil sprays were applied to satsuma trees on April 26 when the fruit was about 0.25 inch in diameter. On

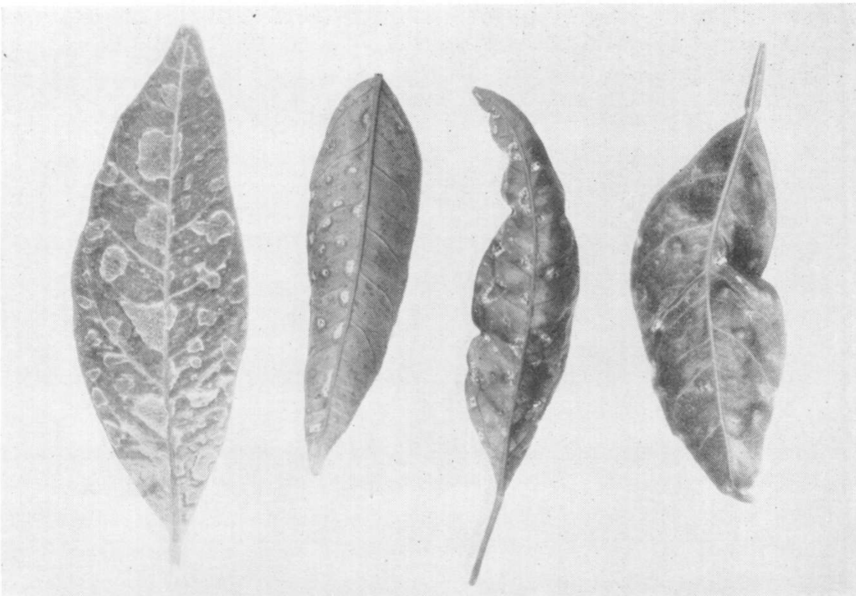


FIGURE 15.--Mal-formation of Young Satsuma Leaves Caused by a Bordeaux-oil Spray.

May 10, a count was made to determine the effect of the oils on fruit drop (Table 16). The relatively unrefined straw oil at concentrations of 1.5 and 3 per cent caused a definite fruit drop in excess of that on the check. At 0.75 per cent no appreciable fruit drop was induced by this oil. On the other hand, the white oil caused slight dropping at a concentration of 3 per cent and perhaps a little at 1.5 per cent. From this test and the experience of others it appears inadvisable to spray with oils after growth starts in the spring and before the fruit is well set.

Injury Caused by Lime Sulphur.—Brock (2) observed that oil sprays mixed with liquid lime sulphur caused severe fruit burn in hot weather and it is generally believed that neither

TABLE 16.—Percentage of Fruit Drop Caused by Oil Sprays.

Oil	Unsulphonated residue* per cent	Viscosity (Saybolt) (seconds) (100°F.)	Per cent fruit dropped caused by oil at concentrations of			
			3.0%	1.5%	0.75%	0.0%
White	86	83	79	67	55	
Straw	64	83	99	87	60	
Untreated check						62

*With 38 N. Sulphuric acid by method of A. O. A. C.

of these sprays should succeed the other in the spray program except after an interval of several weeks.

To obtain more specific information on this point, a block of trees was sprayed with a refined white oil at 1.2 per cent and a second block was sprayed with liquid lime sulphur at a concentration of 2 per cent. The sprays were applied May 1, when the temperature was 81° F. At weekly intervals thereafter for 7 weeks, 2 trees in the oil-sprayed block were sprayed with lime sulphur and 2 trees in the lime sulphur-sprayed block were sprayed with oil, using the original concentrations. No defoliation was caused by any of the treatments. Lime sulphur followed by oil at weekly intervals did not injure the foliage. On the other hand on all plots where oil was followed by lime sulphur a burn or scald to the under side of the leaves was produced (Figure 16). It was evident that so long as there was an appreciable quantity of oil on the leaves, succeeding applications of lime sulphur produced scalding. While it cannot be concluded that oil can always safely follow lime sulphur, it appears that lime sulphur before oil is safer than lime sulphur after oil.

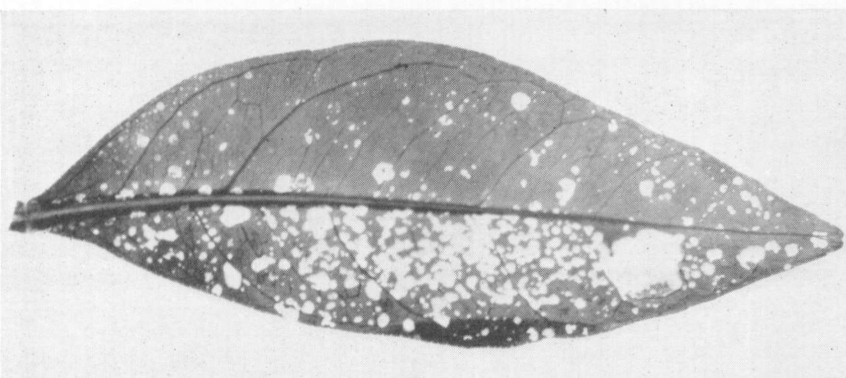


FIGURE 16.—Damage to Underside of a Satsuma Leaf Caused by Lime Sulphur following an Oil Spray.

In an experiment in the southern part of Mobile County applications of lime sulphur at 1.5 per cent, both with and without wettable sulphur added, were made in April, May, July, August, and September for 3 years without perceptible leaf drop on injury of any sort. During the fourth year of the experiment, the August application caused severe leaf drop and scald of fruit. The damage was greatest on the southwest side of the trees. In another experiment, applications of lime sulphur at 1 per cent with 10 pounds of wettable sulphur added to 100 gallons caused even more severe damage (Figure 17). Defoliation was estimated at 20 to 40 per cent and the fruit was so badly scalded on the south side of the trees that it dropped.

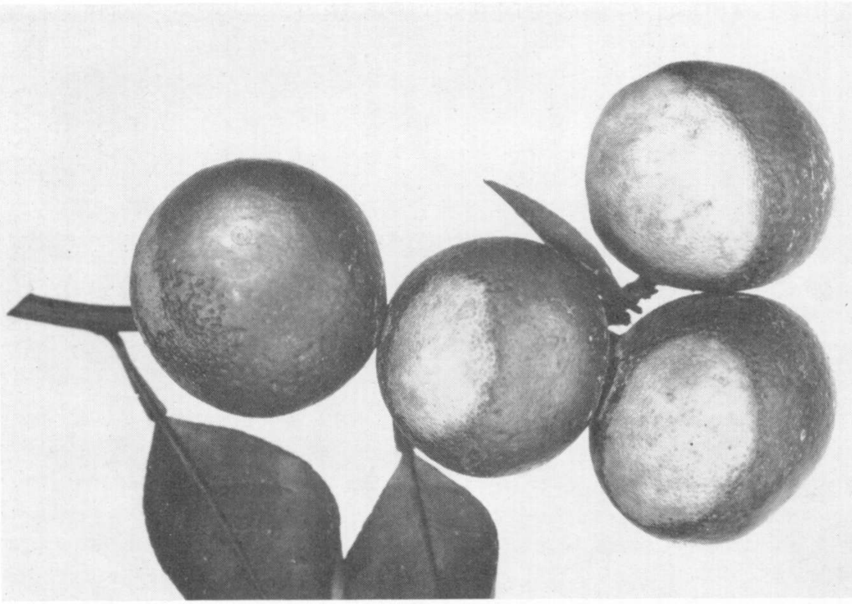


FIGURE 17.—Satsumas Sun-scalded after an Application of Spray Containing 1 gal. of Liquid Lime Sulphur and 10 lbs. of Wettable Sulphur per 100 gals. Water.

Damaged fruits which did not drop were seriously impaired in quality by the dry sections which formed under the scalded area. In this experiment, the maximum temperature on the day of application was only 90.5° F., but there followed 6 bright days with maximum temperatures of 95 to 98° F. There was also a deficiency of soil moisture, which may have been a contributing factor.

It is evident from these experiments that the use of liquid lime sulphur is risky, when there is any probability that air temperatures may go above 90° F., during or shortly after spraying. Applications of wettable sulphur or sulphur dust during this period caused no damage, although some untreated fruits were sun-scalded by the intense sunshine.

The Effect of Sprays on the Maturity and Quality of the Fruit.—In California, Woglum (29), deOng, Knight, and Chamberlin (4), and Brock (2) have noted the retardation of maturity and the inhibition of normal coloring of the fruit caused by the excessive use of oil sprays. In Florida Yothers and McBride (32) noted similar effects. Ohsaki and Hagano (15) found that oil sprays increased the size of the fruit in Japan, but retarded the ripening. The sprayed fruits contained less sugars, by analysis, and the quality was inferior to unsprayed fruit.

Chines and Fischetti (3) also found that the sugar content of citrus fruits was reduced by oil sprays.

In recent years a breakdown of the rind of navel oranges has been a serious problem in California. This "water-rot", as it is called, is much more serious in rainy seasons. It has been found that the percentage of water-rot is much higher on fruit which has been sprayed with oil than on that which has been fumigated, or received no treatment at all (6, 30). Although oil sprays are not the specific cause of this trouble, they appear to be conducive to losses from water-rot. Fortunately, water-rot has not been observed on satsumas in southern Alabama, in spite of the high rainfall. No water-rot was observed on plots which received 2 applications of oil per season for 4 successive years.

In 1932, blocks of 80 to 90 trees, divided into 9 replicates, were sprayed with proprietary oil emulsions at a concentration of 2 per cent (emulsion) in July and 1.5 per cent in September. At the time of harvest, no retardation of coloring could be observed and no difference in the solids-acid ratio analysis (12) of the juice was obtained. Boxes of fruit from each sprayed block allowed to go through the pre-coloring process in the packing house colored up normally. The same treatments were repeated in 1933. At harvest there was definite delay in ripening on the blocks of trees sprayed with emulsions prepared from relatively unrefined oils, but the 2 emulsions made from refined oils caused no delayed ripening, when compared with the untreated check. These quantitative data, obtained from the picking records, suggest that the effect of oils on the ripening of satsumas may be cumulative.

In 1935 a more comprehensive experiment was started in a commercial grove. A highly refined white oil, having an unsulphonated residue of 95 per cent and a viscosity of 79 seconds, Saybolt, was used throughout the duration of the experiment. The oil was applied by the California tank-mix method (23). Five or 6 pickings were required to harvest the entire crop and from the yield records obtained, the percentage of fruit harvested at the last picking was calculated. This calculation gave a quantitative measure of the effect of the various treatments on the maturity of the fruit.

During the winter of 1934-35 the trees suffered partial defoliation but all plots received all sprays outlined in the schedules. A crop was harvested from only one series of triplicate plots and although maturity records for 1935 were incomplete there was no visible evidence of retarded maturity at the time of harvest. At the 1936 harvest, very marked differences in the maturity of the fruit on several plots could be observed. The observations received quantitative verification by the picking records. The fruit which matured earliest was always from the plot receiving Bordeaux-sulphur in March and five applications of lime sulphur-wettable sulphur afterwards (Table 17).

The substitution of one oil spray in July for one of the sulphur sprays more than doubled the percentage of the total crop harvested at the last picking. The further substitution of a second oil spray in September-October for another sulphur spray resulted in even greater delay in ripening, as evidenced by the fact that approximately 35 per cent of the total crop was harvested at the last picking, compared with an average of approximately 5 per cent for the plots receiving only the Bordeaux and sulphur sprays. Whether the early ripening on the plot receiving sulphur sprays was normal or whether it was induced by the treatments could not be determined, because the maturity of the fruit on the untreated check was seriously retarded by the infestation of purple scale. The maturity of the crop from the lime sulphur-treated plot was earlier every year in spite of the failure of these sprays to give commercial control of purple scale. Yothers (31) concluded that lime sulphur sprays did hasten maturity.

An analysis of the data from 12 plots which received various fungicide-insecticide mixtures of Bordeaux-oil, Bordeaux-sulphur, Bordeaux, and lime sulphur-wettable sulphur in the spring, and identical treatments in July, August, and September, showed that the spring treatments had no influence on the maturity of the fruit.

It was concluded from these experiments that the excessive use of oil sprays may retard the maturity of satsuma oranges. Late season applications were particularly objectionable. Although the effect may be cumulative, the application of a highly refined oil at a concentration of 1.5 per cent every July for 4 successive years did not seriously retard maturity, if at all. Every effort should be made to obtain proper insect control with not more than one oil spray per year. From the standpoint of early maturity of the crop frequent applications of lime sulphur are desirable.

The Effect of Sprays on the Yield of Satsumas.—Three plots treated with applications of oil in July and September-October produced an average of 21.8 field boxes of fruit, whereas, three plots treated with sprays containing sulphur in September-October instead of oil produced an average of 35.7 field boxes. Thus it is evident that the early fall application of oil materially reduced the yield (Table 18). From the data in this table there is no indication that the use of oil mixed with Bordeaux and applied in March has any effect on the yield.

Conclusions.—Emulsions made from water-white oils having a residue of 85 to 90 per cent after treatment with 38 N. sulphuric acid should be used in preference to sprays prepared from relatively unrefined oils, with an unsulphonated residue of 60 to 65 per cent. The highly refined oils are much safer,

TABLE 17.—Effect of Sprays on the Maturity of Fruit.

Plot No.	Treatments* 1935 - 1936 - 1937 - 1938 March	April May	May June	July	Aug.	Sept. Oct.	Per cent of total yield harvested at the last picking 1936	1937	1938	Average
16	Bordo-oil	LS & WS		Oil	WS[2]	Oil	40.4	48.8	22.9	37.4
17	Bordo-sul	LS & WS		Oil	WS[2]	Oil	25.6	49.5	28.3	34.5
2	Bordo-oil	LS & WS		Oil	S. dust[2]	LS & WS	13.4	28.2	3.5	11.7
10	Bordo-sul	LS & WS		Oil	S. dust[2]	LS & WS	15.7	16.8	2.1	11.5
24	Bordo-sul	LS & WS	LS & WS[1]	LS & WS	LS & WS	LS & WS	7.7	5.7	1.2	4.9
13	Untreated check-maturity retarded by heavy infestation of purple scale						41.4	45.1	36.3	40.9

*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938), 1½ gals. (1936), 78" viscosity white oil per 100 gals. (tank-mix).
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
Bordo: 6-6-100 Bordeaux mixture.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil: July, 1½ gals. per 100 gals. water; Sept., 1¼ gals. per 100 gals. water, 78" viscosity white oil (tank-mix).
WS: 5 lbs. wettable sulphur per 100 gals. water.

[1]Omitted in 1937.
[2]Omitted in 1935.

TABLE 18.—The Effect of Oil and Sulphur Sprays on the Yield of Satsuma Oranges.

Plot No.	Treatments* 1935 - 1936 - 1937 - 1938 March	April May	July	Aug.	Sept. Oct.	Yield, field boxes per plot 1936	1937	1938	Av.
16	Bordo-oil	LS & WS	Oil	WS[1]	Oil	38.6	17.0	31.8	29.1
17	Bordo-sul	LS & WS	Oil	WS[1]	Oil	28.1	11.3	17.3	18.9
18	Bordo	LS & WS	Oil	WS[1]	Oil	26.4	8.1	17.5	17.3
2	Bordo-oil	LS & WS	Oil	S. dust[1]	LS & WS	37.4	29.5	37.4	34.8
10	Bordo-sul	LS & WS	Oil	S. dust[1]	LS & WS	31.9	42.8	32.4	35.7
6	Bordo	LS & WS	Oil	S. dust[1]	LS & WS	38.4	40.3	31.0	36.6
13	Untreated check					25.6	14.2	2.2	14.0[2]

*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. (1935, 1937, 1938), 1½ gals. (1936), 78" viscosity white oil per 100 gals. (tank-mix).
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
Bordo: 6-6-100 Bordeaux mixture.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Oil: July, 1½ gals. per 100 gals. water; Sept., 1¼ gals. per 100 gals. water, 78" viscosity white oil (tank-mix).
WS: 5 lbs. wettable sulphur per 100 gals. water.

[1]Omitted in 1935.
[2]Low yield caused by purple scale.

especially if their use is followed by critical climatic conditions. If Bordeaux-oil mixtures are used in the spring they should be applied before growth starts. Trees that have been defoliated and have nothing but new growth on them should not be sprayed. Satsuma trees should not be sprayed with oil while the fruit is small. The frequent use of sulphur sprays apparently hastens the maturity of fruit, but liquid lime sulphur should not be used in mid-summer nor at any time when atmospheric temperatures are likely to exceed 90° F. The excessive use of oil sprays may retard the maturity of fruit and reduce the yield. Late season applications, particularly, should be avoided.

COST OF INSECT AND DISEASE CONTROL

One of the objectives of these experiments was to reduce the cost of insect and disease control without sacrificing effectiveness. In computing the cost of spray programs the market price of materials was used. Labor was charged at 25 cents per hour, water at 7 cents per 100 gallons, use of the sprayer at $1.25 per acre, and use of the duster at 35 cents per acre per application. The cost of the separate sprays was based on the use of 400 gallons for an acre of approximately 108 trees (Table 19).

Dusting with sulphur cost $3.13 per acre and was the cheapest treatment. Although the cost of materials was relatively high, the equipment and labor charges were low because of the short time required to dust an acre with a power duster. Unfortunately, sulphur dust cannot be depended on to control any major satsuma pest except the rust mite. It was highly effective for this pest, however, and should always be used when rust mite is the only problem. Wettable sulphur was the cheapest spray, but cost 70 cents per acre more than sulphur dust. The cost of 3-3-100 Bordeaux plus 5 pounds of wettable sulphur was $1.29 per acre less than 6-6-100 Bordeaux plus 7.5 pounds of wettable sulphur. It will be observed that the most expensive sprays were those which contained oil. The tank-mix oil spray which was used in this work was about 35 cents per acre cheaper than a suitable proprietary emulsion, yet the cost per acre was $6.67 for the 1.5 per cent concentration used in July. When fungicides are mixed with insecticides the cost goes up, but such a mixture may be profitable. Thus, while a Bordeaux-oil mixture cost $7.27 per acre, it was effective for the control of sour scab, scale insects, the citrus whitefly, and the citrus red mite.

A satisfactory program which will produce quality fruit over a period of years contains four or five treatments and costs from $20.00 to $25.00 per acre, depending on the size of the trees and the materials used. Economy in insect and disease control can be obtained by using 3-3-100 Bordeaux in place of the usual 6-6-100 formula, mixed with oil when necessary or with wet-

TABLE 19.—Estimated Cost of Spray in Dollars for One Application of 400 Gallons per Acre.

Treatment	Materi- als	Water	Labor	Equip- ment	Total
Sulphur dust, 75 lbs. per acre	2.62		0.16	0.35	3.13
Wettable sulphur, 5 lbs. per 100 gals. water	0.80	0.28	1.50	1.25	3.83
Bordeaux, 3-3-100	0.89	0.28	1.50	1.25	3.92
Lime sulphur, 1½ gals. per 100 gals. water	1.32	0.28	1.50	1.25	4.35
Bordo-sulphur, 3-3-100 & 5 lbs. wettable sulphur	1.69	0.28	1.50	1.25	4.72
Bordeaux, 6-6-100	1.78	0.28	1.50	1.25	4.81
Lime sulphur-wettable sulphur 1½ gals. & 4 lbs. per 100 gals. water	1.96	0.28	1.50	1.25	4.99
Bordo-sulphur, 6-6-100 & 7½ lbs. wettable sulphur	2.98	0.28	1.50	1.25	6.01
Oil, 78″ viscosity white 1¼ gals. per 100 gals. water	3.05	0.28	1.50	1.25	6.08
1½ gals. per 100 gals. water	3.64	0.28	1.50	1.25	6.67
Bordo-oil, 3-3-100 & 1 gal. 78″ white per 100 gals.	3.35	0.28	1.50	1.25	6.38
6-6-100 & 1 gal. 78″ white per 100 gals.	4.24	0.28	1.50	1.25	7.27

table sulphur when oil is not needed, and by the use of sulphur dust instead of sulphur sprays for rust mite control. Since insect and disease control is cumulative, it is cheaper in the long run to maintain a conservative spray program every year rather than allow scab and scale insects to build up and then try to obtain quality fruit by heroic methods.

SELECTING A SPRAY SCHEDULE

The production of quality fruit at low cost is the desire of every grower. Therefore, in selecting a spray schedule it is necessary to make a compromise between efficiency and cost. But the effect of sprays on the maturity and yield of fruit is also very important economically.

Of the spray schedules tested, those containing oil in July and September can be eliminated because of delayed maturity of the fruit, reduction in yield, and cost. Although the most effective control of scab and the earliest maturing fruit was obtained with a schedule containing frequent lime sulphur sprays, it must be eliminated because of failure to control the purple scale, danger to the fruit and trees, and high cost. All schedules containing only one spring fungicide must be eliminated because of poorer control of scab and scale. Thus it becomes necessary to make the selection from the 12 schedules shown in Table 20. All of these were about equally effective in the production of clean fruit except those containing unsupplemented Bordeaux. The schedule used on plot 26 was one of the most effective and at the same time was the cheapest. The cost of this schedule was reduced by substituting 3-3-100 Bordeaux for 6-6-100 Bordeaux in the two spring applications, and by the use of sulphur dust in place of lime sulphur-wettable sulphur in September.

Numerous tests conducted over a period of years have shown that it is seldom necessary to apply sulphur dust for the control of rust mite in September if a good application has been made in August. This would further reduce the cost of the sprays used on Plot 26. It has been found, too, that wettable sulphur may be used in place of sulphur dust where dusting equipment is not available.

In some seasons it is not desirable or necessary to use Bordeaux-oil in March. Occasionally weather conditions make it hazardous to apply Bordeaux-oil before growth starts, and if the application cannot be made before much of the growth gets out it may be damaged by this spray. If a regular schedule, with oil in July, has been followed for several successive years it may not be necessary to use Bordeaux-oil in March for the control of the whitefly and red mite (spider). Under these conditions Bordeaux-sulphur should be used at both the pre-growth and post-bloom stages. A summary of recommended schedules is given in Table 21.

SUMMARY AND CONCLUSIONS

1. The purple scale is the most serious pest of satsuma oranges along the Gulf Coast. If uncontrolled, this insect may cause from 75 to 80 per cent of the fruit to be classed as culls, and trees may be seriously devitalized or even killed. Development is almost continuous but is retarded by cold weather. The shortest life cycles and the greatest hatch of eggs take place during the warm summer months. Spring applications of Bordeaux-oil and Bordeaux-sulphur aid in controlling the purple scale, but the opportune time to use an oil spray is in July. Only one oil spray per year is required for commercial control. Frequent use of sulphur sprays gives only partial control of scale.

2. The rust mite may russet young fruits in the early summer, but more serious damage is caused by the late summer or early fall infestation. If control measures are neglected, from 50 to 70 per cent of the fruit may be russeted. The rust mite

TABLE 20.—A Summary of Results Obtained in 1936, 1937, and 1938, with the Most Effective Spray Schedules.

Plot No.	Treatments*					Per cent of fruit				Per cent yield at last picking	Yield field boxes per plot	Cost per acre $
	March	April	July	Aug.	Sept.	Scabby	Scaly	Russet-ed	Clean			
1	Bordo-oil	Bordo-sul	Oil	S. dust	LS & WS	11.3	1.4	0.0	87.3	10.6	40.5	28.07
2	Bordo-oil	LS & WS	Oil	S. dust	LS & WS	10.0	2.2	0.1	88.3	15.0	34.8	27.05
3	Bordo-oil	Bordo	Oil	S. dust	LS & WS	10.3	3.4	0.4	85.9	21.3	40.7	26.87
5	Bordo	Bordo-sul	Oil	S. dust	LS & WS	8.7	5.7	0.0	85.9	10.4	42.2	25.61
6	Bordo	LS & WS	Oil	S. dust	LS & WS	8.0	5.2	0.0	86.9	11.8	36.6	24.59
7	Bordo	Bordo	Oil	S. dust	LS & WS	9.2	8.1	0.1	83.2	14.1	34.1	24.41
9	Bordo-sul	Bordo-sul	Oil	S. dust	LS & WS	9.2	2.0	0.1	88.8	11.5	38.3	26.81
10	Bordo-sul	LS & WS	Oil	S. dust	LS & WS	8.9	2.7	0.2	88.3	11.5	35.7	25.79
11	Bordo-sul	Bordo	Oil	S. dust	LS & WS	10.5	9.4	0.0	80.8	12.8	44.4	25.61
26	Bordo-oil	Bordo-sul	Oil	S. dust	S. dust	9.4	1.7	0.0	88.8	9.6	44.0	24.03
13	Untreated check					23.8	81.5	19.8	9.8	40.9	14.0	0.00

*Bordo-oil: 6-6-100 Bordeaux plus 1 gal. 78″ viscosity white oil per 100 gals. (tank-mix).
Bordo-sul: 6-6-100 Bordeaux plus 7½ lbs. wettable sulphur per 100 gals.
Bordo: 6-6-100 Bordeaux mixture.
LS & WS: 1½ gals. liquid lime sulphur per 100 gals. water plus 4 lbs. wettable sulphur.
Note: On plot 26, 3-3-100 Bordeaux was used. In April 5 lbs. of wettable sulphur was used with the mixture instead of 7½ lbs.

TABLE 21.—Summary of Recommended Spray Schedules.

	Schedule I	Schedule II
Time to apply	Treatments recommended for sour scab, whitefly, red mite (spider), scale insects, and rust mite.	Treatments recommended if weather is unsuitable for use of Bordeaux-oil, or if whitefly and red mite (spider) are under control.
March, just before growth starts but after all danger of freezes is past.	3-3-100 Bordeaux plus 1 to 1½ gallons of a 75-80" viscosity white oil as an emulsion or 1½ to 2 gallons of reliable proprietary oil sprays per 100 gallons.	3-3-100 Bordeaux plus 5 to 7½ lbs. of wettable sulphur per 100 gallons.
April, or at petal fall	3-3-100 Bordeaux plus 5 to 7½ lbs. wettable sulphur per 100 gallons.	Same as Schedule I
July 1-15	1½ gallons of 75-80" viscosity white oil as an emulsion or 2 gallons of reliable oil sprays per 100 gallons of water.	Same as Schedule I
August 15-20	Sulphur dust, about ½ lb. per tree, or wettable sulphur, 5 lbs. per 100 gallons of water.	Same as Schedule I

is readily controlled by sulphur sprays or dusts, the dust being preferable. August appears to be the opportune time to dust for rust mite control, but occasionally it may be necessary to dust in May or June.

3. The citrus whitefly causes damage by removing plant juices from the leaves and by the egestion of honey-dew in which a sooty mold grows that blackens the leaves and fruit. Infested trees are much more susceptible to low temperatures than uninfested trees. Only larvae are present during the winter months and the adults begin to emerge by the last of March or first of April. The optimum time to spray for the control of the citrus whitefly is just before the adults begin to emerge. Bordeaux-oil mixture is effective.

4. The citrus red mite (or spider) is a major pest of satsumas. The infestation of mites reaches its greatest density during the cool winter and spring months, usually March, April, and May. It does not thrive in hot weather, hence the infestation is light in July, August, and September. Sulphur dusts and sprays are not effective. Oil sprays are effective and if applied in July will keep trees relatively free from mites for several months. If this spray is applied every year, control is easily maintained.

5. Sour scab, the disease which causes bumpy fruit, is a major problem with satsuma growers, and severe infections are

very difficult to control. As much as 65 to 70 per cent of the fruit may be damaged by scab to such an extent that it is classed as cull. There was little difference in the effectiveness of the Bordeaux and sulphur fungicides tested. Frequency of application seems to be more important than the concentration of the spray used. The most practical control is probably obtained by the regular use of two fungicides per year, one before growth of the trees begins in the spring, and the other after petal fall.

6. Oil sprays prepared from highly refined white oils are much more desirable for use on satsumas than those prepared from unrefined oils. This is especially so when the trees are subjected to critical climatic conditions. Spray programs containing applications of oil in July and September seriously delay maturity and reduce the yield of satsumas after the first year. However, a refined white oil with a viscosity of 78-80 seconds (Saybolt) was applied at a concentration 1.5 per cent in July for 4 successive years without material effect on the maturity or yield of the fruit. Although liquid lime sulphur was conducive to early maturity of the fruit, the occasional severe injury caused by this spray makes its use unwise. Sulphur applications should be confined to dust and to wettable sulphur.

7. Spray schedules for effective and economical control of sour scab and the arthropod pests of satsumas are given.

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